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This collection of research papers and case studies is the companion document to the 16th International Conference of Urban Transport, February 2-5, 2015 at Istanbul Technical University Maçka Campus, Istanbul, Turkey.

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Jean-Louis LEONARD, President CODATU

It is a great pleasure for me to announce that my institution is undertaken the mission of hosting the CODATU XVI Conference with the theme “The role of urban transport policies and countermeasures in developing countries and emerging economies” to be held on 2-5 February 2015 at ITU Macka Campus.

This meeting will be held at a geography where two old continents, Europe and Asia, meet at a junction point where the transport corridors extending from West to East & South to North right from the olden times. Furthermore, this junction point is at a distinctive metropolis, Istanbul, which accommodates around 14 m. people and networks of urban transport including the colossal ones like Marmaray to connect the two continents by crossing the fabulous Bosphorus through an underwater rail tunnel.

My university is ready to host and welcome the participants of XVI. CODATU Conference and I wish every success to this worldly event.

Professor Mehmet KARACA, Rector Istanbul Technical University
ACKNOWLEDGMENTS
Thanks to many people who put enormous time and effort into the organization and coordination of this symposium:

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<td>Bernard Rivalta, Vice-President of CODATU, President of SYTRAL, Lyon, France</td>
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<td>Mehmet Karaca, Rector of İTÜ (İstanbul Teknik Üniversitesi), Istanbul, Turkey</td>
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<td>Laurent Bill, Ambassador of France in Turkey</td>
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<td>Mehmet Emin Birpinar, Deputy Undersecretary at Ministry of Environment and Urbanisation, Turkey</td>
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<td>Kadir Topbaş, Mayor of Istanbul, President of UCLG, Turkey</td>
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<td>Chair: Ayla Jean Yackley, Journalist at Reuters, Istanbul</td>
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<td>Gustavo Petro, Mayor of Bogota, Columbia</td>
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<td>Pam O’Connor, Mayor of Santa Monica, California, US</td>
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<td>Mohammad Bagher Ghalibaf, Mayor of Tehran, Iran</td>
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<td>Louis Nègre, President of GART and Vice President of Nice Metropolitan Municipality, France</td>
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<td>Michel Tindano, General Director of SOTRAL, Société des Transports de Lomé (SOTRAL), Togo</td>
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<td>Mümin Kahveci, General Manager of IETT, Istanbul, Turkey</td>
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<td>Chair: Mary Crass, Head of Policy and Summit Preparation, International Transport Forum (ITF)</td>
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<td>Suzana Kahn Ribeiro, Vice-Chair of WG III of IPCC and Sub secretary of Green Economy, Rio de Janeiro Environment State Secretary, Brazil</td>
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<td>Michael Replogle, Managing director for policy and founder, ITDP</td>
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<td>Dario Hidalgo, Director of Research and Practice, EMBARQ-WRI</td>
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<td>Martin Stucki, Head of International Operations, Transitec Consulting Engineers Ltd, Switzerland/France</td>
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<td>Chair: Mary Crass, Head of Policy and Summit Preparation, International Transport Forum (ITF)</td>
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<td>Ian Jennings, Senior Urban Transport Specialist, European Bank for Reconstruction and Development (EBRD)</td>
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<td>Cornie Huizenga, Secretary General, Sustainable Low Carbon Transport (SLoCaT) Partnership</td>
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<td>Rima Le Coguic, Head of Transport, Energy and Sustainable development unit, Agence Française de Développement (AFD)</td>
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<td>François Begeot, Head of Economic and Social Development Section, Delegation of the European Union in Ankara</td>
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<td>Chair: Heather Allen, Coordinator, Bridging the Gap Initiative &amp; Programme Director Sustainable Transport TRL</td>
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<td>Mohamed Sajid, Mayor of Casablanca, Morocco</td>
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<td>Ayman Smadi, General Director of Transport, Greater Amman Municipality (GAM), Jordan</td>
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<td>Ronan Dantec, President of the Environmental Commission, UCLG, France</td>
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<td>Alain Flausch, Secretary General, UITP</td>
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<td>Pierre Mongin, President of RATP, Paris, France</td>
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**Chairs:** Ela Babalik-Sutcliffe & Dave Maunder, Co-chairs of the CODATU XVI International Scientific Committee  
Christian Philip, Secretary General, CODATU - Opening speech  
Sanjivi Sundar, Distinguished Fellow, The Energy and Resources Institute (TERI), India - Assessment and Valuation of Externalities of Transport as Related to Energy and Environment  
David Banister, Professor, University of Oxford, UK - Climate Change, Transport, and Cities |
| 10:30 - 11:00 | Coffee Break Sponsored by SYSTRA |
| 11:00 - 12:30 | Plenary Session: Planning Urban Mobility in Turkey Addis-Abeba Amphitheatre (Translation FR-EN-TR)  
**Chair:** Arzu Tekir, Director, Embarq Türkiye, Turkey  
Abdulmuttalip Demirel, Kocaeli Metropolitan Municipality  
İlker Bektaş, İETT, Istanbul  
Sönmez Alev, Izban, Izmir Metropolitan Municipality  
Göktuğ Kara, EU Delegation of Turkey, Ankara  
Abdullah Keskin, Şanlıurfa Metropolitan Municipality  
**Keynote speaker:** Roland Ries, Maire de Strasbourg et Président de Cités Unies France, France |
| 12:30 - 14:00 | Lunch Sponsored by TRANSDEV |
| 14:00 - 15:30 | French-Turkish Cities Session (Side Event) Bucharest Meeting Room  
**Transport Policy (Sustainable Mobility Policy Assessment & Challenges)** Addis-Abeba Amphitheatre (Translation FR-EN-TR)  
**Chair:** Dario Hidalgo, Director of Research and Practice, EMBARQ-WRI  
Anthony D. May, University of Leeds (UK) - Sustainable Urban Mobility Plans for Developing Cities  
Carlos Alberto Moncada Aristizabal, Universidad de Los Andes (Colombia) - Application of quasi-experimental designs for assessing transport policies in developing cities  
Pablo Salazar Ferro, Centre for transport studies university of Cape Town (South Africa) - The challenge of finding a role for paratransit services in the Global South  
 Oliver Lah, Wuppertal Institute for Climate, Environment and Energy (Germany) - Transferability of sustainable urban mobility solutions |
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<td>Charles Rivasplata, SFMTA, San Francisco, USA</td>
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<td>Chair: Charles Rivasplata, SFMTA, San Francisco, USA</td>
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<td>Yves D. Bussiere, Benemerita Universidad autonoma De Puebla (Mexico) -</td>
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<td>Diego Escobar Garcia, Universidad Nacional de Colombia (Colombia), Urban</td>
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<td>Güneş Uyaniker, Urban Planner, Transportation Planning Department, IETT,</td>
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<td>(Turkey) - An Optimization Model for BRT Systems: Istanbul Metrbus Case</td>
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<td>Romano del Mistro, University of Cape Town Centre for Transport Studies</td>
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<td>Cape Town (South Africa): Appropriate operating environment for</td>
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<td>feeder-trunk-distributor or direct road based public transport</td>
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<td>services in cities of developing countries</td>
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<td>14:00 - 15:30</td>
<td>Panel Session by CODATU, WCTRS &amp; EASTS: Aiming at Further</td>
<td>Ho-Chi-Minh City</td>
<td>Kazuaki Miyamoto, Member of CODATU, WCTRS and EASTS &amp; Professor at</td>
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<td>Collaboration Between Societies with Focus on Capacity Building of</td>
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<td>Tokyo City University, Japan</td>
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<td>Young Researchers and Practitioners in Developing Countries</td>
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<td>Chair: Kazuaki Miyamoto, Member of CODATU, WCTRS and EASTS &amp; Professor</td>
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<td>at Tokyo City University, Japan</td>
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<td>Cheng-Min Feng, President of EASTS &amp; Professor at National Chiao Tung</td>
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<td>University, China</td>
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<td>Yoshitsugu Hayashi, President of WCTRS &amp; Professor at Nagoya University</td>
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<td>Ali Huzayyin, Vice-president of CODATU &amp; Professor at Cairo University,</td>
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<td>15:30 - 16:00</td>
<td>Coffee Break Sponsored by SYTRA</td>
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<td>16:00 - 17:30</td>
<td>Energy, Climate and Air quality <em>(Policy and Technology Initiatives)</em></td>
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<td><em>Chair: Oliver Lah, Project Coordinator, Wuppertal Institute for Climate, Environment and Energy, Germany</em></td>
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<td>Zia Wadud, University of Leeds (UK) - CNG conversion of Vehicles in Dhaka: An analysis of air quality, GHG and congestion impacts</td>
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<td>Thaned Satiennam, Khon Kaen University (Thailand) - Development of On road Emission and Fuel Consumption Models for Estimating Emissions and Fuel Consumption of Motorcycles in Asian Developing Countries</td>
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<td>Dominique Breuil, École d’Ingénieurs en Génie des Systèmes Industriels (France) - Strategy to reduce carbon footprint integrating mobility, energy, territory and behaviours</td>
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<td>Peter Mock, International Council on Clean Transportation (ICCT, Germany) - An international comparison of regulatory measures to reduce fuel consumption and emissions of passenger cars</td>
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<td>16:00 - 17:30</td>
<td>Roundtable on Sustainable Urban Mobility Plans</td>
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<td>Addis-Abeba Amphitheatre (Translation FR-EN-TR)</td>
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<td><em>Chair: Thierry Gouin, Projects manager, CEREMA, France</em></td>
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<td>Roland Ries, Mayor of Strasbourg Metropole (France) - The experience of Strasbourg in conceiving, developing and implementing SUMPs</td>
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<td>Matthias Merforth, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), (Germany) - Urban Mobility Plans - National Approaches and Local Practices</td>
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<td>Bernard Gyergyay, Rupprecht Consult, (Germany) - Overview about SUMP from an EU perspective</td>
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<td>Julien Allaire &amp; Maël Martinie, CODATU (France) - A proposal to combine SUMP &amp; NAMA</td>
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<td>16:00 - 17:30</td>
<td>Round Table: Financing Low Carbon Transport</td>
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<td><em>Chair: Cornie Huizenga, Secretary General, SLoCaT</em></td>
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<td>Open round table dialogue on the development of recommendation for a funding and financing framework for sustainable low carbon transport to effectively achieve the targets on improved urban access from the SLoCaT Results Framework on Sustainable Transport, while improving road safety, air quality and reducing GHG emiss from transport</td>
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| 16:00 - 17:30 | **Special session: WCTRS SIG H5 “Urban Transport in Developing Countries”**  
Ho-Chi-Minh City Room |
|             | Chair: Kazuaki Miyamoto, Professor, Tokyo City University (Japan) & Varameth Vichiensan, Assistant Professor, Kasetsart University (Thailand) |
|             | Yoshitsugu Hayashi, Nagoya University (Japan) - QOL-based Energy and Environmental Sufficiency Seeking Transport and Urban Development - Case Study of Nanjing Under Rapid Urbanization  
Rosario Macario, Instituto Superior Técnico - Lisbon (Portugal) - Energy Challenge in Transport Policy: Combined measures and decision making  
Ashish Verma, Indian Institute of science of Bangalore (India) - Mode choice behavior of non-workers and its impact on environment and energy  
Nuwong Chollacoop, National metal and materials technology center (Thailand) - Impact of biofuel promotion policy on the road transport  
Ashish Verma, Indian Institute of science of Bangalore (India) - Analysis of pedestrian travel behaviour in Bangalore city and its environmental impact |
| 18:00 - 19:30 | **CODATU Members General Assembly (restricted event)**  
Bucharest Room |
Day 3 - Wednesday, February 4th

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<th>Time</th>
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<td>09:00 - 10:30</td>
<td>Plenary on Megacities</td>
<td>Addis-Abeba Amphitheatre (Translation FR-EN)</td>
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<td>Chair: <strong>Haluk Gerçek</strong>, Professor, Istanbul Teknik Universitesi (ITU), Turkey</td>
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<td><strong>Haluk Gerçek</strong>, Professor, ITU, (Turkey) - Moving around the «Endless City»: Urban Transport Policies in Istanbul</td>
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<td><strong>Pan Haixiao</strong>, Professor, Tongji University, (China) - What’s the Effective Urban Transport Policy in Shanghai?</td>
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<td><strong>Krishna Rao</strong>, Professor, Indian Institute of Technology Bombay (India) - An Urban Transportation Perspective of Mumbai, the Maximum City</td>
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<td>10:30 - 11:00</td>
<td>Coffee Break Sponsored by SYSTRA</td>
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<td>11:00 - 12:30</td>
<td>POSTER SESSION</td>
<td><strong>Main Hall</strong></td>
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<td><strong>Geanina Elena Suditu</strong>, <em>Metroul SA (Romania)</em> - The importance of marketing processes on the perception and image of public transport. Implementation stage for an integrated marketing policy in the Bucharest agglomerations</td>
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<td><strong>Rozalia Melania Boitor</strong>, <em>Technical University of Cluj-Napoca (Romania)</em> - Urban mobility and air quality in Cluj-Napoca (Romania)</td>
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<td><strong>Mirko Goletz</strong>, <em>Institute of Transport Research (DLR, Germany)</em> - Informal transport services in Bogotá and N’Djamena: Actors, interactions and characteristics</td>
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<td><strong>David Nelson</strong>, <em>National Centre for Arts and Crafts (CNAM, France)</em> - Imagining Complete Streets for Developing Africa</td>
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<td><strong>Baatarzorig Mandalhai</strong>, <em>Kyushu University (Mongolia)</em> - An Analysis on Rapid Urbanization Issues in Mongolia and its Externalities. A Case Study on Apartment and Ger Residential Areas in Ulaanbaatar City.</td>
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<td><strong>Romano del Mistro</strong>, <em>University of Cape Town, Centre for Transport Studies Cape Town (South Africa)</em> - Sufficient accessibility as a policy to inform urban patterns appropriate to mitigate climate change, air quality and energy challenges in developing countries.</td>
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<tr>
<td>11:00 - 12:30</td>
<td>LRT &amp; MRT(Feasibility and Impact)</td>
<td>Addis-Abeba Amphitheatre (Translation FR-EN)</td>
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<td>Chair: <strong>Ali Huzayyin</strong>, Professor, University of Cairo and Co-chair of CODATU Permanent Scientific and Technical Committee (PSTC)</td>
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<td><strong>Tahar Baouni</strong>, <em>Ecole Polytechnique d'architecture et d'urbanisme d'alger (Algeria)</em> - Impact of LRT Alger</td>
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<td><strong>Riadh Haj Taleb</strong>, <em>President of Association pour le Développement Solidaire de Sfax (ADSS, Tunisie)</em> - Light rail in Sfax</td>
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<td><strong>Ionut-Sorin Mitroi</strong>, <em>Codatu from Romania / Metroul SA (Romania)</em> - Evaluation of the performance of urban public transport connectivity. Background of the connectivity issues in Bucharest public transport main stops</td>
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<td><strong>Eugenia Alina Roman</strong>, <em>Codatu from Romania / Metroul SA (Romania)</em> - Intermodality - A Solution to the Problems of Large Urban Agglomerations</td>
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| 11:00 - 12:30 | **Special Session: Assessment of Public Transport Projects and Quality of Service**  
Buenos-Aires Room |
|             | *Chair:* Etienne Lhomet, Director, Des villes et des hommes, France     |
|             | **Abdullah Önder Turkoğlu**, Transportation Planning Department (İETT), (Turkey) - Istanbul BRT (Metrobus) Punctuality Model  
**Pelin Alpkokin**, Istanbul Technical University, (Turkey) - An Assessment of current operation and policies of Istanbul  
**Hurel Harold**, Systran consulting, (France) - Feedback and impacts of LRT projects in North Africa  
**Ved Mani Tiwari**, Kochi Metro Rail Limited (KMRL, India) - Kotchi metro project |
| 11:00 - 12:30 | **Special session: WCTRS SIG G6 “Disaster Resilience in Transport”**   
Lyon Room                                                                 |
|             | *Chair:* Huapu Lu, Professor, Tsinghua University, China, & Ashish Verma, Assistant Professor, Indian Institute of Science (IISc), Bangalore, India |
|             | **Yoshitsugu Hayashi**, Nagoya University, (Japan) - Sustainable Urban Mobility and Disaster Resilience  
**Huapu Lu**, Tsinghua University, (China) - Disaster Resilience in Transport: Research challenges and Prospects  
**Ashish Verma**, Indian Institute of Science (IISc) (India) - Disaster Resilience in Transport in India  
**Ruimin Li**, Institute of Transportation Studies (ITS), Tsinghua university (China) - Empirical study of inclement weather impact on urban traffic conditions  
**Takayuki Akiyama**, Hitachi, Ltd. (Japan) - ITS application in Disaster Resiliencee |
| 12:30 - 14:00 | Lunch                                                                 |
| 14:00 - 15:30 | **Public Transport in Asia (Planning and Impacts)**  
Buenos-Aires Room |
|             | *Chair:* Rao Krishna, Professor, Indian Institute of Technology Bombay (IITB), India |
|             | **Abdul Azeez Kadar Hamsa**, International Islamic University Of Malaysia (Malaysia) - Planning of Transit-oriented Development Cities for Greater Mobility  
**Atsushi Fukuda**, Professor, Kasetsart University (Thailand) - Determinants of Land Use Change MRT Purple Line in Bangkok Metropolitan Region  
**Ravi Gadepalli**, Shakti sustainable energy foundation (India) - Parking policy as a countermeasure to promote public transport usage: Case study of Nehru Place district centre in New Delhi, India |
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<th>Time</th>
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<th>Presentations</th>
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| 14:00 - 15:30| **Freight Transport (Characteristics, Management & Evaluation)**        | Ho-Chi-Minh City Room         | Chair: **Laetitia Dablanc**, Director of Research, French Institute of Science and Technology for Transport, Development and Networks (IFSTTAR), France | **Sanjay Gupta**, School of Planning and Architecture (India) - Characteristics of agro retail logistics in Metropolitan city of Delhi (India)  
**Binh Nguyen Thi**, Vietnamese German University (Vietnam) - Freight transport management measures in the rice industry in the Mekong Delta of Vietnam: an overview and policy consideration  
**Dominique Breuil**, Ecole d’Ingénieurs en Génie des Systèmes Industriels (France) - Evaluation and transferability of freight transport organisation in cities |
| 14:00 - 15:30| **Special session: Road Safety and Security in Cities (I)**             | Lyon Room                     | Chair: **Ramzi Salame**, Rector, University Saint Joseph, Beirut, Lebanon | **Rami Semaan**, Consultant and lecturer University Saint Joseph (Lebanon) - Case studies on city centers and soft modes plan, Beirut and Zahlé  
**Rafael Capdevila**, Catalan Society of Geography, Barcelona (Spain) - Barcelona case study: How to develop organize and exploit a bike network? How to develop comprehensive approach for road safety including pedestrians, bike, motorcycles.  
**Tolga İmamoğlu**, Road Safety Projects Manager, EMBARQ (Turkey) - EMBARQ Turkey RSLab Project |
| 14:00 - 15:30| **CODATU Session: LRT and MRT systems in developing countries**         | Addis-Abeba Amphitheatre (Translation FR-EN) | Chair: **Youssef Draiss**, Casatransport, Maroc | **Jeremie Simon and Pierre Marx**, Egis (France) - De l'importance du plan d'urbanisme sur le choix d'un reseau de tramway: exemples de Sfax (Tunisie) et de Tebessa (Algerie)  
**Eric Marie**, Alstom - Axonis, (France) - Le nouveau systeme de transport urbain developpe par ALSTOM pour les villes des pays en developpement  
**Cecile Fere**, Lyon Town-Planning Agency (France) - Les projets de TCSP dans les villes en developpement : quelles dynamiques sur la structure urbaine, les projets urbains et le renouvellement de l'espace public ?  
**Nicolas Prego**, Artelia, (France) - Outils d'aide à la decision des acteurs publics : quels enjeux pour les transports urbains ? |
<p>| 15:30 - 16:00| <strong>Coffee Break Sponsored by SYSTRA</strong>                                   |                                |                                                                      |                                                                                |</p>
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<tr>
<td>16:00 - 17:30</td>
<td>Taxis (Operation in African Cities)</td>
<td>Addis-Ababa Amphitheatre (Translation FR-EN)</td>
<td>Tatenda Mbara, Lecturer, University of Johannesburg, South-Africa</td>
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<td>Oluwasegun Aluko, University of Leeds (UK) - A system dynamics approach to understanding traffic law compliance problem in commercial motorcycle operation</td>
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<td>Hassane Mahamat Hemchi, University of Bordeaux Montaigne (Chad) - Mototaxis or clandos between citizen adaptation and political reject in the city of Ndjamena</td>
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<td>Porna Idris Traore, Université d'Abidjan (Ivory Coast) - Mototaxis in Ivory Coast</td>
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<td>Assogba Guezeere, The University of Kara (Togo) - Planning two wheels in Lomé for a sustainable urban mobility vision for 2030</td>
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<td>16:00 - 17:30</td>
<td>Motorcycles (Challenges, Strategies and Evaluation)</td>
<td>Buenos Aires Room</td>
<td>Rao Krishna, Professor, Indian Institute of Technology Bombay (IITB), India</td>
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<td>Rebecca Heywood, M.I.T. (USA) - Challenges and Opportunities for Motorized Two-Wheelers in Asian Cities</td>
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<td>Van Thi Cam Nguyen, Vietnamese German University (Vietnam) - Strategies for Integrated Urban and Transport Development in Motorcycle Dependent Cities - Case Study in Ho Chi Minh City (Vietnam)</td>
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<td>Abimbola Odumosu, Nigerian Institute of Transport Technology (Nigeria) - Sustainable Policy for, and Environmental Implications of, Motorcycle Operation in a Historical City (Kano, Nigeria)</td>
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<td>16:00 - 17:30</td>
<td>Special session: Road Safety and Security in Cities (II)</td>
<td>Lyon Room</td>
<td>Ramzi Salame, Rector, Saint Joseph University, Beyrouth, Lebanon</td>
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<td>Rayane Wehbé, TMS Consult (Lebanon) - Road safety audit, applications and procedures</td>
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<td>Joel Yerpez, Director of Laboratory of Incidents Mechanisms - Road safety for calm urban circulation, lessons and findings from French cases</td>
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<td>Ana-Maria Ciobica, Codatu from Romania / Metroul SA (Romania) - The assessment of road safety in the Romanian cities. The influence of the assessment process on the safety performance of public transport based on the SAFENET project</td>
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<td>16:00 - 17:30</td>
<td>CODATU PSTC Session : Getting Researchers and Practitioners Closer</td>
<td>Ho-Chi-Minh City Room</td>
<td>Ali Huzayyn &amp; Anthony May, Co-chairs of the Permanent Scientific and Technical Committee of CODATU</td>
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<td>Ali Huzayyn, CODATU - Presentation of the Committee</td>
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<td>Lorenza Tomasoni, CODATU - How to better link research and practice? Results from the internal PSTC survey.</td>
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<td>Charles Rivasplata, SFMTA, San Francisco (USA) - Researchers and practitioners: presentation of some success stories of cooperation.</td>
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<td>Tony May, CODATU &amp; Rao Krishna, Indian Institute of Technology Bombay, (India) - Proposals of future initiatives</td>
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<td>Discussion</td>
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<td>18:00 - 20:00</td>
<td>Attendees Cocktail at ITU</td>
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Day 4 - Thursday, February 5th

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<tr>
<td>08:30 - 18:00</td>
<td>SOLUTION Project Final Mediterranean Workshop &amp; Training (Side Event)</td>
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<td>Ho-Chi-Minh City Room</td>
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<td>09:00 - 10:30</td>
<td>Non-Motorised Transport &amp; Sustainable Transport Policies (Access and User Attitudes)</td>
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<td>Buenos-Aires Room</td>
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Chair: Valerie Ongolo Zogo, Professor, University of Yaoundé, Cameroon

Paulo Ancaes, University College of London (UK) - Mapping pedestrian accessibility and the quality of walking in an African city: Praia, Cape Verde

Dilek Çol Yılmaz, Istanbul Metropolitan Municipality (Turkey) - Prioritization of the bicycle network clusters integrated with the public transport system in Istanbul Metropolitan Area

Tatenda Mbara, University of Johannesburg (South Africa) - Achieving sustainable urban transport in Harare, Zimbabwe? What are the required milestones?

Yao Godefroy Konan, Ministry of transport (Ivory Coast) - Integrated planning of transport and land-use in Greater Abidjan

09:00 - 10:30 | CODATU Session: Urban mobility in Africa (Translation FR-EN) |
|              | Addis-Abeba Amphitheatre                                              |

Chair: Nico McLachlan, ODA, Cape Town (South Africa)

Martin Stucki, Transitec Engineering & Consulting (Switzerland) - A policy paper for urban mobility in Africa

Nico McLachlan, ODA (South Africa) - How the introduction of bus rapid transit services can be structured to achieve multiple outcomes in cities of the developing world. Learnings from the design and implementation of the Cape Town MyCiti Integrated Rapid Transit system.

Antoine Atiou, City of Ouagadougou (Burkina Faso), & Marie Dols, Lyon Town-planning Agency (France) - Institutional challenges for the implementation of an urban transport policy. The case of Ouagadougou

Matthias Nuessgen, EURIST (Germany) - Success factors for urban ropeway systems in Africa, Tools for transport planning and urban development
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<tr>
<td>09:00 - 10:30</td>
<td><strong>Special session: Young Academics Turkey</strong></td>
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<td>Lyon Room</td>
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<td><em>Chair:</em> Ela Babalik-Sutcliffe, Associate Professor, Middle East Technical University, Turkey</td>
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<td>Ezgi Kundakci, Integrated Systems and Systems Design, Ankara (Turkey) - Safe Urban Speed Management</td>
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<td>Bashar Ozbilen, Middle East Technical University, Ankara (Turkey) - Public Transport Smart Card Systems in Turkish Cities: The Challenge of Paratransit</td>
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<td>Cihan Ercegin, Middle East Technical University, Ankara (Turkey) - Planning and management of bike-sharing: lessons from the Turkish case studies</td>
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<td>Hifzi Aksoy, Istanbul Technical University, (Turkey) - The change of regional transport accessibility over time by using spatial analyses</td>
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<td>Ahmet Bas, Istanbul Technical University, (Turkey) - How New Urban Settlements can Effect the Urban Transport Demand in Istanbul: A Case Study of Kayasehir</td>
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<td>10:30 - 11:00</td>
<td><strong>Coffee Break Sponsored by SYSTRA</strong></td>
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<td>11:00 - 12:30</td>
<td><strong>Closing Plenary</strong></td>
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<td></td>
<td>Addis-Abeba Amphitheatre (Translation FR-EN)</td>
</tr>
<tr>
<td></td>
<td><em>Chairs:</em> Ela Babalik-Sutcliffe &amp; Dave Maunder, Co-chairs of the CODATU XVI International Scientific Committee</td>
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<td></td>
<td>Ali Huzayyin, Vice-President, CODATU - Tribute to Jean-Claude Ziv</td>
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<td>David Maunder &amp; Ela Babalik-Sutcliffe, Co-chairs of the International Scientific Committee of the Conference - Wrap-up on scientific sessions</td>
</tr>
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<td></td>
<td>Students, Master in Engineering of urban services networks in developing countries (ISUR, France) - Wrap-up on Social Network</td>
</tr>
<tr>
<td></td>
<td>Tony May, Vice-President, CODATU - Research perspectives for the CODATU Community</td>
</tr>
<tr>
<td>12:30 - 14:00</td>
<td><strong>Lunch</strong></td>
</tr>
</tbody>
</table>
2023 ISTANBUL MOBILITY PROJECTION AND IMPORTANCE OF THE PUBLIC TRANSPORTATION IN ECONOMIC GROWTH PERSPECTIVE

İlker Bektas

1 IETT General Directorate, Transportation Planning Department, Turkey

Abstract

In big cities in mature (developed) economies and big cities that are in emerging economies has confront with a serious issue named “rapidly increasing private car ownership”. According to OECD Transport Report 2013, car ownership will increase fifty percentage in 2050.

“Sustainability” became not only popular but also an important word in last two decade. Tripod of sustainability consist of Economic, social and environmental legs. It is sure that urban mobility is just in the intersection of these legs. It became a paradox if Mobility effects Economic growth or vice-versa. But it is a fact that Urban mobility is a very powerful limitation factor for not only economic growth but also sustainability.

Herein, current situation will be explain in the dimension of urban mobility performance and economic performance of İstanbul. After that 2023 projections, estimates and plans will be given according to Turkey Strategic Vision 2023.
SUSTAINABLE URBAN MOBILITY PLANS FOR DEVELOPING CITIES

Anthony D May

Abstract

Objective The paper reviews the development of Sustainable Urban Mobility Plans in Europe, and considers the relevance of the guidance and decision-support tools which are being developed to the needs of cities in the developing world.

Methodology The European Commission is encouraging all cities in Europe to develop Sustainable Urban Mobility Plans. It has developed guidance on the preparation of such Plans, and a range of decision-support tools which are available to support such Plans. The paper draws on the author’s experience of these developments, and of a current EC-funded project, CH4LENgE, which is working with cities throughout Europe to develop and test such tools. The paper summarises the guidance and the remaining barriers to effective planning, and assesses their relevance to the cities of the developing world.

Data The paper draws on the experience of partner cities in Europe, and the data which they have provided on their needs. It also uses the results of a recent survey of members of the newly established Permanent Scientific and Technical Committee of CODATU.

Conclusions Based on the reviews above, the paper makes a series of recommendations on ways in which the guidance and tools can be further developed to make them more widely applicable in the developing world.

1 Introduction

The European Commission’s attitude to urban transport has changed dramatically in the last decade. Ten years ago, its approach was still influenced by the principle of “subsidiarity”: avoiding becoming involved in policies which could reasonably be pursued at national, regional or local level. However, its analysis (EC, 2007) demonstrated that urban transport was responsible for 80% of congestion costs and 14% of all carbon emissions. Moreover, urban areas accounted for 60% of Europe’s
population, but over 85% of its economic output. On both these grounds, it was argued, urban transport was too important to be left solely to local government to manage.

These arguments had first been developed in working groups established by the Environment Directorate in 2003 and 2004, the latter resulting in a report which laid the foundations for future development of Sustainable Urban Mobility Plans (SUMPs) (DGE, 2004). Those working groups in turn drew on the pioneering work of the Land Use and Transport Research cluster of the Commission’s fifth research framework, which was subsequently encapsulated in a Decision-Makers’ Guidebook on developing sustainable urban land use and transport strategies (May et al, 2005).

The Commission’s Action Plan on Urban Mobility (EC, 2009) recommended encouraging the adoption of Sustainable Urban Mobility Plans. In June 2010, the Council of the European Union stated that it “supports the development of sustainable urban mobility plans for cities … and encourages the development of incentives, such as expert assistance and information exchange, for the creation of such plans”. More recently the 2011 White Paper (EC, 2011) proposed that there might be a mandatory requirement for such Plans for cities over a certain size, and that the allocation of regional and cohesion funds might be made conditional on the submission and auditing of such Plans.

A subsequent project, ELTISplus, provided guidance on such plans (ELTISplus, 2014). In doing so, it drew on the experience of local transport planning in member states, and on advice on the essential and desirable elements of the process (ELTISplus, 2012). The resulting guidelines are based on eleven elements and 32 specific activities under the broad headings of preparing well; rational and transparent goal setting; elaborating the plan; and implementing the plan (ELTISplus, 2014).

At the outset the guidelines emphasise the differences between the traditional approach to urban transport planning and that advocated for Sustainable Urban Mobility Plans. Table 1 summarises these differences. As can be seen, it is argued that Sustainable Urban Mobility Planning has a greater emphasis on developing a long term vision, involving citizens and stakeholders throughout the process, specifying objectives and setting targets related to all aspects of sustainability, and developing effective packages of measures, without undue emphasis on supply-side solutions.
Table 1 – Differences between traditional transport plans and SUMPs (ELTISplus, 2012)

<table>
<thead>
<tr>
<th>Traditional Transport Plans</th>
<th>Sustainable Urban Mobility Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Often short-term perspective without a strategic vision</td>
<td>Including a long-term strategic vision with a time horizon of 20-30 years</td>
</tr>
<tr>
<td>Usually focus on particular city</td>
<td>Geographic scope</td>
</tr>
<tr>
<td>Limited input from operators, and other local partners, not a mandatory characteristic</td>
<td>Level of public involvement</td>
</tr>
<tr>
<td>Not a mandatory consideration</td>
<td>Sustainability</td>
</tr>
<tr>
<td>Low, transport and infrastructure focus</td>
<td>Sector integration</td>
</tr>
<tr>
<td>Usually not mandatory to cooperate between authority levels</td>
<td>Institutional cooperation</td>
</tr>
<tr>
<td>Often missing or focussing on broad objectives</td>
<td>Monitoring and evaluation</td>
</tr>
<tr>
<td>Historic emphasis on road schemes, infrastructure development</td>
<td>Thematic focus</td>
</tr>
<tr>
<td>Not considered</td>
<td>Cost internalisation</td>
</tr>
</tbody>
</table>

The companion State of the Art Report (ELTISplus, 2012) demonstrates the extent of the challenge still to be faced in Europe. It groups member states into three categories:

- those with a well-established transport planning framework (7, but only including Flanders in Belgium and England and Wales in the UK)
- those which are moving towards sustainable urban mobility planning (12, including Wallonia in Belgium and Scotland in the UK)
- those which have yet to adopt sustainable mobility planning (11, including Northern Ireland in the UK).

Even in the first category, most countries fail to meet all the requirements, as illustrated in Table 2. The principal barriers to such planning in these countries are identified as strong pro-car and infrastructure lobbies, lack of joint working between transport and land use, lack of relevant knowledge, lack of funds for the preparation of Plans, inadequate coordination between tiers of government, the demands of intensive public and stakeholder involvement, and political conservatism (ELTISplus, 2012).
A current European project, CH4LLENGE, is working with cities to help overcome these barriers, with particular emphasis on improved ways of involving the public in participatory input to plans; improved approaches to partnership working in plan development and implementation; improved methods for identifying appropriate policy measures and packages; and improved approaches to monitoring, appraisal and evaluation (www.sump-challenges.eu).

In this paper we review the guidance on SUMP development in Europe at both a European and a national level, and summarise the research on which it is based and the decision-support tools which have been developed to facilitate SUMP development. We consider briefly the principal barriers to effective SUMP development in Europe and use these as a basis for assessing the barriers and needs in cities of the developing world. On this basis we assess the relevance of European guidance and decision-support tools to developing cities, and suggest ways in which they could be further enhanced.

Table 2 – The status of SUMPs in the most advanced European countries (ELTISplus, 2012)

<table>
<thead>
<tr>
<th>Country</th>
<th>Legally Defined</th>
<th>National Guidance</th>
<th>Plans in Place</th>
<th>Sustainability Objective?</th>
<th>Full Public Involvement?</th>
<th>Linked with Finance</th>
<th>Political Support?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium (Flanders)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>France</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>?</td>
<td>Yes</td>
<td>?</td>
</tr>
<tr>
<td>Germany</td>
<td>No</td>
<td>Under discussion</td>
<td>Yes</td>
<td>No</td>
<td>?</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Italy</td>
<td>Yes</td>
<td>Yes</td>
<td>Some</td>
<td>?</td>
<td>Yes</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Netherlands</td>
<td>Yes</td>
<td>Yes</td>
<td>Most</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Norway</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>UK (*)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>?</td>
<td>Yes</td>
<td>Yes</td>
<td>?</td>
</tr>
</tbody>
</table>

[1*] Relates to England and Wales, the Scottish system is more akin to the next block of countries and Northern Ireland to the third block.

2 The guidance available and its sources

2.1 European guidance

As noted in the introduction, the guidelines for the preparation of Sustainable Urban Mobility Plans were published in 2013 (ELTISplus, 2014). Figure 1 illustrates the recommended SUMP cycle, including its four phases, eleven elements and 32 specific activities.
A current European project, CH4LLENGE, is working with cities to help overcome these barriers, with particular emphasis on improved ways of involving the public in participatory input to plans; improved approaches to partnership working in plan development and implementation; improved methods for identifying appropriate policy measures and packages; and improved approaches to monitoring, appraisal and evaluation (www.sump-challenges.eu).

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Table 2 – The status of SUMPs in the most advanced European countries (ELTISplus, 2012)

<table>
<thead>
<tr>
<th>2</th>
<th>The guidance available and its sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>European guidance</td>
</tr>
</tbody>
</table>

As noted in the introduction, the guidelines for the preparation of Sustainable Urban Mobility Plans were published in 2013 (ELTISplus, 2014). Figure 1 illustrates the recommended SUMP cycle, including its four phases, eleven elements and 32 specific activities.

![Figure 1 – The SUMP cycle (ELTISplus, 2014)](image)

The guidelines draw on three principal sources, each of which is duly acknowledged: good practice in individual cities, national guidance documents, and underpinning research on the barriers to effective planning and on ways of overcoming them. We outline the latter two sets of sources in what follows.

### 2.2 National guidance

Several European countries now encourage or require the production of Sustainable Urban Mobility Plans. The requirements in England and France are the most fully developed, and are outlined below. Provisions in Belgium, Germany, Italy, Scandinavia and Spain are outlined in May (2013a).

**France**

French cities of over 100,000 population have been required to produce Plans de Déplacements Urbains (PDU) since 1996 (ELTISplus, 2012), but
the goal of PDUs was first specified in 1982, as ensuring a sustainable equilibrium between the needs for mobility and accessibility and the requirements to protect the environment and health. Subsequent legislation in 2000, 2005 and 2010 has broadened the requirements for PDUs, which now need to include issues of mobility, urban development, social inclusion and environmental protection, to provide a detailed financial and implementation plan, and to be based on a five yearly evaluation and review. Guidance is provided by the Groupement des Autorités Responsables de Transport (GART), who conducted an overview of PDUs (GART, 2009) and a more recent environmental evaluation (GART, 2011). An earlier guidance document is available from CERTU (1999). It is not clear, however, whether such guidance is underpinned by a broader research base.

UK (England outside London) May (2013b) provides a detailed assessment of the 37 years’ experience of providing guidance on local transport plans in England, and offers an assessment matrix to which we return later in this paper. Since 2000, local authorities in England outside London have been required to produce three sets of Local Transport Plans (LTPs). The first round of LTPs covered the period 2001-6, based on guidance which prescribed in detail the coverage of the Plans, their need to be consistent with regional guidance, the specification of objectives, the measurement of indicators and the setting of targets (DETR, 2000). The Plans and subsequent annual progress reports were assessed in detail by national government, with funding based in part on the quality of the Plan and on the achievement of targets (DfT, 2006).

The guidance for the second round of LTPs, covering 2006-11 (DfT, 2004), was somewhat less prescriptive, in particular reducing substantially the requirement for extensive monitoring. However, it required all local authorities to focus on four “shared priorities” which had in practice been specified by government: accessibility, congestion, air quality and road safety. It required statements of strategy for each “priority”, as well as parallel statements for each principal transport mode (DfT, 2004). They were again assessed in detail by national government, with the funding allocated based in part on that assessment.

The guidance for the third round of LTPs (for the period 2011-16) was issued in 2009 (DfT, 2009), and reflected a desire in government to give local authorities more autonomy. Local authorities were given greater freedom to choose the period and area of coverage of their plan, with greater opportunities for sub-regional collaboration. They were encouraged to set their own objectives, while being expected to consider their contribution to specified national transport goals: supporting economic growth, reducing carbon emissions, promoting equality of
opportunity, contributing to better safety, security and health, and improving quality of life and a healthy natural environment.

The first round of guidance drew little on research. However, the government commissioned an evaluation of the LTP process and outcomes (Atkins, 2005; 2007), and based its requirements for the second round of LTPs (for the period 2006-11) in part on that study’s interim findings. In parallel, a UK research programme, DISTILLATE (May, 2009), was established to develop decision-support tools for plan development. The third round of LTP guidance drew substantially on both the Atkins study and DISTILLATE.

2.3 Research into the barriers to effective planning

The ECMT study The European Conference of Ministers of Transport (ECMT) conducted a 15 year programme of work into urban transport policy, which recommended a series of policy instruments (ECMT, 1995), carried out an international survey of cities’ ability to implement such policies (ECMT, 2002) and followed this up with a number of case studies. The 2002 report found that cities considered the implementation of the advocated policies “more easily said than done”. It highlighted the principal barriers as poor policy integration and coordination, counterproductive institutional roles, unsupportive regulatory frameworks, weaknesses in financing and pricing, poor data quality and quantity, limited public support and lack of political resolve. It and the subsequent study developed a set of recommendations to national governments, who were seen as crucial in enabling and supporting local government initiatives. Briefly, these were that national governments should:

- establish a national policy framework for urban travel which supports and influences policy on land use, health and the environment;
- improve institutional coordination and cooperation, horizontally between policies and vertically between tiers of government;
- decentralise responsibilities where possible and centralise them where necessary;
- support local or regional authorities through technical, financial or other means as necessary and appropriate in the development, appraisal, monitoring and evaluation of integrated, sustainable, urban travel strategies;
- encourage effective public participation, partnerships and communication;
- provide a supportive legal and regulatory framework, particularly for public transport, demand management, emissions and safety;
- ensure a comprehensive pricing and fiscal structure which sends appropriate signals to users and operators;
- rationalise financing and investment streams so that they are consistent across all modes;
improve data collection, monitoring and research, particularly by carrying out consistent monitoring of the implementation of urban transport policies (ECMT, 2002, 2006).

The PROSPECTS project

PROSPECTS was one of a number of projects funded by the EC Directorate General for Research as part of the Land Use and Transport Research (LUTR) programme. It developed three levels of guidance for the preparation of urban land use and transport plans, focusing on decision-making, methodology and policy. To provide a context it conducted a survey of 60 European cities which asked them, *inter alia*, to identify the principal barriers which they faced. These were identified as institutional, financial, attitudinal and technological (May and Matthews, 2007). The decision-makers’ guidance included a section on ways of overcoming these barriers through strategy development. The initial guidebook developed by the project was subsequently expanded to include the findings of the other projects in the LUTR programme (May, 2005).

The Atkins study

The interim report of the Atkins study (Atkins, 2005) concluded that the first round of UK LTPs had been welcomed by local authorities, that it had introduced a step change in the level of consultation and partnership working, that local authorities were using long term funding more effectively, and that there had been a focus on wider policy goals and on support for sustainable transport modes. However, it also highlighted a series of weaknesses, including conflicts between transport plans and those for other public policy sectors, managerial and political barriers to cross-boundary working, lack of integration between transport and land use planning, a weak evidence base, limited expertise in setting targets, reluctance to share good practice, limitations of staffing and skills, and inappropriate financial and political structures. To some extent the second round of LTPs was designed to overcome these problems. The final report (Atkins, 2007), carried out in parallel with the implementation of LTP2, reinforced the positive impacts of the Local Transport Plan process, but identified weaknesses in option generation, and particularly in the use of demand management measures, in efforts to achieve national targets, in balancing capital and revenue funding, in the delivery of major schemes, in the fragmented decision-making structure in some local authorities, and in the lack of powers over public transport operators. It concluded that guidance needed to become less prescriptive, but that local authorities needed to “raise their own competence, ability and confidence to pursue innovative, inclusive and locally-relevant transport (policies)”. The third round of Local Transport Plans was designed to overcome these weaknesses.

The DISTILLATE project

In parallel with the Atkins review, a four year research programme, DISTILLATE, was established in 2004 to conduct research into the
barriers faced by local authorities and into ways of overcoming them. At the outset, the research reviewed the principal barriers. Funding was the most widely experienced problem, followed by problems with modelling and monitoring and evaluation. Strategy option generation and strategy appraisal were both problems for half the respondents, while only a minority experienced problems with scheme option generation, design and appraisal. Table 3 indicates the severity of these problems as they affect different types of policy instrument (May, 2009).

Table 3 – Seriousness of barriers to the implementation of policy instruments at each stage of the policy process (source: May, 2009)

<table>
<thead>
<tr>
<th></th>
<th>Overall Implementation</th>
<th>Monitoring</th>
<th>Option generation</th>
<th>Finance</th>
<th>Modelling</th>
<th>Appraisal</th>
<th>Coordination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buses</td>
<td>***</td>
<td>**</td>
<td>**</td>
<td>***</td>
<td>**</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>Demand management</td>
<td>***</td>
<td>**</td>
<td>***</td>
<td></td>
<td>***</td>
<td></td>
<td>***</td>
</tr>
<tr>
<td>Fares</td>
<td>***</td>
<td>**</td>
<td>**</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>Land use</td>
<td>***</td>
<td>**</td>
<td>***</td>
<td></td>
<td>***</td>
<td>**</td>
<td>***</td>
</tr>
<tr>
<td>Light rail</td>
<td>**</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>***</td>
</tr>
<tr>
<td>Mobility management</td>
<td>**</td>
<td>-</td>
<td></td>
<td></td>
<td>***</td>
<td></td>
<td>***</td>
</tr>
<tr>
<td>Traffic management</td>
<td>**</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>***</td>
</tr>
<tr>
<td>Information</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>***</td>
</tr>
<tr>
<td>Walking and cycling</td>
<td>-</td>
<td>***</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>***</td>
</tr>
<tr>
<td>Roads</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>***</td>
</tr>
</tbody>
</table>

Key:
- Seriousness score > 0.5 (Hull, 2009)
- Seriousness score 0.4 – 0.5 (Hull, 2009)
- Seriousness score < 0.4 (Hull, 2009)
- Most severe problems identified in DISTILLATE case studies and Atkins (2007)
- Least severe problems identified in DISTILLATE case studies and Atkins (2007)
- Not addressed in the survey
2.4 Research on ways of overcoming the barriers

PILOT The PILOT project was funded by the European Commission to demonstrate the process of SUMP preparation and to propose tools and guidelines for their development. It produced a manual, a series of training tools, and a series of recommendations (www.pilot-transport.org). Among its recommendations were the need to provide financial incentives for SUMP preparation; to provide training, including national contact points; to encourage the exchange of experience; to establish legal frameworks in member states; and to conduct further research, particularly into easy to use decision support tools. The current SUMP guidelines draw heavily on the outcome of PILOT, particularly in the elements involving policy coordination, vision, objectives, targets and monitoring.

GUIDEMAPS The GUIDEMAPS project, also funded by the European Commission, focused on project management and stakeholder involvement in the preparation of SUMPs. Its handbook provided a framework for good project management and stakeholder engagement, and a series of fact sheets, including some 32 engagement tools (www.osmose-os.org/documents/316/GUIDEMAPSHandbook_web[1].pdf). The current SUMP guidelines draw on the GUIDEMAPS handbook particularly in their advice on stakeholder involvement, monitoring, implementation and reviewing achievements.

DISTILLATE and PROSPECTS The DISTILLATE programme (outlined above) developed a set of 18 decision-support tools to tackle the main barriers to transport policy formulation at strategy and scheme level. Table 4 lists these in terms of the barriers which they were designed to overcome, their applicability to strategy formulation or scheme design, and whether they were analytical tools or guidance documents. Further detail is available in May (2009) and its associated papers, and in www.distillate.ac.uk. The programme drew on earlier work in the PROSPECTS project (also outlined above), which produced a Decision-Makers’ Guidebook, designed to provide an introduction to the principles of urban transport policy development, a methodological guidebook and a policy guidebook. The Decision- Makers’ Guidebook was updated in 2005, drawing on research elsewhere in the Land Use and Transport Research cluster (May, 2005). It and the policy guidebook are now combined in the web-based Knowledgebase on Sustainable Urban Land Use and Transport (KonSULT) (www.konsult.leeds.ac.uk). The methodological guidebook is separately available (Shepherd et al, 2003). The current SUMP guidelines refer to DISTILLATE and PROSPECTS in their advice on problem analysis, scenario development, monitoring and target setting.
Table 4 – The DISTILLATE products (source: May, 2009)

<table>
<thead>
<tr>
<th>Project</th>
<th>Strategy development</th>
<th>Scheme design</th>
<th>Both</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicators</td>
<td>Integration of indicators across sectors</td>
<td></td>
<td>Selection and use of indicators</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Specification of new indicators</td>
</tr>
<tr>
<td>Option generation</td>
<td>KonSULT option generator</td>
<td>Road space reallocation option generator</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Accessibility strategy planner</td>
<td>Public realm improvement generator</td>
<td></td>
</tr>
<tr>
<td>Finance</td>
<td>Implications of funding mechanisms</td>
<td></td>
<td>Funding toolkit</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Advice to funding agencies</td>
</tr>
<tr>
<td>Predictive models</td>
<td>MARS optimisation tool</td>
<td>Demand management modelling</td>
<td></td>
</tr>
<tr>
<td></td>
<td>STM public transport and land use model</td>
<td>Public transport modelling</td>
<td></td>
</tr>
<tr>
<td>Appraisal</td>
<td>Distributional impacts of strategies</td>
<td>Distributional impacts of schemes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Good practice in appraisal</td>
<td>Small scheme appraisal tool</td>
<td></td>
</tr>
<tr>
<td>Effective collaboration</td>
<td></td>
<td></td>
<td>Good practice in partnership working</td>
</tr>
</tbody>
</table>

Key: standard font: Tools; Italic font: Guidance
Other sources The only other area in which the SUMP guidelines draw on related research is in their advice on developing effective packages of measures. Here they draw on KonSULT (www.konsult.leeds.ac.uk) as well as the ELTIS portal (www.Eltis.org), the European Platform on Mobility Management (www.epomm.eu), and the outcome of CIVITAS projects such as CATALIST and CARAVEL (www.civitas-initiative.org).

CHALLENGE Strictly, CHALLENGE is not a research project, but a support action designed to assist cities. In this role it is enhancing decision-support tools in the fields of public participation; partnership working; option generation and packaging; and monitoring, appraisal and evaluation. In relation to public participation, it is testing alternative approaches for direct citizen involvement. For partnership working it is developing guidance on good practice in determining partner institutions’ hierarchy, roles and relationships, on how to involve less willing partners, on leadership and facilitation and on effective partnership budgeting. Under the heading of option generation, it has updated and expanded the KonSULT knowledgebase to include some 58 policy measures and substantially upgraded the option generation facilities to enable cities to identify suitable measures and packages; it will be using this knowledgebase to document more fully effective processes for strategy development. For monitoring, appraisal and evaluation it is specifying the appropriate level of activity for different sizes of city, identifying a common set of outcome indicators, identifying the resources required for effective monitoring, and suggesting ways in which political commitment to monitoring and evaluation can be encouraged; as a separate strand it will also be developing procedures for evaluating the planning process itself (www.sump-challenges.eu).

3 The barriers to effective Sustainable Urban Mobility Plans

3.1 The principal barriers in European cities

As will be clear from the previous section, most European cities still lack many of the basic building blocks for creating Sustainable Urban Mobility Plans, despite several decades of development. The ELTISplus State of the Art Report (ELTISplus, 2012) is remarkably consistent with the earlier ECMT (ECMT, 2002, 2006), PROSPECTS (May and Matthews, 2007), Atkins (Atkins, 2005, 2007) and DISTILLATE (May, 2009) reports in its assessment of the barriers to effective planning. The principal ones are:

1. conflicting institutional roles, both vertically and horizontally;
2. hesitant political commitment to the principles of sustainability and to the solutions needed;
3. poor integration between the policy sectors, and particularly between transport and land use;
4. inappropriate financing, both for plan preparation and for implementation;
5. limited skills in option generation and undue emphasis on supply-side solutions;
6. limited public support and lack of experience in stakeholder involvement; and
7. poor data and lack of evidence of the performance of specific solutions.

At a more detailed level, the Atkins and DISTILLATE studies highlight weaknesses in monitoring, target setting, appraisal and implementation.

3.2 The barriers in developing cities

Not surprisingly, cities in the developing world are typically even less advanced. Some insights into the problems which they face can be found in responses to a survey of the members of CODATU’s new Permanent Scientific and Technical Committee. In addition to its two co-chairs, the Committee has 20 members from 18 countries, all selected for their expertise in the transport needs of developing country cities. Five are experts from developed countries, three from Latin America, four from Asia, three from Africa and five from Eastern Europe and the Middle East. Sixteen had provided answers to the following questions, all relating to urban transport and development:

- What are the major gaps between research and practice?
- What are the obstacles to transfer between research and practice?
- Which are the most important themes on which practitioners need additional information?
- How could research best assist this?
- What are the major barriers to fruitful collaboration between research and practice?
- How could these barriers be overcome?
- What are the prevailing critical issues of urban transport?

The answers to these questions will be presented more fully in a discussion session in the Conference, and will be used as a basis for identifying the critical issues in research and practice on which CODATU might focus. In relation to the barriers identified above in European practice, the most relevant findings were:

1. the lack of a coordinated approach to policy formulation, including the development of Sustainable Urban Mobility Plans; and more specifically the
lack of effective governance at a local level and the absence of policy at national level;
2. the failure to define sustainability and appropriate performance indicators, though only one respondent referred specifically to lack of political will and the influence of the electoral cycle;
3. the need for an integrated approach to transport and land use;
4. the lack of funding for the policy formulation process and its underpinning research; and in particular the lack of funding for policy implementation;
5. the need for transit oriented development and travel demand management; though none raised the underlying concern in Europe over the option generation process;
6. the lack of stakeholder involvement and citizen participation; reinforced by the pressures of lobby groups, industry and the private car sector;
7. the lack of data, lack of skills in interpreting that data and, in particular, lack of evidence on policy performance and transferability.

Perhaps the most compelling assessment of the barriers to effective policy development in developing countries is the Asian Development Bank’s publication: Changing course: a new paradigm for sustainable urban transport (ADB, 2009). It lists the principal problems as follows (numbers in brackets relate these, where possible, to the seven barriers listed above):

- transport plans derived from black box models rather than empirical evidence (7);
- dominance by experts, with too little involvement of stakeholders, users and residents (6);
- expert planning which is too deterministic and too ready to assume a predictable future with readily available finance (-, 4);
- plans based on wish lists rather than feasible strategies (3, 5);
- city institutions which thwart effective management and are unable to deliver the promised policies (1);
- a dominance of politics over professional advice (2);
- inadequate enabling environments provided by national governments (1).

These seven problems can be seen to relate well to those identified in Europe, but with one notable addition: the over-reliance on less than effective experts. This is a particularly important consideration in assessing the transferability of decision-making tools developed in Europe.
4 Developing appropriate guidance and decision-support tools for cities of the developing world

The ADB’s new paradigm involves:

- basing transport policy on what is needed and what works, using empirical evidence and the expertise of stakeholders, users and residents;
- using land use planning as part of the solution, both to enhance public transport and to reduce the need to travel;
- using demand-side measures alongside supply-side ones, including traffic restraint, enhanced public transport and attitudinal and behavioural measures;
- plans and projects which reflect a wider city vision and spatial strategy and are affordable, adaptable and implementable;
- demonstrating policy effectiveness to sceptical stakeholders.

Throughout the paradigm there is a clear emphasis on decision-making which is led locally, focusing on local needs and on what is likely to work in the local context, with external experts involved in a supportive rather than a leading role. While the ADB has stressed this for the resulting Plan, it should apply to the plan making process as well. A similar view was expressed by the External Advisory Panel to the World Bank (World Bank, 2007).

Given this, it is clearly inappropriate simply to identify guidance and tools emanating from Europe which might be applied directly to cities in the developing world. Instead we consider what types of tool might be needed, to address each of the barriers identified in the previous section, and to what extent European practice might be modified to meet those needs.

4.1 Conflicting institutional roles

These were highlighted twice in the ADB report: at a national and a local level. Not only are roles often conflicting; they may well also be unclear. Since it is difficult and disruptive to change governance structures, more is likely to be gained by using the principles of partnership working to encourage the various actors to contribute more effectively. The SUMP guidelines consider this under the headings of “define the development process and scope of plan” and “agree on clear responsibilities...”, and offer several suggestions. More detailed guidance is available in the DISTILLATE guidebook on partnership working (Forrester, 2009). Additional guidance should be available in 2015 from the work of the CH4LLENGE project. It would be valuable to review these documents in the context of one or more developing country cities to assess their transferability, and the additional types of institution and skill which might be needed. This would be the appropriate point at
which to consider the role of the expert in SUMP development. The expert, whether an individual, a consultancy or a specialist team from a funding agency, clearly operates as a partner in plan development and, as the ADB report indicates, too often dominates the process. As the Advisory Panel to the World Bank commented, experts too often assume that developed country experience can simply be transferred to the developing world. Any review of partnership working in case study cities should consider the role of the expert, so that expertise is not lost, but is applied where it is needed.

4.2 Hesitant political commitment

This is the barrier which is least well addressed in the guidance reviewed in this paper, perhaps because most of the work cited comes from a planning rather than a political science discipline. In practice the final decisions on strategy are usually the responsibility of politicians, who are likely to be influenced also by partisan policies and short electoral cycles. Research on the role of policy entrepreneurs demonstrates the key role of strong policy advocates, who are often politicians (Borins, 2002). In the absence of a single political leader, decision-makers need to rely increasingly on network governance to achieve a convergence of political aims. While those aims may well still be shorter term ones, a longer term perspective can be encouraged through a focus on transition management (Loorbach and Thissen, 2011). However, these concepts need to be tested in a developing world context, which in turn requires a broadening of the disciplinary base for SUMP development.

4.3 Poor integration between the policy sectors

The ADB report stresses the importance of integrating transport and land use. The SUMP guidelines consider this briefly under “develop effective packages of measures” but do not do justice to the role of land use planning as part of an integrated strategy. The KonSULT option generator (May et al, 2012) and the MARS optimisation tool (Shepherd et al, 2009) both incorporate land use measures and encourage policy makers to consider them, and these tools may be of value outside Europe. But what is needed is a more fundamental understanding of how to plan land use and transport together, particularly reflecting the rapid rate of development in many cities in developing countries, and how, institutionally, the long term commitments in land use plans can be realised.

4.4 Inappropriate financing

The European assessments highlight the lack of finance for the planning process itself, and also inconsistent financing rules for different policy interventions, leading to bias in strategy development. The ADB report stresses the importance of working
within the funding available, and being flexible enough to respond to new funding sources or shortfalls. The SUMP guidelines cover funding under “agree on clear responsibilities and allocate funding”; they perhaps fail to raise early enough in the planning cycle the question of how much funding might be available. The financing toolkit developed in DISTILATE (Binsted and Paulley, 2009) offers a UK-specific example of how the range of funding sources and their appropriateness and pitfalls might be assessed. The MARS optimisation tool (Shepherd et al, 2009) enables the user to select that set of policy measures which perform best under a given financing constraint. Such methodologies may be of relevance, if appropriately modified to reflect the funding opportunities and constraints of developing cities.

4.5 Limited skills in option generation

The ADB report stresses the need to focus on what works, and to combine demand-side and supply side approaches. These considerations are central to the SUMP guidelines, and covered in detail under “develop effective packages of measures”. The need to stimulate planners and politicians to consider a wider range of possible measures, and to identify how best to package them, is the main driver of the development of the KonSULT option generator (May et al, 2012). As noted above, KonSULT is currently being enhanced in the CH4LLENGE project, and is now populated with information on the application of some 60 policy measures in cities of the developed world. There is no reason why a version more directly relevant to developing country cities could not be produced. At the same time, care should be taken to check that the principles of integration on which it is based are transferable.

4.6 Lack of experience in stakeholder support and citizen engagement

Stakeholder and citizen involvement appear twice in ADB’s new paradigm: as an input to the planning process and as a critical check on the appropriateness of the resulting plan. This sense of stakeholder involvement throughout the planning process is also central to the SUMP guidance, which addresses it first under “identify key actors and stakeholders”. The relevant sections of the report provide further guidance, and more will be forthcoming in 2015 from the work of the CH4LLENGE project. Again it would be valuable to review these documents in the context of one or more developing country cities to assess their transferability, and the additional types of stakeholder which might be involved.

4.7 Poor data and lack of evidence on the performance of specific solutions

The ADB report stresses the importance of using what works but, as the PSTC members note, there is a dearth of evidence on the effectiveness of specific policy measures and, in particular, of their transferability to other contexts. The SUMP
guidelines offer some sources of evidence, as indicated above. These sources have been used to populate the evidence of performance sections of the KonSULT knowledgebase but, as noted above, these focus on experience from the developed world. It would be invaluable to be able to collate, perhaps in a similar format, empirical evidence on the performance of different policy measures in developing cities. This of course presupposes that funding and political commitments are forthcoming to carry out such evaluations.

5 Conclusions

The last decade has seen major changes in policy in Europe on sustainable urban mobility planning, culminating in the recent publication of guidance on how to develop Sustainable Urban Mobility Plans (SUMPs). Despite this, several critical barriers to SUMP development remain; in particular relating to: governance, political commitment, integration with land use, inappropriate financing, ineffective option generation, lack of stakeholder involvement, and inadequate data and evidence.

Similar barriers are evident in developing country cities from a survey of experts for CODATU and a detailed review by the Asian Development Bank. The ADB and the World Bank have also questioned the over-dependence on external experts and their frequent assumption that experience can simply be transferred from the developed world.

European research has led to a number of guidebooks and decision-support tools which may offer assistance for SUMP development in developing countries. It will be important, however, to assess them critically and modify them as necessary to reflect the particular needs and contexts of developing cities. It would be valuable to assess the transferability of the SUMP Guidelines to the developing world and, in particular, to strengthen their coverage of political involvement, integration between the policy sectors, and financing. More specifically it would be informative to select a few case study cities in which to test, and enhance, existing guidance on partnership working (including the role of experts), funding opportunities, option generation, stakeholder involvement and monitoring and evaluation. These are potentially tasks which CODATU’s newly appointed Permanent Scientific and Technical Committee might coordinate.
This paper draws in part on a paper presented at the 13th World Conference on Transport Research in Rio de Janeiro in July 2013, and on the helpful comments made there. The author has also benefited from discussions with colleagues in the EC CH4LLENGE project, and from inputs from the members of CODATU’s PSTC. He acknowledges in particular the valuable suggestions made by Ali Huzayyin. The conclusions drawn, however, remain the author’s own.

References


CERTU (1999) PDU guide méthodologique. Lyon, CERTU.


European Commission DG Move (2011) Road map to a single European transport area: towards a competitive and resource efficient transport system.


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APPLICATION OF A METHODOLOGY TO ASSESS POLICIES TO CONTROL PRIVATE VEHICLE TRAFFIC IN CITIES

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Abstract

Vehicle congestion and sustainability of mobility in the long run have been identified as one of the main problems in Latin-American dense cities. Therefore, some of them cities have decided to implement vehicle restrictions in order to reduce the levels of vehicle congestion and the rational use of private cars. Measures such as the prohibition to use vehicles during some periods of time, and congestion pricing are traffic control mechanisms in peak hours and they are also used as environmental control mechanisms in some cases. These interventions want to discourage people from using their vehicle at certain hours during the day or to charge an amount of money if they want to get to some areas of the city. Unfortunately, the quantitative assessment of the impact of these measures is not an easy task. This work tries to analyze the effect of vehicle restrictions measures implemented in cities, using double differences impact assessment techniques on the indicator of car ownership analyzing O-D households’ surveys. The results try to establish the influence of the restriction policy on the decision to buy more vehicles for household members. “All day” vehicle restriction such as implemented in Bogotá, instead of contributing to reduce the use of private vehicles, they have promoted the purchase of more cars in higher strata. As it is observed in the results of this research paper, households affected by the measure show a tendency of 10% more for the purchase of a another vehicle when they are compared with the control group.

Methodology

To evaluate the effect of a policy, it is necessary to use measurements on a group of intervention and a control group that can be compared with those participating in the experiment. This control group is called the counter-factual group of the intervention. A city with similar conditions to those of the population treated must be chosen. To apply the methodology, two cities were chosen. In this case the policy of “all day” car restriction of the City of Bogotá will be evaluated compared to the city of Medellín where restriction during the whole day was not applied. The comparison among households is done with the information provided by mobility surveys carried

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out at households, which gather socio-economic information, information about transport trips, vehicle ownership and about household members. These types of surveys have been applied in three different moments in both cities, contributing with a valuable amount of cross-section data.

Structure and Limitations of Information

These surveys allow identifying people with the same socio-economic characteristics in both cities who have similar traveling habits and who can be directly compared at certain periods of time. They represent near 5% of randomly chosen households in those cities. These surveys are carried out in the main cities approximately every 5 years.

Unfortunately, as the same format is not always used, the organization of the information takes a lot of time and it implies a long period to process and standardize variables. Higher strata especially have problems concerning representation in household surveys due to the restrictions imposed on the access of interviewers, which can constitute a minimum bias for selection.

The three periods of time permit isolating the natural changes of the factors that affect mobility in cities and also of the changes attributed the application of the policy. Unfortunately and due to the fact that these processes are coordinated by the administrations of the cities, there are some variations in the data of one or the other city in periods between one or two years. Differences in time were not taken into account and the data of the variables was not adjusted because it is considered that strata or family composition have not dramatically changed in two years as not to be able to compare them.

1. BACKGROUND OF VEHICLE RESTRICTION POLICIES

Temporal vehicle restrictions in cities in developing countries are traffic control measures that try to reduce emissions as in Mexico City or traffic congestion as in Bogotá.

In November 1989, the program called “Do not Drive Today” was launched in order to fight air pollution in Mexico City. The program officially became mandatory for private vehicles in March, 1990, and for public transport vehicles in January, 1991. The restriction period was from 5 a.m. to 10 p.m. This program has also been implemented in Guadalajara, Pachuca, Puebla and Toluca. In 2008, Mexico City also started to restrict vehicle mobility one Saturday monthly.

In 1998, a measure to restrict access of vehicles to urban roads was implemented for the first time in the City of Bogotá. This measure was used to reduce traffic congestion in peak hours. This policy used the last digit of the plate and it implied
the restriction for groups of 4 digits per day, which meant that each vehicle could not run a total of 4 hours, two days a week. The period of time was from 7 to 9 a.m. and from 5:30 to 7:30 p.m. Restricted hours in the morning were soon increased from 6:00 to 9:00. This restriction worked under these conditions for 11 years.

By the end of 2000s, the city administration toughened this measure. At the end of 2009, Bogotá had about 9 million inhabitants and nearly one million private vehicles (Figure 1). Therefore, due to the steady growth of the fleet of vehicles and to many infrastructure construction sites oblige the corresponding authorities to extend the period of restriction to a continuous period between 6:00 a.m. and 8:00 p.m.

<table>
<thead>
<tr>
<th>Año</th>
<th>Medellín</th>
<th>Bogotá</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>87,015</td>
<td>590,900</td>
</tr>
<tr>
<td>2003</td>
<td>85,134</td>
<td>590,373</td>
</tr>
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<td>2004</td>
<td>124,560</td>
<td>665,520</td>
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<td>2005</td>
<td>745,000</td>
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<td>2006</td>
<td>658,000</td>
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<tr>
<td>2007</td>
<td>434,000</td>
<td>839,251</td>
</tr>
<tr>
<td>2008</td>
<td>434,000</td>
<td>915,567</td>
</tr>
<tr>
<td>2009</td>
<td>455,000</td>
<td>375,613</td>
</tr>
<tr>
<td>2010</td>
<td>499,000</td>
<td>1,070,572</td>
</tr>
<tr>
<td>2011</td>
<td>550,457</td>
<td>1,186,387</td>
</tr>
<tr>
<td>2012</td>
<td>577,329</td>
<td>1,289,499</td>
</tr>
</tbody>
</table>

Figure 1. Private fleet increase for Bogotá city 2002-2006, Source: SDM, and Environmental Secretary of Bogota, 2007-2013 Medellín (Secretaría de Transportes y Tránsito de Medellín, 2002)

The measure was applied in Medellín during the first half of 2005, restricting the flow of selected vehicles with the last two digits of the plate at peak hours. These days continue being rotated every six months. The change implemented in the first semester of 2012, was that peak hours were from 6:30 a.m. to 8:30 a.m. and from 5:30 p.m. to 7:30 p.m. It was estimated that this measure reduced the movement of private fleet in 20%. According to National Statistics projections, Medellín has nearly 2,700,000 inhabitants and nearly 537,000 private vehicles in 2011.

Free-trade agreements signed with manufacturing countries and Colombia’s economic growth allow thinking that the figures about the growth of the fleet of vehicles would have been constant during last years in all cities affected and non-affected by restriction measures. The tendency of the growth of the fleet of vehicles in both cities and the comparison with the general behavior of cities in Colombia allows foreseen that there is a parallel trend in the behavior of the fleet of vehicles, which could be affected by the restriction systematically applied all day long.

However, Bogotá is the city with the highest rate of increase in the private fleet. For this reason, it is advisable to apply a quantitative measure on the dynamics of growth
of the fleet. Due to the restriction policies implement by the last three mayors of the City of Bogotá, it is important to establish whether these policies have been efficient to rationalize the use of the car, or on the contrary, whether these policies have contributed to increase the purchase of more cars by households with greater economic capacity in order to evade the restriction applied during the whole day.

According to vehicle volumes observed during a normal working day, it can be clearly seen that the measure has not been effective in terms of reducing traffic congestion up to day. According to the figures provided by the Office of the Secretary of Mobility, the number of vehicles has significantly increased since the extension of the measure. Other cities in Colombia (Figure 2) have experienced a growth of the fleet although many of them have not implemented measures, as strong as in Bogotá, to control traffic congestion. Those cities have had the same behavior of the City of Medellín where the restriction has been maintained per hours.

Figure 2. – Growth of Private fleet Colombia, 1990-2008, Mintransporte.

To estimate the effect of vehicle restriction policies in the City of Bogotá and their possible contribution to the increase of private fleet the impact assessment techniques described below were applied.

2. DATA SOURCES

The data used for the analysis of this proposal were taken from mobility surveys done in Bogotá in 1998, 2005 and 2011. Household surveys have been the methodologies used in Colombia in recent years in order to establish not only the characteristics of transport demand, but also to measure the indicators of motorization of the population.

The International Corporation Agency of Japan carried out the survey of mobility for the Master Plan of the City in 1996, and the Office of the Secretary of Mobility of Bogotá conducted two surveys in 2005 and 2011. Such surveys provide
disaggregated information about the socioeconomic characteristics of households, the characteristics of household members, the number of vehicles available and the trips in all modes of transport. The sizes of the samples were 4,107, 4,753 and 6,087 households respectively, which corresponded to households that have reported to own vehicles.

In the case of the City of Medellín, the records of the survey done by the Municipality of Medellín in 2000, the information gathered by the National University in 2005 and the studies done by Steer Davies and Gleave Company in 2012 were taken into account. In general, these surveys use the same methodology proposed by the Ministry of Transport, which make it possible to compare information among them. The sizes of the samples were 5,009, 3,073 and 16,012 households respectively.

3. METHODOLOGY USED

The method applied was an evaluation, using a double matched differences quasi-experimental methodology between two populations that are expected to have the same expectations concerning vehicle ownership.

This methodology wants to weight the observations of both the treatment and control groups in order to visualize similar characteristics in both of them (Bernal and Peña, 2011a). The difference in vehicle ownership in households, which in this case is the outcome variable, is contrasted with the estimators using explanatory variables because they have the same probability of participation in the restriction policy P(X). It has been demonstrated that when the matching is done in function P(X) consistent estimators are obtained. Therefore, they will be consistent estimators to determine the effect of the treatment (Rosembaum and Rubin, 1983).

3.1. Variables used

When trying to explain the difference about vehicle ownership in two different periods of time, not all the information included in the surveys in both cities is relevant for the purpose of the study. A description of the set of variables that explain vehicle ownership in households will be done in the next paragraphs. These variables have been successfully used in Colombia to build motorization models (Gómez y Obando, 2013).

*Home Stratum (Stratum)*: Although household income, by nature, is one of the variables with a stronger relationship with vehicle ownership, in these surveys only the stratum is consistently captured across all instruments. This variable was used to establish household socioeconomic status.

*Working Adults (Workingadults)*: the number of household members who work is a very important factor that determines the number of cars in the household. When the number of members who work is high, there are greater needs to move from one
place to another and, therefore, it is expected to have much more cars. However, not all people have the same need concerning mobilization. Generally, a differentiation of variables between adults who work and those who do not work is established. Adults who work and those who do not work (Nonworking adults) were separately analyzed so that this information could be easily included in databases used.

**Children at home (Children):** Similarly, it is observed that if there are children in the household, there are a greater needs of mobilization and, therefore, the number of cars required by the family also increases.

**Motorcycles (Vehimotorcycles):** As the use of this type of vehicle has increased, and as its sales have also increased in Colombian markets, the motorcycle is a substitute of the car at households. This variable of control of the model was included as a part of the analysis in order to assess the influence of a second vehicle (a motorcycle) in the household.

**Taxis (Vehitaxis):** This variable of control of the model was included in order to assess the influence of the presence of a taxi in the household, which was not subject to restriction measures and which normally rendered a service to household members.

**Bicycles (Vehibicycles):** In recent years, sustainable transport strategies have suggested the bicycle as a substitute vehicle. Therefore, the variable of control of the model was included in order to assess the influence of this means of transport as a mobility mechanism in the household.

**Sex of the head of the household (jefeeshombre):** A control of the sex of the head of the household was carried out in order to determine the effect that this variable had on the decision made about purchasing another vehicle.

**Traveling Information of the head of the household (householderjourneyinfo):** A control of the information available about the head of the household was done because this aspect determines the priority use of household vehicles.

**Time spent in traveling by Household Head (mainjourneytime):** When comparing Households, this variable was used to establish the average travel time spent by the household head during his first trip, which normally would correspond to the primary use of the private vehicle in the household.

### 3.2. Formulation/Stating of the Model

Double matched difference method adjusted by fixed effects allow assuming that both populations have been subjected to the same national economic policies, freedom to buy vehicles and to other fixed effects that maintained throughout time.
This permits that both the control and the treatment samples reflect in the three different periods of time the results of these non-observable variables, which are expected to be constant regarding their behavior and guaranteeing the internal coherence of the model.

Double difference methodology follows a procedure, which allows estimating the difference of a dependent variable between the two populations in three periods of time. The observations in these three periods of time are known as cross-section data because they refer to the observations of households in three different moments.

The study variable to be foreseen for this case will be the one calculated deducing the difference in the variable of household vehicles (Vehículos Bog. And Vehículos Med.) between the two periods of time: before restriction per hours, during restriction per hours and during the period after the treatment (during the whole day), and both for the population treated, equations (1) and for control population, equations (2).

\[
\text{Effect of the Policy (variouscars)} = \text{Vehicles Bog.2005(t2)} - \text{Vehicles Bog.2005(t1)} \tag{1}
\]
\[
\text{Effect without the Policy (variouscars)} = \text{Vehicles Med.2005(t2)} - \text{Vehicles Med.2000(t1)}
\]

\[
\text{Effect of the Policy (variouscars)} = \text{Vehicles Bog.2011(t3)} - \text{Vehicles Bog.2005(t2)} \tag{2}
\]
\[
\text{Effect without the Policy (variouscars)} = \text{Vehicles Med.2012(t3)} - \text{Vehicles Med.2005(t2)}
\]

The effect to be analyzed is the possibility of purchasing a second vehicle, understanding that households already have one car because they have already been under the policy of vehicle restriction, and influence it has on the number of vehicles of households treated with respect to the ones that have not been treated.

The possibility of comparing the information gathered about both cities is based on the matching process in order to find the counter-factual sample of household treated among non-treated households.

At the beginning and in order to establish that both populations have similar behaviors, only households with the economic capacity to buy more than one car were chosen, and the subgroup of analysis was only composed of households of both populations that already had one car by the first period of time in which the measure was not applied. In this way it was possible to build a combined database of both populations, with 38,347 observations, in which it was only observed those households that had one or two vehicles for the periods of time t1, t2 and t3.

The effect of the change in the number of vehicles (variouscars) throughout the time between the two periods, according to equations (1) and (2), was calculated subtracting one vehicle from each of the records of both cities for the periods of time t2 and t3, which reported vehicles. Therefore, if the household had one vehicle at the periods of time t2 and t3 when the measure was applied, the variation (variouscars)
would be 0. If, on the contrary, the household reported more than one vehicle at the periods of time t2 and t3, the variation of the fleet of vehicles (variouscars) would be higher than 1.

If the household had more than two vehicles in the period time t2, the function estimates the effect of having increased the number of vehicles of the household. The ownership of more than two vehicles in households was not assessed. The purchase of a second vehicle is to be exclusively assessed because it is not frequent the purchase of a third or fourth vehicle due to the implementation of the policy.

The matching with a probability of participation P(X) tries to establish that households in both cities can be compared so that there is not difference between the household treated and the one under treatment. Using the variables previously described, an analysis of a probit type of regression model was done in order to establish the possible interactions of the variables over the probability to participate in the treatment, that is, of having been affected by the restriction.

Using the concept of common support (SC in Spanish) (Bernal and Peña, 2011b), it is possible to establish that if households share the same vector of explanatory variables they have the same probability of being or not being part of the policy. Common support is verified analyzing the predictable behavior of the dependent variable, in this case, variouscars, based on the explanatory variables of both the treatment and the control groups.

3.3. Results of matching methodology

Matching was used for the analysis done each year in order to interpret the tendency of households to purchase a second car.

It is understood that both Bogotá and Medellín were not under the effect of any policy in the first period of time in which the measure was implemented (Bogotá, 1998, and Medellín 2000), but they were subjected to vehicle restriction measures per hours (both in 2005) in the second period of time, constituting in this way two periods of pre-treatment. In the last period (Bogotá, 2011, and Medellín, 2012) the restriction treatment was applied during the whole day in Bogotá and the restriction per hours was maintained in Medellín. This is specifically the effect to be measured with the methodology.

In this way it was possible to find for each year a “clone” for each household in Bogotá within the population of Medellín with the same socioeconomic characteristics of people who work, with motorcycles, bicycles and children. This allowed finding decisions about whether to have one or two vehicles based on the similarity of observable characteristics. STATA software which was used to assess the methodology produced the results shown in the document.
During the first period in which the measures were implemented it was possible to match 3,838 households in Bogotá with 5,009 households in Medellín, for a total of 8,847 records.

The average effect on those treated (ATT) produced the following results in the first period of pre-treatment: the average household in Bogotá had a higher tendency to buy a second vehicle, 5.2% more than its counterpart in Medellín. The graph in Figure 3 shows the common support region found with the matching technique, in which the results of the analysis can be observed.

The graphic analysis shows a similar tendency of the variable between the two groups, probing that the variables included in the probit model used to calculate the probability of participating in the treatment also explain the behavior concerning the decisions of households with respect to the number of cars. This is due to the fact that the evolution of non-observed variables has nothing to do with participating or not in the restriction policy.

The influence of the variables within the model, their significance and confidence intervals are presented in the Table 1.

When the variables that better adjusted to the model were included, it was observed that some variables, such as the number of taxis or bicycles, did not have any relevance influence within the model. This was the reason why only the variables described, which had significant effects in the participation in the treatment were included.
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Figure 3. Distribution of households in treatment (1) and control group (0)

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<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>_treated</td>
<td>0.10***</td>
<td>0.01</td>
<td>0.16***</td>
</tr>
<tr>
<td></td>
<td>(0.007)</td>
<td>(0.007)</td>
<td>(0.004)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.09***</td>
<td>0.11***</td>
<td>0.03***</td>
</tr>
<tr>
<td></td>
<td>(0.005)</td>
<td>(0.006)</td>
<td>(0.002)</td>
</tr>
<tr>
<td>Observations</td>
<td>8,903</td>
<td>7,520</td>
<td>21,748</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.02</td>
<td>0.00</td>
<td>0.07</td>
</tr>
<tr>
<td>Adj. R-squared</td>
<td>0.02</td>
<td>0.00</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Table 1. Comparison of model accuracy

Standard errors in parentheses
*** p<0.001, ** p<0.01, * p<0.05

For the second period in which measures were applied, it was possible to match 4,492 household in Bogotá with 3,025 households in Medellín, for a total of 7,517 data within the supporting region.

The average effect on those treated (ATT) showed that after the restriction was implemented per hours (second pre-treatment period) the average household in Bogotá had a tendency of purchasing a second vehicle of only 3.3% more than its counterpart in Medellín. The common support region found with the matching and in which the results of the analysis are observed is in the Figure 3.

The graphic analysis shows a more homogeneous supporting region in both groups, with a cumulative similar behavior in the number of households within each probability.

Although the tendency to buy a second vehicle in the two groups diminishes when compared with the first period of time in which the measures were implemented, the City of Bogotá continues showing a higher tendency to buy a second vehicle.

The influence of the variables within the model, their significance and confidence intervals are presented in the Table 1.

For the last period of measurement in which the effect of the restriction measure during the whole day was to be established, it was possible to match 5,836 households in Bogotá with 15,912 households available in Medellín. In this case, the control sample was nearly three times the population treated and, therefore, the search for a clone was highly effective.
The average effect on those treated (ATT) showed that after applying the restriction during the whole day in Bogotá (Post-treatment period) and having maintained the restriction per hours in Medellín, the average household in Bogotá had a higher tendency to purchase a second vehicle, 10% more than households in Medellín. This so high relative difference had not been observed in the other two pre-treatment periods.

The Figure 3 shows the common supporting region found in the matching, in which the results of the analysis can be observed.

In order to establish the goodness of estimations and understanding the limitations of Kernel’s methodology for matching, a bootstrap type of sampling in all the comparisons among observations was carried out in order to determine the real standard deviation of the average results found and the matching confidence interval of the results.

The assumption of conditional independence (IC in Spanish) (Wooldridge, 2010) leads to the conclusion that households in the City of Bogotá would have evolved in their variables in the same way as the households in the City of Medellín if the restriction policy would not have been implemented during the whole day. That is to say that the dependent variable that represents the change in the number of household vehicles (variouscars) would maintain a common tendency for both groups, with a slight difference between the two cities.

The test of joint significance among the variables and the possibility to be under treatment showed that no variable is explained by the treatment, which allows establishing that the matching method was very relevant and robust.

4. FORMULATION/STATING AND RESULTS OF THE MODEL OF DOUBLE MATCHING DIFFERENCES

Assuming that the conditions of common support (SC in Spanish) explained in Numeral 2.2 and the conditions of conditioned independence (IC in Spanish) of Numeral 2.3 are fulfilled within the model, it would be possible to obtain, based on the matching carried out, the estimator of the average effect of the implementation of vehicle restriction policy $T_{ATT-DDE}$. This was obtained using double matched differences (DDE in Spanish) within the common support region, which would specifically be given by equation (3):

$$T_{ATT-DDE} = E_{P(X)} \{ E[(variouscars)/ D = 1, P(X)] - E[(variouscars)/ D = 0, P(X)] \} \quad (3)$$

The variable (variouscars) is explained with equation (4) within the general probit model, where its coefficients $\beta$ are understood as marginal effects of the variables of
the change in the number of vehicles at households. This is due to the fact that dummy “d” variable which represents the treatment group is a binary variable.

\[
\text{variouscars} = \alpha_i + \beta_1 \text{stratum} + \beta_2 \text{vehimotorcycles} + \beta_3 \text{workingadults} + \beta_4 \text{children} + \beta_5 \text{jefeeshombre} + \beta_6 \text{householdjourney} + \beta_7 \text{meanjourneytime}
\]  

(4)

4.1. Analysis of Results

According to the results found, the population under treatment presented an 18% of variation in the number of vehicles with respect to the 8% variation reported by households in the control group. The impact of the application of the vehicle restriction policy during the whole day, using the methodology explained in the previous numerals, showed that the impact estimated within the common support is 10% in the increase of vehicles (variouscars) with respect to the non-treated population. In other words, this means that households affected by the vehicle restriction policy have a marginal tendency of 10% in the purchase of a new vehicle when they are compared with the population that has not been affected by the vehicle restriction measure during the whole day.

![Figure 4 – Tendency to buy a second vehicle in the Cities of Bogotá and Medellín for the three periods of analysis: pre-treatment period (1998, 2000), (2005, 2005) and post-treatment period (2011, 2012)](image)

<table>
<thead>
<tr>
<th>ANOS</th>
<th>BOGOTA</th>
<th>MEDELLIN</th>
<th>DIFERENCIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>98-00</td>
<td>18.7%</td>
<td>18.7%</td>
<td>5.2%</td>
</tr>
<tr>
<td>05-05</td>
<td>13.5%</td>
<td>8.0%</td>
<td>5.3%</td>
</tr>
<tr>
<td>11-12</td>
<td>11.3%</td>
<td>8.7%</td>
<td>2.6%</td>
</tr>
</tbody>
</table>
5. Conclusions

The objective of this paper was to model the influence of vehicle restriction on the change with respect to the number of cars of the population affected. This was done using a disaggregated approach of the households in Bogotá, which were compared with a control group in the City of Medellín that was not subjected to the measure. The data used for the analysis corresponded to mobility surveys carried out in both cities in two different periods of time in order to observe changes in both populations.

The approach of the methodology was the specification and estimation of a double matched difference model that could explain changes throughout the time concerning vehicle ownership in the population under treatment and the control population.

The three matching models allowed obtaining an assignment of households that represented the control group and that could be compared with households affected by the measure.

Explicative variables used up to 99% allowed probing the coherence and robustness of Kernel’s matching algorithm.

Although there is an increase in the number of vehicles in the households of both groups, probably because of the combined effect of the increase of purchasing power, the reduction in the cost of vehicles and other non-observable aspects, households affected by restriction measures tend to have more vehicles.

The double difference model showed significant variations in the change of number of vehicles for the cross-section observations of treatment and control groups. The results allow concluding that in average the people affected by vehicle restriction measures – as the one implemented in the City of Bogotá – have a tendency to have 10% more vehicles than the people who has not been affected by the restriction measure during the whole day.

Double matching difference methodology was a very effective econometric analysis instrument to be applied in the analysis of private transport, including broader databases in order to improve the analyses that do not have observations about the same person or household throughout the time.

6. References


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References


DANE. Departamento Nacional de Estadística, Censo Nacional, 2005


THE CHALLENGE OF FINDING A ROLE FOR PARATRANSPORT SERVICES IN THE GLOBAL SOUTH

Pablo Salazar Ferro

Abstract

Often considered to be an obstacle to public transport system’s modernisation and/or transformation, paratransit services can also be perceived as a vital component of the dualistic systems of most cities of the Global South. While formal modes and paratransit modes operate in a shared urban territory, their relationships are usually explained as a coexistence of discrete elements in the system. Relationships are, however, far more complex. The two types of services interact with each other, generating hidden and visible interdependencies and trade-offs in daily operations that define most public transport systems in the Global South.

Paratransit modes have continuously found new niches and innovative roles largely relying upon their inherent flexibility and demand responsiveness—two of their more cited advantages. This paper focuses on these services’ adaptability in times of public transport transformation to respond to newly re-regulated operational contexts. Through a review of international experiences, the objective of the paper is to highlight and to analyse the roles and generated externalities of untransformed modes coexisting with a formal system and the newly reformed paratransit sector, where it exists.

It is argued that while providing necessary public transport options to large urban areas, the nature of the paratransit system also results in significant externalities, mainly in the form of operational inefficiencies and pollution. Dilemmas then arise when attempting to reduce these externalities: the challenge of renewing fleets and reorganising services is closely linked to the challenge of not losing paratransit-like advantages—largely beneficial in the Global South—during the process.
1. Introduction: Paratransit - formal duality in the Global South

According to most definitions, paratransit are conceived as the counterpart of formal services in public transport systems. A myriad of other terms are used to describe such services (or a part of them); they include: ‘informal transport’, ‘illegal transport’, ‘traditional transport’ – notably in Latin America–, ‘artisanal transport’ – in Francophone Africa – or ‘unregulated transport’. Indeed, while a precise and consensual definition of what constitutes paratransit services is often lacking, it is widely agreed that they represent a privately developed service profiting from relaxed or non-existing regulatory frameworks. The options for providing services under these circumstances are many. Regulatory options and operational demands vary widely between cities and, similarly, business structures, while comparable, also take many forms. Paratransit operators resort to a wide range of vehicles, from conventional buses to motorcycle taxis, to provide services, but it is often accepted that the archetypical mode is the minibus (Kumar & Barrett 2008).

Paratransit services’ role as a key component of public transport services in the Global South is unquestionable. The non-exhaustive review of urban transport systems modal share percentages depicted in Figure 1 shows the substantial differences between cities in Latin America and Africa. Acknowledging that collected data has reliability issues and taking into account notable exceptions (in Figure 1, the examples of Sao Paulo, Tunis, Recife and Cape Town), paratransit modes can be depicted as the main component of public transport services in terms of passenger modal shares.

Often presented as a transport mode that acts as an obstacle to the modernisation of public transport services (Maillot 2008), paratransit services undoubtedly require transformation. This transformation has two main components: (1) business structure and organisation and (2) operations – routes, schedules or frequencies, fleet, etc. –. Approaches to transformation vary widely from one city to another: they take different forms that range from recognition coupled with gradual formalisation to, more radically, full substitution by newly established formal services.

As a result, not all paratransit services are included in transformational programmes and they often maintain a role – albeit a new or modified one – in the city’s transport system. Consequently, remaining services (i.e. those not targeted for formalisation or substitution) coexist and keep interacting with formal modes, new ones and already established ones. In this sense, in public transport systems of the Global South, paratransit and formal modes cannot be considered discrete elements (i.e. with limited or no interaction) of a system. Any transformation programme meant for either one of the two elements will inevitably impact the element not targeted for reform.

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2 Various definitions add elements that characterise those services. Wilkinson et al. (2012), for instance, indicate that variables pertaining to official endorsement of services, low-performing and aging small vehicles, service flexibility and lack of sufficient regulation. Godard (2013) explains that paratransit services are those based on individual initiatives that result in fragmented ownership and on a structure based on given drivers entire operational responsibility to produce financial surplus. Behrens et al. (2014) define three variables (regulation, business and services) that define paratransit services comparing them to formal public transport services; in this sense, paratransit services are largely unregulated and display unplanned services. In general, paratransit services are often perceived as simply as those that are not formal, thus resulting in a wide variety of possibilities.

3 It is necessary to note that, in Cape Town, the modal share for paratransit services has been consistently increasing in recent years. The latest survey suggests that, in 2012, 44% of all-purpose daily trips are the responsibility of minibus-taxis (i.e. paratransit modes) (CoCT 2013). This number was 11% in 1987 and it was 24% in 2000 (Grey 2006).
This document is structured around a secondary sources case study review. Its objective is not to produce generalisation of the outcomes, rather its purpose is to highlight how paratransit services have responded to changing environments and to identify what role they have taken in public transport systems. After introducing the characteristics of paratransit services and presenting a classification of current transformational experiences in Section 2, a review of three cases depicts widely different experiences in paratransit reform. First is the case of Santiago where drastic change to the road-based system was brought upon with the overnight citywide implementation of Transantiago. The second case is that of Bogota where initial progressive corridor-by-corridor BRT implementation has had substantial and unforeseen consequences in parallel corridors. And, finally, the third case is Dakar where the analysis focuses on the fleet renewal scheme for paratransit minibuses and how they have reacted to it. The fourth and final section of the document introduces the dilemma that arises when formalising paratransit modes as the city loses it advantages. It also introduces questions pertaining to how pollution control and energy efficiency policies are integrated into formalisation programmes in the Global South.

2. The role of the paratransit sector

3.1. Advantages of the paratransit sector versus its externalities

Pertaining to the consequences of the growing numbers of paratransit services in most cities of the Global South, a number of negative externalities have been linked to these modes. Amongst these, congestion, accident rates and pollution problems are often first cited when describing damaging effects of the paratransit sector (cf. Figueroa 2005; Gauthier &
Amongst these, congestion, accident rates and pollution problems are often first cited when of the Global South, a number of negative externalities have been linked to these modes. Pertaining to the consequences of the growing numbers of paratransit services in most cities, advantages of the paratransit sector versus its externalities

Yet, paratransit operations also provide certain advantages to public transport systems in the Global South. Amongst these, demand-responsiveness, operational flexibility and territorial coverage appear as important advantages in the urban contexts of most cities of the Global South (Godard 2008). Often cited as another advantage, adaptability in terms of schedules and/or frequencies is a characteristic that can be contested. Indeed, adaptability to, for instance, peak periods and off-peak periods combines scheduling flexibility of paratransit operators and, at the same time, forced adaptation by users that suffer practices of reduced service. Additionally, pertaining to general advantages of paratransit services and even if sometimes challenged or questioned, comparatively lower fares and the possibility to negotiate fares between a driver and a user and, most importantly, the lack of direct capital or operational subsidies can also be included as benefits of the paratransit sector.

Advantages and externalities of the paratransit sector are closely linked together: they express in the transport system the fragmented and demand-driven nature of the sector. In recent analyses and diagnostics of current public transport systems conditions have suggested that, partly as a result of the growing dominance of paratransit modes, transport systems are in a state of crisis (i.e. in need of urgent change) (cf. Kumar & Barrett 2008; Lupano & Sanchez 2009; UATP & UITP 2010; etc.). According to these analyses, systemic crises are mostly evidenced in congestion as its archetypical expression on urban roads. Local and national authorities have recently initiated or planned a number of attempts at ‘formalising’ paratransit modes and/or ‘organising’ and ‘professionalising’ these same public transport modes. Approaches vary and so do outcomes.

3.2. Options for paratransit in times of reform

At first, three families of approaches can be distinguished: (1) those that aim at gradual or immediate citywide transformation based on implementing a new formal mode; (2) those that are based on gradual transformation of selected public transport corridors or main axes through the introduction of a formal mode; and (3) transformations based on fleet renewal schemes and professionalization initiatives. Within each one of these families of cases, more or less radical approaches to transformation can be identified. Approaches to transformation dictate the possible role for remaining paratransit services (i.e. those that are not targeted for formalisation, if they exist). It is also important to note that, in some cities, it is possible to plan and/or implement programmes from two different families, notably when combining the third set of cases with one of the first two families.

In relation to the first family of cases, experiences that seek citywide –usually immediate– transformation of the entire public transport system, most radical approaches aim at fully substituting paratransit services with new or existing formal modes. One such approach can be identified in Santiago’s recent Transantiago programme where most paratransit operators...
were either excluded from the system or absorbed into recently created operational companies without paratransit-like characteristics (the experience is further detailed below). In such cases, paratransit services are often marginalised and likely forced out of the system without this resulting directly in improved citywide transport conditions in terms of accessibility. Curitiba’s transformation in the 1970’s can also be included in this family. Indeed, the trinary road system –later designed for BRT operations– is the main element of the system but it is not the only one: secondary transport routes and area distribution are important elements of the initial model of the 1970s and 1980s (cf. Macedo 2004). Systemic transformation was implemented citywide by professionalising and formalising incumbent operators early in the process (Ardila Gomez 2004).

Figure 2: BRT implementation surge, by number of corridors

The second set of cases includes a large number of examples. The recent surge in BRT planning and construction across the Global South (see Figure 2) relying on progressive phased corridor implementation is at the base of this family of cases. Emblematic cases include Quito (cf. Hidalgo & Grafiteaux 2006), Bogota (this experience is further detailed below) and Mexico (cf. Flores & Zegras 2012) in Latin America; and Lagos (cf. Kaenzig et al. 2010), Johannesburg and Cape Town (cf. Gauthier & Weinstock 2010) in Africa. In the same manner as the previous family of cases, approaches vary from aggressive paratransit substitution in selected corridors to formalisation of existing operators through the creation of operating companies. However, contrary to the previous family of cases, an important number of incumbent operators is not included in (initial) corridors and, as a result, no transformation is envisioned for them. In all, this set of cases exhibits a duality in the systemic transformation approach: parallel to new formal and formalised corridors, paratransit operators not having experienced significant levels of transformation persist. Thus, it is not unusual to find alternative or additional reform programmes that aim at complementing corridor-by-corridor implementation.

The third family or set of cases includes cities that have attempted or that are planning paratransit’s reorganisation using most notably paratransit upgrade (e.g. Accra (cf. Finn 2008)), fleet renewal schemes (e.g. Dakar (this case is further detailed below)) and professionalization and re-regulation initiatives (e.g. Buenos Aires (cf. Gutierrez 2004) and
Casablanca (cf. Le Tellier 2007)). Similar to previous groups of cases, authorities in these cities seek to introduce regulations in terms of operations, business structures and roadworthiness that aim at upgrading the quality of the entire public transport system in the city. This type of approach affects all paratransit services. It also tends to be less radical than the two previous families of cases. While a new formal mode implementation is not necessarily excluded, these cases do not rely on catalytic projects such BRT implementation or similar.

Arguably a fourth group of cities could be considered: cases where no transformation is imminently planned. Analyses of such public transport systems where paratransit services are one of the main modes, if not the more important in terms of modal shares, describe the sector’s original forms of self-regulation (including relative lack of operational regulation) and organisation. These cases will not be detailed in this document.

The above conceptual typology of cases is synthesised in Figure 3. Selected cases were placed according to the interpretation of their recent or current transformational programme. From the large list of possible cases, three cases were selected to describe the roles and adaptations of paratransit services included in each family. Case analyses do not claim generalisation of consequences of paratransit practices and behaviours during or after transformational programmes. On the contrary, cases are used to explore what possibilities paratransit operators have found to maintain a place in the system. In this sense, three experiences are analysed: Santiago, Bogota and Dakar. The following section focuses on the new or modified roles paratransit operators have found in these cities and what consequences followed.

3. Roles for paratransit services: Three experiences

3.1. Santiago, Chile

Santiago’s recent BRT project is part of a larger programme referred to as Transantiago that includes programmes for road infrastructure, rail-based public transport services and road-based public transport services. Pertaining to road-based public transport services, its premise
was to modernise the entire system (Maillet 2008): incumbent paratransit modes, in the form of conventional buses and collective taxis, were included in the transformation programme but a reduction of the number of operating companies was envisioned (Forray & Figueroa 2011). Muñoz & Gschwender (2008) explain the initial situation for existing paratransit operators:

> Although public opinion was against any participation in the Transantiago process by the incumbent [paratransit] operators who were members of the owner cooperatives, in the end they were permitted to take part. The Transport Ministry had no legal grounds on which to limit their involvement and banning them risked triggering a serious social conflict.

Source: Muñoz & Gschwender 2008:48^4

Initially, then, paratransit services in the form of conventional buses –“micros amarillos”– and collective taxis were to be absorbed into the road-based public transport services systemic transformation programme. But, the situation quickly changed; ultimately few incumbent operators were effectively included in the recent system.

First, in relation to former paratransit conventional bus services, before Transantiago’s trunk and feeder model was implemented in 2007, operators were presented with two options: (1) to create or take part in feeder area formal operating companies or (2) to fully and immediately withdraw from the new system. Incumbent operators – irrespective of their size or affiliation– were, hence, not expected to be a part of trunk BRT operations. Distinction between trunk services and feeder services was decided early in the process:

> The decision of dividing the bus system in two separate networks was made with the aims of (1) reaching a better adjustment between demand and offer, through the use of bigger vehicles in the main routes and smaller ones in the feeder lines, and (2) allow the authority to make a good planning of the main routes. In effect, considering the difficulty that the design of the main routes (where the city development and the patronage are more consolidated), and that the adjustment of the feeder lines should be proposed by the operators themselves. So it was necessary to give them adequate incentives in this direction. On the other hand, the available data and the design tools developed by the authority were able to give adequate answers to the route designs in the main lined, but were not so reliable in the periphery of the city, where the demand is spread across and changes quickly.

Source: Gschwender 2005:10-11

Another consequence of one such approach was that smaller paratransit conventional bus companies were effectively removed from the system, while larger incumbent companies formed formalised feeder area companies and remained in the system –albeit with radical changes to their practices and organisation–. Authors have argued that the formalisation of a part of paratransit services and the withdrawal of the rest of paratransit bus operators has resulted in problematic conditions in peripheral areas of the city (Jouffe & Lazo Corvalan 2010).

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^4 Minteguiaga (2006) explains that, even considering the paratransit sectors evident advantages to users, the service was poorly rated by inhabitants. Advantages, in this case, included: large territorial coverage, high accessibility in terms of distance to bus stops, frequency of services (less than 4minutes waiting time, on average) and low flat fare (Minteguiaga 2006).
Second, pertaining to incumbent collective taxi operators, the initial proposal to include them or to reorganise their services according to Transantiago’s feeder area division of the city was ultimately aborted and a different type of programme changes was designed for the collective taxi sector. The relatively limited transformation allowed these services to remain highly adaptable and to maintain some of the characteristics most appreciated by users: door-to-door services at night when other options are not available and, importantly, territorial coverage (Figueroa 2007).

In terms of the aborted proposal, the first objective was to encourage collective taxi paratransit services to consolidate and create operating companies attached to one of the ten predefined areas (Figueroa 2007). The implemented programme primarily sought a rationalisation of routes and an optimised use of rank infrastructures. It is also noteworthy that fare integration was not contemplated between collective taxis and the rest of the road-based system; the only condition is that they remained above the fares for bus services in order to avoid disruptive competition (Beltran & Flores 2005). The programme consisted of awarding tendered routes to incumbent operators without prioritising the larger existing collective taxi associations. Of the 300 tendered routes, 73% of them (219 routes) were awarded to associations operating less than 40 vehicles; what is more, a total of 91 routes (30%) were awarded to the smallest associations (Figueroa 2007). This transformation was enacted without it resulting in paratransit reform: operators’ consolidation as a condition for implementation was ultimately not achieved (Figueroa 2007).

Before the implementation of Transantiago’s trunk and feeder model and before the implementation of the collective taxis reorganisation initiative, collective taxis were responsible for approximately 6% of motorised public transport demand5 (Rivasplata 2008). During the chaotic Transantiago implementation, and as a result of the disappearance of former paratransit bus services, collective taxis were forced, in the same manner as the Metro network, to take on a larger role in the system (Figueroa 2007). Furthermore, considering that paratransit collective taxis were not formalised as initially planned, they managed to preserve important flexibility and demand-responsive characteristics that allowed them to serve users living in urban peripheries where new formalised bus services had become scattered (cf. Briones 2009; Forray & Figueroa 2011).

The transformational experience of Santiago’s road-based public transport system, when analysing paratransit-related reforms, consisted of two distinct programmes: (1) a conventional bus programme that sought substitution of paratransit services citywide and (2) a collective taxi programme that was modified to allow paratransit services to continue operating. While the conventional bus programme effectively managed to formalise the conventional bus paratransit operators through consolidation and substitution, and as a result it introduced a system based on competition ‘for the market’; the collective taxi programme failed to consolidate operators. However, after formalisation of conventional bus services, advantages of the previous system in terms of territorial coverage, frequencies and demand-responsiveness were lost, with important consequences for inhabitants in the peripheral areas of the city. Collective taxi services preserved those qualities and ensured services to these urban zones.

3.2. Bogota, Colombia

5 Public transport modal shares for Santiago, before the implementation of Transantiago, were estimated at: Metro network 14%; conventional bus services 80% and collective taxis 6% (Rivasplata 2008).
Bogota’s experience with introducing BRT corridors in an otherwise strictly paratransit-dependent system is renowned for the substantial—mostly positive—changes it brought to the public transport system. Indeed, prior to the implementation of Transmilenio in 2000, the city was solely dependent on a privately supplied system based on conventional buses, micro and midi-buses:

Bogota’s transport system matched the city perfectly. Its fleet of poorly maintained buses, driven by lowly paid semi-formal drivers was a mirror image of the city’s lack of effective planning, its poverty and inequality, and the general neglect of most people’s quality of life.

Source: Gilbert 2008:445

The Transmilenio programme’s implementation initially consisted of four phases to be completed in 2016 (Duarte Guterman & Cal y Mayor 2006). This timeframe was later modified to propose eight phases finishing in 2031 (Duarte Guterman & Cal y Mayor 2006). Implementation relied on corridor-by-corridor BRT trunk and feeder construction.

The premise of Bogota’s approach to BRT implementation was to negotiate with selected incumbent operators in order to include them as operators to the new formal mode (Ardila Gomez 2004; Gilbert 2008). This strategy effectively created two types of operators in the public transport system: (1) those that were consolidated and formalised and (2) those that have not gone through formalisation processes that was required for their eventual inclusion in the BRT network (Lleras 2005). Broadly, once the implementation of Transmilenio began, paratransit operators were presented with two options: consolidate and formalise or withdraw from the corridor where the system is planned. Indeed, the first option was only presented to operators whose lines used the road where BRT was planned (i.e. affected operators).

Concerning the first set of operators, those included in the BRT programme, implementing local authorities chose to negotiate with the top level of the paratransit hierarchy: associations. One such approach has been sometimes criticised:

Since the owners and drivers seem to earn very little and the city continues to suffer from high rates of unemployment, many feel that it is socially irresponsible not to involve them in the new system.

Source: Gilbert 2008:450

Reform of affected operators focused on incumbent transport companies, in the form of associations or cooperatives exploiting route licenses, affiliating vehicle owners and relying on daily fees collected by drivers. In order to participate in bidding processes for BRT trunk and feeder services, companies or associations were asked to consolidate (i.e. group or merge into larger companies) and create formal operating companies where they would become majority stakeholders. The strategy did not contemplate guarantees for all operators and a number of affected paratransit operators were thus forced out of the corridor. The strategy was also accompanied by an initiative to reduce oversupply of buses in the city; transformed operators were asked to scrap old vehicles when introducing newer articulated buses into the city. For the initial phase, the number of buses to scrap per articulated bus was set at 2,7 vehicles; this was later increased to 7,7 vehicles for the second phase (Gilbert 2008).
Indeed, as BRT implementation was being carried through, authorities did not manage to reduce vehicle oversupply in the system. In 2005, it was estimated that the oversupply in the public transport system amounted to 7,500 buses (Ardila Gomez 2005)\(^6\) for a fleet of 20,500 vehicles excluding Transmilenio’s vehicles (Ardila Gomez 2007). A consequence of Bogota’s strategy was that, true to their nature, paratransit operators circumvented the programme’s demand and they managed to transfer their vehicles to other roads in the same urban territory.

Ardila Gomez (2007) explains that operators scrapped a number of old buses but they also immediately replaced them with newer ones resulting in fleet numbers staying broadly the same citywide. It was estimated that, in 2005, of the 6,080 vehicles expected to be withdrawn from the system, approximately 4,670 were simply relocated in other roads (Echeverry et al. 2005). In all, the city’s paratransit services quickly adapted to new conditions. It also resulted in roads not directly concerned by Transmilenio BRT trunk implementation experiencing worsening levels of congestion and pollution (Echeverry et al. 2005\(^7\)).

Pertaining to paratransit services directly affected by BRT corridors, the city’s approach to using catalytic and phased BRT implementation has been criticised by certain authors:

> Bogota’s impressive project showed that BRT could be implemented in massive corridors but offered few answers to the more system-wide problems.
> Source: Muñoz & Gschwender 2008:46

> Initial evidence from Quito and Bogota show that even if high-quality public transport networks were implemented, these have only partial coverage of the city, often limited to few corridors leaving other main axes unattended and in the hands of low-quality traditional services.
> Source: Translation from Figueroa 2005\(^8\)

The progressive phased approach used in Bogota effectively formalised several former paratransit operators. It also forced the rest of incumbent paratransit operators into parallel roads where they were forced to compete for passengers with public transport services already operating in these corridors. Problematically, as more BRT corridors are planned and implemented, remaining unreformed paratransit services are able to operate on fewer roads but competing with more public transport vehicles than before. Displaced paratransit services –directly and indirectly– resulting from BRT implementation enter coverage areas of unaffected paratransit operators. Yet, there are unexpected advantages to this approach. The group of paratransit operators maintain adequate coverage in the peripheries isolated from newly formalised operators (Lleras 2005; Gilbert 2008).

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\(^6\) Fleet numbers are however contested. A different estimation suggests that the total fleet for the city was estimated at 14,545 vehicles (CAF 2010). This number includes conventional buses and microbuses. It is also important to note that, compared to other cities in the region, the case of Bogota shows an elevated number of public transport vehicles per inhabitant: Lima 7veh/1,000inhhab; Bogota 4veh/1,000inhhab; Santiago 2veh/1,000inhhab; Quito 1veh/1,000inhhab (Avellaneda Garcia 2007).

\(^7\) The analysis presented by Echeverry et al. (2005) has been contested by Peñalosa (2005) who argues that there is uncertainty as to whether worsening conditions are the responsibility of Transmilenio because the analysis does not consider the theoretical increasing role of private vehicles. Nonetheless, other analyses tend to indirectly confirm conclusions by Echeverry et al. (2005) (cf. Ardila Gomez 2005; Lleras 2005).

\(^8\) The original text, in Spanish, is: Las primeras evidencias en Quito y Bogotá muestran que a pesar de la consecución de redes de transporte público de alta calidad, ellas tienen una cobertura parcial en la ciudad, limitándose a ciertos corredores y dejando otros desatendidos y servidos por los sistemas tradicionales, de muy baja calidad.
The lack of integration between the formal BRT network—operated by transformed former paratransit services—and the untransformed paratransit sector has been identified as one of the main problems in Bogota’s public transport system (cf. Rivasplata 2008; Duarte & Rojas 2012). Yet, integration of formal and paratransit modes is a highly complex task: formal modes require clear regulations and planning, while paratransit modes thrive and are most beneficial to users in contexts of relative deregulation and limited scheduling.

Recently, Bogota’s strategy to systemic transformation has changed. Planning authorities are in the midst of implementing a citywide programme—referred to as the Integrated Public Transport System (SITP)—that seeks to include existing paratransit operators. The objective is to reorganise the system while also attempting to forcefully remove as few incumbent operators as possible. Of the existing 66 paratransit companies, in the form of route associations, 52 would effectively be included in the programme (Kash & Hidalgo 2012). This recent programme has not come without problems and, currently, its outcomes are uncertain.

3.3. Dakar, Senegal

Dakar’s case, contrary to Santiago and Bogota, did not seek the outright implementation of a new mode. Its focus was on formalising existing paratransit operators through a bus renewal scheme (SSATP 2003). The premise was that operators would more easily accept new regulatory measures introduced by authorities when benefitting from vehicle renewal financial advantages (Godard 2013). Authors explain the characteristics of the programme:

In Dakar, the fleet renewal programme was aimed at leveraging bus finance to introduce long-term reforms in the transport sector. The proposed reforms focused on the formalization (or professionalization) of the sector with the introduction of a formal system of route allocation and an official fare structure [...] The minibus operators were expected to finance up front 25 percent of the cost of the new buses, pay back the loan [...] and operate the minibuses as business as usual, without any direct subsidy from the state.

Source: Kumar & Diou 2010:2

Irrespective of the programme’s success, the inclusion of paratransit operators was arguably limited. Explanations can point to financial difficulties of implementing one such programme in the Global South. Be it as it may, the programme focused only on paratransit minibus services (referred to as “cars rapides”); it dealt with approximately 20% of “cars rapides” (Godard 2013). As a result, a large number of existing minibus operators and all collective taxi (referred to as “clandos”) operators were left out of the initial process. Minibus and collective taxi operations experienced different consequences directly or indirectly linked to the renewal programme.

Pertaining to paratransit operators included in the renewal programme, authors have argued that a positive outcome of the project has been an improved level of service for these vehicles (cf. UATP & UITP 2010). Godard (2013), however, claims that improvement is directly linked to the newer vehicles and not necessarily to the introduction of regulatory variables in the system. This critique resonates with others that claim that effective minimal regulation of operators has not been successful as, even with the incentive of fleet renewals, they refuse to
accept new demands— in the form of schedules and/or frequencies and maintenance practices—proposed by planning authorities (cf. Kumar & Diou 2010).

Minibus operators not involved in the fleet renewal process have not been directly affected by the introduction of new regulatory measures. These operators continue to use their old vehicles in a largely unregulated environment. What is more, part of the incentives presented to operators involved in the programme was that they would find a certain exclusivity in selected areas of the city; yet, untransformed operators continue using the roads they have always used thus maintaining practices linked to competition ‘in the market’ and hampering newly established formalised operations (Kumar & Barrett 2008).

Relatively foreign to the minibus reform, collective taxis have maintained the unregulated practices. Considered the ‘parasites’ of the public transport system (Lammoglia et al. 2012), “clandos” operators kept their already established niches: (1) as the sole public transport option in some areas and (2) as an additional mode in roads where public transport supply has not met demand (Lammoglia et al. 2012). The general perception of these services is negative, yet they provide users with an option where no other alternative is at hand. Indeed, their modal share is not marginal in the public transport system: in 2005, they represented 17% of public transport all-purpose demand (Godard 2013).

Indirectly, collective taxis of Dakar have shown substantial resilience in times of systemic transformation. Their place is the system is a complex one: they are viewed as problematic elements of the transport system in the eyes of authorities while, at the same time, being considered as a competitive service—in terms of quality, fare and travel time—by users (Lammoglia et al. 2012). Not included in formalisation or professionalization initiatives, based on their flexibility, they have maintained a relatively stable place in the transport system, filling gaps and taking advantage of regulatory and enforcement weaknesses of public authorities:

The transport provision network is organized in the first place according to the trip flows towards the modern sector employment sources located in the Plateau in Dakar. The road network is also designed according to this dominant scheme. The institutional system is not equipped to assume other types of transport provision at a reasonable cost, especially in the illegally urbanised areas with a low accessibility level where small-scale [paratransit] operators provide a better adapted service.

Source: Godard 2001:7

4. Conclusion: A role for paratransit services?

Finding a role for paratransit services is a complex challenge for planning and regulatory authorities. When seeking more structured and planned services through reform, paratransit’s fragmented and disorganised nature certainly represents an obstacle to such programmes. The objectives of systemic operational efficiency, eventually accompanied by energy consumption

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9 According to Kumar & Barrett (2008), estimations suggest that the average age of minibuses’ fleet is between 15 and 20 years. This number is relative elevated when compared to other cases in the region: Abidjan 15 years; Conakry 10 to 15 years; Doula 15 to 20 years (Kumar & Barrett 2008).

10 Public transport modal share, in 2005, was estimated to be: 17% for collective taxis, 77% for minibuses (thus, 94% for paratransit services) and 6% for formal conventional buses (Godard 2013). Public transport’s share in the transport system was calculated at 77.5% (Godard 2013).
reduction and pollution control targets, rely on consolidated and corporatized operational companies capable of respecting new regulatory measures and they clash with the nature of paratransit services.

Nonetheless, it is argued that paratransit services have a role to play in urban contexts of the Global South. Flexibility and demand-responsiveness, as well as the relative low cost, are assets often overlooked and lost during radical formalisation initiatives. In Santiago, users have been less than satisfied with the new trunk and feeder model performance, mainly because of increased transfer times and loss of accessibility in peripheral areas (Jouffe & Lazo Corvalan 2010; Muñoz 2012). This last element is of importance. Lazo Corvalan (2008) argues that inhabitants in the low-income peripheries are more isolated after the implementation of the new trunk and feeder system than they were with the previous paratransit dominant bus-based model.

Finding a role for paratransit services in the Global South will hence likely require finding novel models where formal services and paratransit services are complementary. Indeed, implementation of formal modes coupled with formalisation initiatives can bring about positive changes. For instance, in Bogota, not only has Transmilenio been presented as a key element in the reversal of the urban crisis (Salazar 2008), even critics point to the benefits of the new BRT system in corridors where it was implemented: travel times reduced by 32%, speed increases, carbon emissions reduced by 9% and accident rates reduced by 90% (Echeverry et al. 2005). However, in Bogota, the role for paratransit operators not involved in the reform was overlooked, leading to increasingly complex conditions for public transport outside of Transmilenio’s corridors.

Indeed, another layer of complexity is added when energy consumption and environmental targets are involved. The nature of paratransit services is not aligned with these purposes. Environmental, noise and optimised operational efficiencies are not top priorities for paratransit operators. Yet, effects of hiking fuel costs affect all public transport operators and formal services appear best equipped to manage these costs. Godard (2013) introduces two examples to illustrate this argument. First, in Doula in 2008, when after fuel prices increased, collective taxi operators conducted a strike arguing that such rises reduced even more their already meagre revenues (Godard 2013). And, second, in Lagos in 2012, when riots ensued after fuel price increases enacted by authorities (Godard 2013). In the case of Dakar, the renewal process also appears vulnerable to fuel price increases. It is calculated that fuel expenses are approximately 40% of operational costs for new “cars rapides” (Kumar & Diou 2010; Godard 2013). Fuel increases are thus likely to be of concern to new vehicles, as it will hamper revenues that, in turn, will have a negative impact on loan amortisation and incomes.

Transformational initiatives concerning paratransit services often overlook the inherent dilemma of formalising paratransit operators. The review of cases presented in this document, depicts three different approaches to transformation with different results, both in terms of success of the formalisation initiative and in terms of consequences of the programme for the role of formal and paratransit services. One the one hand, as formalisation attempts become more radical and seek to fully substitute or replace the element in the system considered to be problematic, benefits of such element are lost. Flexibility, demand-responsiveness and adaptability –characteristics that are arguably beneficial in urban contexts of the Global South– are eroded when paratransit services disappear from the system. On the other hand, when introducing programmes that attempt to maintain advantages of the paratransit nature of
services, regulatory measures are difficult to implement and incumbent operators often revert to traditional practices linked to informal modes.

In all, attempts at formalising –accompanied by objectives of improved energy consumption and pollution reduction– are likely to clash with the advantages of the paratransit sector. Public transport systems in the Global South require modifications that, in some cases, call for consolidation of operators and corporatisation. However, paratransit operators have proven to be highly adaptable: helped by rapid urbanisation, they continuously change finding new roles and gaps in the public transport system\textsuperscript{11}.

Formal services undoubtedly have a role in the envisioned and future public transport systems of the Global South. It can be argued that paratransit services can also have a role in those systems. They bring about territorial coverage, demand-responsiveness and flexibility that are useful in urban contexts such as those in the Global South. Arguments for complementarity between formal and paratransit services are to be studied and encouraged. Original models for formal-paratransit complementarity are yet to be developed. Harmonious coexistence of formal and paratransit modes is difficult to achieve due to their contradictory natures, yet approaches to transformation that allow paratransit services to have a role in the system might end up being more adapted to the cities in the Global South that still experience drastic transformations.

\textbf{References}

Corporacion Andina de Fomento (CAF), 2010: \textit{Observatorio de movilidad urbana para America Latina}. CAF. Bogota, Colombia.

City of Cape Town (CoCT), 2013: \textit{Household survey report}. City of Cape Town. Cape Town, South Africa.


\textsuperscript{11} When describing the informal sector of economies, Daniels (2004) explains that informality is a “floating, kaleidoscopic phenomenon, continuously changing in response to shifting circumstances and opportunities”. This description fits the nature of paratransit services in public transport systems of the Global South when faced with transformational projects.


ECHEVERRY Juan Carlos, IBAÑEZ Ana Maria & MOYA Andres, 2005: *Una evaluacion economica del sistema Transmilenio*. Revista de Ingenieria no.21, pages 68-77.


FINN Brendan, 2008: *Market role and regulation of extensive urban minibus services as large bus service capacity is restored*. Transportation Economics no.22, pages 117-125.


LLERAS German Camilo, 2005: *Transmilenio y el transporte colectivo tradicional, una relacion incierta*. Revista de Ingenieria no.21, pages 84-93.


MACEDO Joseli, 2004: *City profile – Curitiba*. Cities vol.21 no.6, pages 537-549.


PEÑALOSA Enrique, 2005: *Comentarios al articulo ‘Una evaluacion economica del sistema Transmilenio’*. Revista de Ingenieria no.21, pages 78-82.


TRANSFERABILITY OF SUSTAINABLE URBAN TRANSPORT SOLUTIONS

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Abstract

While there is a wealth of information about the need for more sustainable transport, and policies and practices to achieve this, progress in this area varies greatly between countries. There is a common assumption that political and institutional frameworks can and will implement best-practice policies provided that technical information is available (e.g. through assessments). This is considered to be overly optimistic and lacking in conceptual and empirical sophistication, in particular considering socio-economic and institutional conditions in many countries. There is a critical difference between a policy’s potential and the extent to which this potential can be realised. This paper focuses on sustainable transport policies in selected developed and developing countries and testing their transferability. This builds on the SOLUTIONS project (www.urban-mobility-solutions.eu); using the project’s concept and objectives, and reports on progress made in the focus regions of Europe, Asia, Latin America and the Mediterranean.

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1. Introduction

Transport is a key enabler of economic activity and social connectedness. While providing essential services to society and economy, transport is also an important part of the economy and it is at the core of a number of major sustainability challenges, in particular climate change, air quality, safety, energy security and efficiency in the use of resources (EC, 2011). Cities across the world have a need to establish sustainable transport systems, which provide efficient and safe mobility for their citizens with the minimum of environmental impact. The implementation of innovative urban transport and mobility measures varies widely: some cities are well advanced with leading approaches towards sustainable transport, whilst others are rather less developed. At the same time, the forecasted population growth and increase in urbanisation present a significant challenge to cities in Latin America, Asia and the Mediterranean Partner Countries. The SOLUTIONS project aims at achieving more widespread implementation of innovative and sustainable urban mobility solutions. This paper introduces the project, its inherent methodology and first results - including a collection of innovative urban mobility solutions that have been successfully implemented in Europe, Asia or Latin America and have a high potential for transfer to other cities across the world. Context conditions, interests and needs of cities in the target regions are identified. Transferability analysis and approaches to assess the socio-economic impacts of a policy or measure will guide the selection and implementation of urban mobility solutions in the target cities and are introduced in the present paper. In the end a conclusion and outlook to further project activities is given.

2. Methodology

The overall objective of the SOLUTIONS project is to make a substantial contribution to the uptake of sustainable urban mobility solutions in cities across the world. It goes beyond the sole dissemination of technical information, but takes a structured approach to foster the active take up and transfer of sustainable solutions between cities in different regions of the world. Cities in Europe, Asia and Latin
America have developed a wide range of innovative sustainability mobility solutions. A set of existing solutions with a high potential for transfer to cities in Asia, Latin America and Europe is compiled based on an initial transferability assessment.

Ten cities from around the world are actively involved in the project as leading cities and take-up cities. Leading cities will share their expertise in the development and implementation of sustainable urban mobility solutions. They have been selected as they have practical experience in the successful implementation of urban mobility solutions. Within SOLUTIONS, they will pass on their knowledge and experience to take-up cities, which are the ones that are going to prepare the actual implementation of innovative and sustainable urban mobility solutions in feasibility studies. The feasibility studies explore the economic viability and public acceptability of measures and assess the success factors and barriers that may accelerate or inhibit uptake.

3. Urban mobility solutions

As the first step in the SOLUTIONS project, 58 different urban mobility solutions with high transferability potential were selected and categorised into 6 thematic clusters (briefly described, below). The clusters themselves built on relevant previous research projects on urban mobility and their transferability. The clusters provide the basis for targeted knowledge-exchange and the transfer of innovative sustainable urban mobility solutions and technologies. In the SOLUTIONS project the need for a balanced approach of urban mobility measures is being emphasised to achieve a maximum sustainability impact (Sims et al. 2014, Fulton et al. 2013). This includes measures that manage and reduce demand (avoid), foster low-carbon transport modes (shift) and achieve efficiency gains and fuel switch (improve).

Cluster 1: public transport

Public transport – an important factor for providing access and achieving liveable cities and metropolitan areas – plays a prominent role in sustainable urban mobility concepts, which aim to reduce urban traffic congestion, air pollution, climate change and fossil-fuel consumption. The transferability of successful high-capacity mass
transit is of significant interest and importance to cities in emerging countries, particularly those suffering from increasing urban populations and limited space for transport. Table 1 presents an overview of selected solutions in the public transport cluster with some good-practice examples.

Table 1: overview of selected solutions in the public transport cluster

<table>
<thead>
<tr>
<th>SOLUTIONS</th>
<th>Type of impact</th>
<th>Good practice cities/projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>BRT systems</td>
<td>Improve/shift</td>
<td>Curitiba (Brazil) and the TransMilenio system in Bogota (Columbia)</td>
</tr>
<tr>
<td>Trolley bus systems</td>
<td>Shift/improve</td>
<td>Zurich (Switzerland), Salzburg (Austria), Athens, Lyon (France), and Beijing and Taiyuan (China)</td>
</tr>
<tr>
<td>Metro systems</td>
<td>Shift/improve</td>
<td>London, Paris, New York, Moscow, Washington, Berlin as well as many cities in Asia, including Singapore, Beijing, Shanghai and Dalian</td>
</tr>
<tr>
<td>Alternatively fuelled public transport</td>
<td>Improve</td>
<td>CNG buses in Delhi, Berlin, Lille (France), Hong Kong, LNG buses in Guiyang and Xian (China)</td>
</tr>
<tr>
<td>Electric and hybrid public transport vehicles</td>
<td>Shift/improve</td>
<td>Electric vehicles in Shenzhen and Beijing (China) and hybrid buses in Guiyang (China), Aachen and Bremen (Germany) and London</td>
</tr>
<tr>
<td>Public transport ITS</td>
<td>Improve</td>
<td>ITS in public transport in Asia has grown in use faster than in Europe, led by Korea and Seoul’s metro</td>
</tr>
<tr>
<td>Integrated fare systems</td>
<td>Improve</td>
<td>London’s Oyster, Bremen’s Mobility pass, the Netherland’s smart card, Hong Kong, Beijing, Seoul and Tokyo</td>
</tr>
<tr>
<td>Integrated public-transport network planning</td>
<td>Improve</td>
<td>London, Budapest, Stockholm, Curitiba (Brazil) and Hefei and Yinchuan (China)</td>
</tr>
<tr>
<td>Public transport financing</td>
<td>Improve/shift</td>
<td>Transport Tax in Paris, integrated ticketing systems in Germany, Japan and China</td>
</tr>
<tr>
<td>Eco-driving for professional drivers</td>
<td>Improve</td>
<td>European transport projects such as ACTUATE and BENEFIT, eco-driving training in Leipzig (Germany), Salzburg (Austria), Parma (Italy), Brno (Czech Republic) and China</td>
</tr>
<tr>
<td>Bike sharing and public bicycles</td>
<td>Shift/avoid</td>
<td>Paris, Brussels, London, Berlin, Hangzhou (China) and Changzhou (China)</td>
</tr>
</tbody>
</table>

Cluster 2: transport infrastructure

The transport infrastructure cluster summarises available information and provides recommendations for the design of safe urban streets including facilities for both public transport (such as tramways and light rail, bus lanes, passenger waiting and
boarding areas) and for soft modes (cycling and pedestrian). Table 2 provides an overview of selected solutions in the transport infrastructure cluster with some good practice examples.

**Table 2: overview of selected solutions in the transport infrastructure cluster**

<table>
<thead>
<tr>
<th>SOLUTIONS</th>
<th>Type of impact</th>
<th>Good practice cities/projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dedicated bus lanes</td>
<td>Improve</td>
<td>London, Berlin, Paris, Nice, Nantes, Lille and Dublin</td>
</tr>
<tr>
<td>Intermodal interchanges</td>
<td>Improve</td>
<td>Monclova interchange in Madrid, <em>St Pancras International</em> in London, <em>Gare du Nord</em> in Paris and the Köbányp-Kispest in Budapest. The EU NICHERS, NODES and CITYHUBS projects</td>
</tr>
<tr>
<td>Pedestrian infrastructure</td>
<td>Improve/avoid</td>
<td>Worldwide</td>
</tr>
<tr>
<td>Non-motorised infrastructure</td>
<td>Improve/avoid</td>
<td>The Netherlands, Germany and France</td>
</tr>
<tr>
<td>Cycling infrastructure I - innovative</td>
<td>Improve/avoid</td>
<td>The UK, the Netherlands and Germany</td>
</tr>
<tr>
<td>safe cycling infrastructure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cycling infrastructure II – cycle highways</td>
<td>Improve/avoid,</td>
<td>The Netherlands, Denmark, Germany, the UK and Spain</td>
</tr>
<tr>
<td>Infrastructure for car- and bike-sharing</td>
<td>Improve/shift</td>
<td>Brussels, London, Paris and Berlin</td>
</tr>
<tr>
<td>Pedestrianisation of city-centres and streets</td>
<td>Improve/avoid</td>
<td>European cities - market towns and numerous historical cities (e.g. Italy)</td>
</tr>
</tbody>
</table>

**Cluster 3: city logistics**

The city logistics cluster focuses on acknowledging freight’s important role in economic activity, while decreasing the environmental and social impact of delivering this freight. This implies decreasing the number of commercial vehicles (without other traffic compensating for this), decreasing delivery vehicles’ noise and emissions (PM, NOₓ and CO₂) and reducing traffic congestion. The solutions can be introduced by public authorities (e.g. traffic-restriction regulations, low emissions zones, transport pricing, taxes and planning, and developing infrastructure dedicated to urban freight movement) and by private companies (e.g. increasing their fleets’ fuel efficiency and load factor through consolidation, or improving the efficiency of home deliveries through collective delivery/pick-up depots). Table 3 provides an
overview of selected solutions in the city logistics cluster, along with good practice examples.

**Table 3: overview of selected solutions in the city logistic cluster**

<table>
<thead>
<tr>
<th>SOLUTIONS</th>
<th>Type of impact</th>
<th>Good practice examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban delivery using cargo-cycles</td>
<td>Improve/avoid</td>
<td>Paris and Barcelona - the SMILE pilot, Donostia/San Sebastian (Spain) - a CIVITAS ARCHIMEDES project</td>
</tr>
<tr>
<td>Low Emission Zones (LEZ)</td>
<td>Avoid/improve</td>
<td>Europe (&gt;250 cities/regions. A good overview can be found at <a href="http://www.lowemissionzones.eu">www.lowemissionzones.eu</a>)</td>
</tr>
<tr>
<td>Forums, portals, labels and training programs</td>
<td>Improve</td>
<td>Paris and Toulouse (France) - London (FORS) and Norwich (the UK)</td>
</tr>
<tr>
<td>Networks of pick-up points</td>
<td>Avoid</td>
<td>Kiala (UPS) in France and Belgium, Packstations in Germany</td>
</tr>
<tr>
<td>Promotion of off-peak deliveries</td>
<td>Improve/avoid</td>
<td>NYC, several European cities (Dublin, Barcelona, Paris, many in the Netherlands – PIEK program)</td>
</tr>
<tr>
<td>Urban Consolidation Centres (UCCs), urban service centres</td>
<td>Avoid/improve</td>
<td>Several UK cities (Bristol, London), several cities in Italy (Verona, Modena, Padua), La Rochelle in France, Binnenstad service in several Dutch cities</td>
</tr>
<tr>
<td>Municipal procurement reorganisation</td>
<td>Avoid/improve</td>
<td>Delivery Servicing Plans in London, projects in Gothenburg, Sweden for clean deliveries in municipal buildings, the Green Link in Paris</td>
</tr>
<tr>
<td>Greater use of rail and water</td>
<td>Shift/avoid</td>
<td>Waterways in Utrecht (NL), heavy rail in Paris, France (Monoprix) and light rail in Dresden, Germany</td>
</tr>
<tr>
<td>Lorry lanes for urban freight transport</td>
<td>Improve</td>
<td>Barcelona, Berlin, Padova and other Italian cities, several UK cities</td>
</tr>
<tr>
<td>Pricing schemes, taxes and tolls</td>
<td>Improve</td>
<td>Milan, AreaC (Italy), Norwegian cordon pricing schemes, Switzerland (LSVA), several other European metropolitan areas, some US large cities.</td>
</tr>
</tbody>
</table>

**Cluster 4: Integrated planning and Sustainable Urban Mobility Plans (SUMP)**

Integrated planning considers all of the transport modes used in a city, and aims to take a broader social, environment and economic perspective on the transport system. The European Sustainable Urban Mobility Plans (SUMP) concept brings that approach into a formalised structure and gives the participation from various stakeholders and the public an important role. The SUMP concept and approach are increasingly seen as useful basis for integrated planning also outside Europe. Within the SOLUTIONS project the SUMP guidelines are being adapted to the conditions in Latin America. China and North Africa have also shown interest in adopting the
guidelines. Table 4 provides an overview of selected solutions in the integrated planning and SUMP cluster, along with some good practice examples of SUMPs.

Table 4: overview of selected solutions in the integrated planning and SUMP cluster

<table>
<thead>
<tr>
<th>SOLUTIONS</th>
<th>Type of impact</th>
<th>Good practice cities/ projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparation of a SUMP</td>
<td>Avoid, shift and improve</td>
<td>France (Nantes, Lille), UK (Leeds), Sweden (Lund), Denmark (Aalborg), Belgium (Gent) and Germany (Aachen). Projects: CIVITAS, CH4LLENGE, BUMP, ENDURANCE; Quest, ADVANCE, ECOMOBILITYSHIFT, PILOT, BUSTRIP, TIDE and PUMAS</td>
</tr>
<tr>
<td>Vision-building for future sustainable urban mobility</td>
<td>Avoid, shift and improve</td>
<td>Bath (UK), Gent (Belgium), round-tables with stakeholders in Berlin, Dresden and Aachen (Germany), Barcelona’s social pact and Bremen’s (Germany) planning application. Projects: GUIDEMAPS, ELTIS Plus, Fiets van Troje, and CH4LLENGE</td>
</tr>
<tr>
<td>Participation (Involving stakeholders and engaging citizens)</td>
<td>Avoid, shift and improve</td>
<td>Many Brazilian cities</td>
</tr>
<tr>
<td>Participatory budgeting</td>
<td></td>
<td>The QUEST (<a href="http://www.quest-project.eu">www.quest-project.eu</a>) and ADVANCE (audit schemes)</td>
</tr>
<tr>
<td>SUMP audit schemes and quality management</td>
<td></td>
<td>CH4LLENGE (<a href="http://www.ch4llegen.eu">www.ch4llegen.eu</a>) and CIVITAS (<a href="http://www.civitas.eu">www.civitas.eu</a>)</td>
</tr>
<tr>
<td>Measure/measure-package selection strategies</td>
<td></td>
<td>Toulouse (FR), Dresden (DE), West Yorkshire (UK) and Gent (BE). Projects: CH4LLENGE, CIVITAS, QUEST and ENDURANCE</td>
</tr>
<tr>
<td>Monitoring and evaluation of SUMP</td>
<td></td>
<td>Gdynia (PL) TRISTAR and Aachen (DE)</td>
</tr>
<tr>
<td>Modelling and visualisation tools in SUMP</td>
<td></td>
<td>PDUs (Plan de Déplacements Urbains) in France and LTPs (Local Transport Plans) in the UK</td>
</tr>
<tr>
<td>SUMP framework conditions</td>
<td></td>
<td>DYN@MO Baltic SUMP competence centre, SUMP capacity building under ELTIS, and SUTP of GIZ in Asia</td>
</tr>
<tr>
<td>Capacity building and training schemes in SUMP</td>
<td></td>
<td>PDUs in France, LTPs in UK, Verkehrsentwicklungspläne in Germany</td>
</tr>
<tr>
<td>Engaging external support for SUMP development</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Cluster 5: Network and mobility management

Network and mobility management comprises a number of technical and planning measures, to ensure seamless transport, connectivity, more flexible travel opportunities, lower environmental impact and support of multimodal mobility behaviour and lifestyles. It is important that multiple mobility options are provided that make best use of already available resources and help make a more intelligent mobility choice that considers advantages and disadvantages of different transport modes. Table 5 provides an overview of selected solutions in the network and mobility management cluster with some good practice examples.

Table 5: overview of selected solutions in the network and mobility management cluster

<table>
<thead>
<tr>
<th>SOLUTIONS</th>
<th>Type of impact</th>
<th>Good practice cites/ projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parking management</td>
<td>Avoid/shift</td>
<td>The EU-funded projects MOBILIS , ELAN and CARAVEL</td>
</tr>
<tr>
<td>Access restriction</td>
<td>Avoid/shift</td>
<td>Bergen, Oslo and Trondheim (Norway), London, Stockholm and Milan</td>
</tr>
<tr>
<td>Traffic management</td>
<td>Improve/shift</td>
<td>Projects: MIMOSA and EasyWay</td>
</tr>
<tr>
<td>Multimodal journey planners</td>
<td>Improve/shift</td>
<td>Sweden and Austria</td>
</tr>
<tr>
<td>Cooperative ITS (C-ITS)</td>
<td>Improve/shift</td>
<td>EasyWay, Conduits and SARTRE</td>
</tr>
<tr>
<td>Car-sharing schemes</td>
<td>Shift</td>
<td>Car2go, DriveNow and Quicar</td>
</tr>
</tbody>
</table>

Cluster 6: Clean vehicles

This cluster examines clean vehicles in a broader sense, along with those readily available fuels and technologies, which offer substantial GHG emissions reduction potential, and other energy-efficiency options. The suitability of different clean vehicle technologies depends not only on local, but also on national conditions. The measures analysed in this cluster include a wide range of technologies and vehicle types in order to accommodate the variety of cities in SOLUTIONS’s regions. This cluster also builds upon the findings of several European electric mobility projects and upon the European Green Cars Initiative. The solutions in this cluster have been selected based on their potential to address the urgent need to reduce local air
pollution, especially in Asian cities, and to limit transport-sector oil consumption. Table 6 provides an overview of selected solutions in the clean vehicles cluster along with good practice examples.

**Table 6: overview of selected solutions in the clean vehicles cluster**

<table>
<thead>
<tr>
<th>SOLUTIONS</th>
<th>Type of impact</th>
<th>Good practice examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Registration restrictions/number plate auctions</td>
<td>Shift/improve</td>
<td>Vehicle quota system in Singapore, Shanghai and Beijing</td>
</tr>
<tr>
<td>Management of electric two-wheelers</td>
<td>Shift/improve</td>
<td>Charging infrastructure in Murcia (Spain), Rome, Rotterdam and Barcelona</td>
</tr>
<tr>
<td>Fuel economy/CO₂ standards</td>
<td>Improve</td>
<td>The USA, the EU</td>
</tr>
<tr>
<td>Fuel switch in taxi fleets: EVs</td>
<td>Improve</td>
<td>Electric taxis: Shenzhen (China), Mexico City, Kanagawa Prefecture (Japan), Dublin and London. Replacement of diesel-fuelled three-wheelers with electric ones in Kathmandu (Nepal)</td>
</tr>
<tr>
<td>Fuel switch in taxi fleets: LPG/CNG</td>
<td>Improve</td>
<td>Taxis and auto rickshaws in Delhi and Ahmedabad (India)</td>
</tr>
<tr>
<td>Emissions-based vehicle taxation</td>
<td>Improve/shift</td>
<td>Tax exemption for electric vehicles in Kanagawa Prefecture (Japan), exemption from VAT in Norway and the bonus-malus system in France</td>
</tr>
<tr>
<td>Clean vehicles in municipal fleets</td>
<td>Improve</td>
<td>Grenoble (France). Projects: CIVITAS ELAN in Zagreb (Croatia), CIVITAS TELLUS in Rotterdam, TURBLOG in Utrecht (Netherlands) and EU CIVITAS TRENDSETTER in Stockholm</td>
</tr>
<tr>
<td>Information and promotion of clean vehicles</td>
<td>Improve</td>
<td>Use of bus lanes and free parking in Norway, exemption from paying the congestion charge in London (UK). Projects: CIVITAS Trendsetter, NICHES and ECOSTARS</td>
</tr>
<tr>
<td>Infrastructure for clean vehicles</td>
<td>Improve</td>
<td>Various European cities. Subsidies for charging station construction and installation of public charging facilities in Rotterdam</td>
</tr>
<tr>
<td>Fleet renewal schemes</td>
<td>Improve/shift</td>
<td>Subsidies for EV purchase in the UK and the Netherlands</td>
</tr>
</tbody>
</table>

4. SOLUTIONS take-up cities: a brief overview

The SOLUTIONS project has selected the following take-up cities: Belo Horizonte (Brazil), Guiyang (China), Cochin (India), Leon (Mexico) and Kocaeli (Turkey) (described, below). The cities were selected from over 70 applications based on their motivation and organisational capacity as well as on their size and population (the
project focuses on mid-sized cities). Table 7 provides an overview of the take-up cities and their areas of interest.

Table 7: the take-up cities with their clusters of interest

<table>
<thead>
<tr>
<th>City</th>
<th>Size</th>
<th>Region</th>
<th>Clusters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belo Horizonte, Brazil</td>
<td>1-5m</td>
<td>Latin America</td>
<td>Public Transport, SUMP, City Logistics, Clean vehicles</td>
</tr>
<tr>
<td>Guiyang, China</td>
<td>1-5m</td>
<td>Asia</td>
<td>SUMP, Clean vehicles</td>
</tr>
<tr>
<td>Cochin, India</td>
<td>1-5m</td>
<td>Asia</td>
<td>Public Transport, SUMP</td>
</tr>
<tr>
<td>Leon, Mexico</td>
<td>1-5m</td>
<td>Latin America</td>
<td>Public Transport</td>
</tr>
<tr>
<td>Kocaeli, Turkey</td>
<td>1-5m</td>
<td>Mediterranean</td>
<td>Public Transport, SUMP, City logistics</td>
</tr>
</tbody>
</table>

Belo Horizonte, Brazil

Belo Horizonte, situated in the state of Minas Gerais in the south-eastern region of Brazil, is one of Brazil’s most populous cities with around 5 million inhabitants in the metropolitan area and over 2 million in the municipality, with an average per capita income of 17,313 BRL (≈€5600) per annum. The public transportation system is insufficient and not well developed, and the city suffers from traffic congestion and air pollution due to the increasing number of private vehicle trips. Although data shows that the number of bicycle and pedestrian trips is higher, the city’s infrastructure for these modes is also insufficient. Therefore, the clusters public transport, SUMP, city logistics and clean vehicles are particularly relevant here.

Guiyang, China

Guiyang, situated in the Guizhou province in Southwest China, has a population of 4.4m, with an average per capita income of 23,376 RMB (≈€2802) per annum. The city has a good public transport system, which made a total of 658m trips in 2012. In comparison, 154m trips were made with taxis. The clusters SUMP and clean vehicles are the most relevant for Guiyang.
Cochin, India

Cochin, situated on the west coast of India in the state of Kerala, is a densely populated city with a population of 2.1m (2011). Light Motor Vehicles (LMV) are the most common vehicle type (24,635 and 21,522 goods and passenger autos), followed by taxis (10,346), buses (7,005) and trucks (5,290). The majority of the passenger trips are made with inter and intra city busses, followed by 2-wheelers, cars and metro-busses. The sustainable urban mobility solutions of highest interest to Cochin are public transportation and application of SUMP.

León, Mexico

León is located in Guanajuato state of Mexico, with a population of 1.4m (2011). Although vehicle registrations are increasing in the city, led by passenger cars (265,311), freight vehicles (105,9344), 2-wheelers (26,004) and other modes (4,995) in 2012, the city also has a high number of cyclists. Total trips per day (cars, 2-wheelers, busses, rail, bicycles and walking) can reach 450,000 trips/day. Public transportation is the focus area for León.

Kocaeli, Turkey

Kocaeli province lies in Marmara region of Turkey with an urban population of 1.6m. In 2013, the number of registrations was highest for cars (64%), followed by vans (18.16%), 2-wheelers (6.70%), HGVs (6.12%), busses (2.40%) and minibusses (2.18%). In Kocaeli’s road network, the total number of HGV trips reaches 100,215 daily. Regarding passenger travel, pedestrian traffic dominates, with 40%, followed by public transport (23%), private vehicles (23%) and private services (school or factory busses etc.) (13%). Kocaeli is especially interested in actives related to public transport, city logistics and SUMP.

5. Transferability analysis

A transferability analysis is a broad analysis of the considerations around taking a (successful) policy or measure from one place and implementing it in another (Macário & Marques, 2008). In this case, it refers to the transferability of policies or
measures from SOLUTIONS’s Leading cities to the take-up cities. This process will be documented in the feasibility studies that each take-up city will produce. The transferability analysis provides an opportunity to learn from previous experience; identifying opportunities and avoiding mistakes. The success in transferring a policy depends on the interaction of the policies’ and cities’ characteristics. • The process of conducting a transferability analysis in itself leads to stakeholder and expert involvement that can make take-up cities more open for innovation. There is a wealth of knowledge on transferability methodologies upon which the SOLUTIONS project builds, in particular from the EU projects CIVITAS, NICHES+ and TIDE (CIVITAS, 2012; NICHES+, 2011; TIDE, 2013). The findings of two EU projects have particularly influenced the development of the SOLUTIONS transferability analysis: CATALIST (which co-funded adoption activities in the CIVITAS project between 2008-2012) and TIDE (duration 2012 – 2015, building on the experience and findings of predecessor projects NICHES and NICHES+). Of the two transferability methodologies, TIDE is the most relevant to SOLUTIONS, and has been used as the basis for SOLUTIONS transferability methodology. The SOLUTIONS transferability analysis methodology, produced from a desktop study, interviews, workshop and field visits, has seven steps:

1. Formulate a mission statement, objectives and scoping
2. Clarification of the impacts of the measure
3. Identification of the need for change in scale
4. Identification of the main components and sub-components
5. Identification of the relative importance of various characteristics
6. Assessment of the characteristic in the take-up city
7. Conclusions

The final step of the transferability assessment is to draw conclusions about the potential for transferability though consideration of the factors identified and the assessment values ascribed to each. This should include discussion of all the key success factors and key barriers for transferring the innovative solution. In addition, it should include discussion of the mitigating actions that could overcome key
barriers. Based on the discussion, the concluding remarks on the chances of successful transferability should be made.

SOLUTIONS is currently performing two different transferability analyses in order to show the ‘general’ points which should be considered when transferring innovative measures from one city to another: (1) clean city logistics and (2) road user charging (RUC). Following is a brief summary of the former.

The example transferability analysis discussed here involves a clean city logistics measure based on the use of battery electric (BEV) transporters for their reduced pollutant and noise emissions compared to conventional trucks.

In step 1, the ways in which BEV use can be encouraged are identified, e.g. charging infrastructure provision, dedicated delivery zones, night-time delivery in inner-cities, allowing BEVs to use bus lanes, reducing any congestion charges and allowing entry into inner-city low emission zones.

The impacts of BEVs, such as on efficiency, safety, environment, accessibility, financial efficiency (affordability), economic impacts and overall impacts are analysed in step 2.

The scaling required (step 3) depends on logistics companies being able to integrate BEVs into their fleets (route-distances, size of goods, topography, economic factors etc.).

Step 4 involves identifying concerns around the measure such as political support, policy measures, fleet utilization, CSR/marketing, costs (running, capital and charging infrastructure), market analysis, range, driver’s safety, charging infrastructure development and advanced ICT.

Steps 5 and 6 involve the assessment of the measure in the destination city. This is done through the categorisation of the relevant characteristics based on their importance. For example, characteristics such as existing policies such as congestion charging, low emission zones, conditions surrounding night-time delivery, driver’s safety and grid integration might be of the highest importance, while incentives (bus lanes, dedicated parking), range of BEVs and strategic distribution of charging infrastructure and street layout are of medium importance, with eco-driving training and charging infrastructure are of lower importance.
Lastly, this example concludes (step 7) that private companies are the key drivers of the transfer and thus that it is essential to create incentives (e.g. subsidies and low-interest loans) for them to use BEVs. Other key drivers include increasing energy costs, increasing restrictions concerning emissions and noise in dense inner-city areas and rising customer-awareness. The key barrier for transfer is the high purchase price. Other barriers include the lower range of BEVs and drivers’ safety concerns.

6. Assessing the benefits

For the SOLUTIONS take-up cities, assessing the socio-economic benefits is an important step for the implementation and the selection of urban mobility solutions. The investment of (limited) public funds should deliver the maximum economic, social and environmental benefits possible, over the short and long term and for all of a city’s residents. Five assessment methods, which are considered to be applied in the selection and implementation phase are briefly presented and compared:

• Tool for the Rapid Assessment of Urban Mobility (TRAM). This tool is intended for use in cities with scarce information on mobility. It can be quickly and easily carried out in close collaboration with government officials (Sudra et al, 2013).

• Cost-Benefit Analysis (CBA). The most commonly used assessment method is often used to justify a project’s or measure’s implementation (or not) from an economic perspective, citing specific economic viability indicators (Jansson, 2010).

• Multi-Criterion Analysis (MCA). This is an increasingly popular method for transport project appraisal (Macharis & Ampe, 2007), which takes into account quantitative and qualitative criteria, and can, as such, include soft impacts otherwise difficult to quantify or monetise (Browne & Ryan, 2011).

• Transport Innovation Deployment for Europe (TIDE) assessment method. This method combines aspects of the CBA and MCA methods (including quantitative and non-quantified aspects of urban transport projects). If costs or benefits are known or can be easily calculated, they are included in monetary form, as per CBA. If, however, the costs are not known or cannot be easily or reliably
calculated, the measures can also be assigned as performance score by experts, as per MCA (TIDE, 2014).

- Transportation Emissions Evaluation Model for Projects (TEEMP). This relatively simple tool has been developed for use in areas where relevant data is limited. With TEEMP, municipalities can make an ex-ante estimation of the effect of a planned measure in terms of direct GHG emissions (ITDP, 2010).

An overview of the strengths and weaknesses of these assessment tools is provided in Table 8, below.

**Table 8: strengths and weakness of various assessment tools**

<table>
<thead>
<tr>
<th>Tool</th>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRAM</td>
<td>Quick and easy to perform</td>
<td>Data extrapolation diminishes the result’s reliability</td>
</tr>
<tr>
<td></td>
<td>Specifically addresses women’s, children’s and the poor’s needs</td>
<td></td>
</tr>
<tr>
<td>CBA</td>
<td>Transparent and easy to communicate</td>
<td>Extensive data requirements</td>
</tr>
<tr>
<td></td>
<td>Highlights economic efficiency</td>
<td>Monetisation is difficult and controversial</td>
</tr>
<tr>
<td></td>
<td>Rational behaviour assumption</td>
<td>Non-monetary effects often limited to VTTS and safety</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Results often dominated by VTTS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Requires the monetisation (willingness to pay) of qualitative effects</td>
</tr>
<tr>
<td>MCA</td>
<td>All impacts (quantitative &amp; qualitative) can be evaluated</td>
<td>Subjective</td>
</tr>
<tr>
<td></td>
<td>Promotes public participation and compromises</td>
<td>Little consistency</td>
</tr>
<tr>
<td></td>
<td>Applicable to soft and local-level measures</td>
<td>Participation process may be elaborate</td>
</tr>
<tr>
<td>TIDE</td>
<td>Quick and easy to perform</td>
<td>Limited consistency</td>
</tr>
<tr>
<td></td>
<td>Addresses both qualitative and quantitative effects</td>
<td>Shares subjectivity concerns with MCA</td>
</tr>
<tr>
<td></td>
<td>Applicable to a variety of measures</td>
<td></td>
</tr>
<tr>
<td>TEEMP</td>
<td>Quick and easy to perform</td>
<td>Little acknowledgement of co-benefits</td>
</tr>
<tr>
<td></td>
<td>Reflects direct and indirect GHG emissions</td>
<td>Limited range of measures which may be assessed</td>
</tr>
<tr>
<td></td>
<td>Comparability</td>
<td></td>
</tr>
</tbody>
</table>

7. Conclusion and outlook

SOLUTIONS take up cities are committed to assess the opportunities for the transfer of innovative solutions to their context and identified thematic fields that are most
relevant for them to tackle their most pressing urban mobility issues. During the course of the project, a feasibility study will be developed for each take up city, which will contain packages of solutions that will be selected based on the local context conditions in a city, the measures’ transferability to these conditions and the potential socio-economic benefits of the measure. The feasibility studies are an important step in preparing the implementation of innovative solutions among a wider set of cities and will be an important showcase for the transferability of innovative urban mobility measures. By providing insights of the take-up process from five cites with different socio-economic, cultural and political contexts the SOLUTIONS project aims to contribute to the wider take-up of sustainable urban mobility solutions.

References


WILL PEAK TRAVEL OBSERVED IN NORTHERN METROPOLITAN AREAS OCCUR IN THE SOUTH?

Irving TAPIA- VILLARREAL ¹, Yves D. BUSSIÈRE ², Jean-Loup MADRE ¹

ABSTRACT

In most developed countries urban mobility and car traffic have stagnated since the early 2000s. In France, various data sources show that the trend can be attributed primarily to people living in large urban areas: trips have become less frequent (with unbroken workdays) and less exclusively taken by car (as more young adults adopt multimodal behaviours), and car ownership is decreasing in the most densely populated areas, and to a lesser extent, in suburbs. Does this leveling off of traffic suggest that the saturation point is approaching? Is this a structural phenomenon (population ageing, etc.) or a cyclical one linked to rising and volatile fuel prices and to the recession? We shall explore these issues in the light of data collected in the Urban Areas of Montreal and Lille, and then move on to a comparison with two Mexican cities, Juarez on the northern border of Mexico where the level of motorization is high compared to Puebla, our second Mexican case study, where motorization is still low. To each city we apply demographic based projections models in order to consider the extent to which, and in what time frame, the trends observed in developed cities could spread southward to the emerging economies.

Keywords: Mobility, car ownership, peak travel, North, South, France, Mexico.

This paper is a largely revised version of Madre et al. (2012), introductive paper presented at the round table on long term trends in travel demand organised by ITF/OECD, and Tapia-Villarreal et al.(2013) presented at the 13th WCTR, 2013 - Rio de Janeiro, Brazil.

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1. SITUATION OBSERVED IN DEVELOPED COUNTRIES

After expanding rapidly in the 1960s and 1970s, growth in car traffic (as a per capita average) slowed in the early 2000s and seemed to approach the saturation point in a number of industrialized countries (Litman, 2009; Millard-Ball and Schipper, 2010; Newman and Kenworthy, 2011, Madre et al., 2012) (Figure 1). The Australian Bureau of Infrastructure, Transport and Regional Economics, which has compiled a long series for 25 countries, explains this trend as a reflection of fuel prices and economic activity, as well as a time-related saturation effect (BITRE, 2012). A comprehensive analysis of global transport demand trends over the next 40 years was presented by the JTRC/ITF in May 2011 in Leipzig (OECD/ITF, 2011). Having noted an apparent saturation in the developed countries, this working group nonetheless took a critical view of extrapolating demand on the basis of this assumption alone, stressing the need to take account of such other factors as rising fuel prices and the distribution of wealth, as well as the scope of future transport demand trends in the emerging economies. A round table on long term trends in travel demand organized by the International Transport Forum in November 2012 concluded that while some explanatory factors are fairly well understood, others are more uncertain.

In most developed countries, the proportion of people holding driving licences at any given age had always been on the rise as compared with previous generations, and the increase had been greater for women than for men, thus indicating that their respective behaviour patterns were becoming more similar. It has now been found that the licence-holding percentage among young people has started to decline in some 10 countries (Sivak and Schoettle, 2012), in parallel with the development of the Internet, and that this is especially perceptible in the case of young males; these countries are located in North America (Canada and the USA), in the Nordic regions (Norway and Sweden, but not Finland), in Western Europe (United Kingdom, France and Germany, but neither Switzerland nor the Netherlands), and in the most densely populated areas of the Far East (Japan and South Korea); the diffusion of car ownership is too recent in Central Europe (Poland, Latvia), and to a lesser extent in the Mediterranean countries (Spain, Israel), for such a phenomenon to be observable yet. In France, the decline in the number of licence-holders could be attributed to the abolition in 1997 of compulsory military service, which had enabled young men to start driving at virtually no cost to themselves (Avrillier et al., 2010).

According to a comparative study of young adults (aged 20 to 29) in six industrialized countries (Germany, United Kingdom, France, Japan, Norway and the United States), between 1975 and 2010, in most countries, the average distance
travelled peaked around the end of the 1990s, or at the beginning of the 2000s in the United States, and subsequently declined (Figure 2). Thus, young people are less likely to have a driving licence and to travel exclusively by car than youth in the previous generation (Kuhnimohf et al., 2012). There are a number of possible explanations for this phenomenon: the fact that a growing proportion of young people pursue higher education, which defers their entry into the labour market; the tendency to start a family at a later age; rising fuel prices; the introduction of demand-management measures to reduce car traffic in cities; and lastly, a change in mentalities.

In Great-Britain (Metz, 2010) observes that over the past 30 years the average travel time has remained stable at about 1 hour per day (375 hours per person per year), as has the average number of trips (1 000 trips per person per year). Car ownership has more than doubled, as well as speeds, which in combination with rising income prompted a substantial increase in distances travelled, until a certain levelling off as from the mid-1990s (Figure 3). Metz puts forward a number of explanations for the stagnation of traffic: fewer local trips due to longer absences from home (Madre and Armoogum, 1997), worsening congestion, fewer trips as a result of strides in telecommunications, and structural saturation of the demand for travel. Do the trends being observed reflect the approach of the saturation point via a decoupling of the growth rates for traffic and income? (Millard-Ball and Schipper, 2010). Is this decoupling manifesting itself first in the most densely populated regions and/or over a certain standard of living? Or does the levelling off of traffic result rather from a cancelling out of opposite trends (continued growth in rural and suburban areas and decline amongst residents of the most densely populated areas) (Goodwin, 2010-2011)? Some authors explain the reduction in travel in the developed countries in
the medium terms, by a variety of socio-economic factors (Litman, 2011). One could well ask whether this is a socio-demographic phenomenon (population ageing, re-densification of large city center areas, fewer but more-intensive workdays, without returning home for lunch, etc.) or an economic one linked to rising and volatile fuel prices and the recession (Gardes et al, 1996; Collet, 2012).

![Vehicle-km trends](source)

Source: Kuhnimohf et al. (2012).

Figure 2. Vehicle-km trends (car driver and car passengers) per traveller, per day for young adults aged 20-29 (6 countries)
When observing sociodemographic variables more closely we note that the linkage between age and mobility is well established. For instance, as can be observed in the figures 4 and 5, general mobility is bell-shaped. In Montreal Canada, data of 1993 shows that it peaks at around age 35, and declines regularly thereafter until advanced ages. In Puebla Mexico, a virtually identical curve can be observed (Figure 4). With regard to modal choice, car driver mobility is bell-shaped, peaking in Montreal at about age 40. The form of the curve in Puebla is also similar. Public transport being in direct competition with cars, the observed curve is U-shaped in the case of Montreal and adopts a similar form in the case of Puebla (Figures 4, 5 and 8). The combined result of these trends will inevitably yield high individual car use in active age groups, translating into car/km such as can be noted in the United States for the period 1995-2001-2009, where a decrease in car/km can be seen in respect of the youngest drivers, but an increase for the over-65 age groups (Figure 6).
Figure 4. Overall mobility by age, Montreal and Puebla (1993) (Trips per day by age) Trips/Pop.

Source: Household Origin-Destination Surveys.

Figure 5. Modal choice by age Car – driver and Public transport (PT), Montreal (1982-1987)

Source: Household Origin-Destination Surveys.

Figure 6. Annual vehicle-miles per driver by age USA, 1995, 2001, 2009

To illustrate long term demographic and mobility trends in the Montreal case we did a straightforward extrapolation which considers mobility of 1982 for 5 years age groups as constant over time, multiplied by long term population time-series in the future as well as for the past in the form of a retrofit. This projection was made over a 40-year time span (1971-2011) in order to measure the effect of population growth and ageing through time (Figure 7) (Bussière & Fortin, 1990). In these simulations all other factors are kept constant, namely behaviour based on 1982 O-D Survey and urban form. We observe peak travel around 2000.

Source: (Bussière, Y. March 2012)

Figure 7. Transport demand trends measuring population impact (All modes, public transport, Car Driver) Montreal 1971-2011 (1971 = 1) - At fixed 1982 behaviour

2. SITUATION OBSERVED IN DEVELOPING COUNTRIES

The same method was applied on Puebla over a 100-years period (1950-2050), based on constant behaviour observed in the 1994 O-D Survey (Figure 9). In Puebla we should assist to two decades of heavy demographic pressure conducive to an increase in individual car driving and a slowdown in Public Transit. The inflection point is to come at around 2035, after which there should be a slowdown in individual driving and still decreasing Public Transport. This simulation represents a minimalist scenario because it assumes a continued low level of car ownership. If the growth in living standards and household car ownership factor is added in, the result would be
explosive for at least another 20 years. A recent household origin destination transport survey in Puebla (2011) gives us interesting input with which to complete the picture. Between 1994 and 2011, per capita mobility remained stable (at 1.75 trip per day per person), as did individual car ownership; thus, the total number of cars followed population growth (+50%), but persistent poverty did not allow household car ownership to increase. On the contrary, the proportion of households with cars fell to 33% in 2011, as compared to 39% in 1994, and the proportion of households with more than one car was only 3.8% in 2011 versus 10.3% in 1994. To a large extent, this trend reflects the persistence of poverty and increasing inequality. While in 1994 19.0% of households suffered from food poverty, the rate did not change in 2008, with 19.5% (Coneval, 2009). In addition, over the same period, the average age of cars on the road increased from 9.4 to 13.0 years. A 2012 O-D survey in the city of Colima on the west coast of Mexico indicated also an average age of household cars of 13 years. In France, there has been an ageing of the cars on the road, the average age of which increased from 6.2 years in 1993 to 8.2 years in 2007 (Kolli, 2012), but for quite different reasons: the greater number of second cars, which are driven less and last for longer. In the next decades if poverty persists the answer to the demographic pressures towards more individual motorization may be further ageing of the vehicles.

Figure 8. Modal choice by age Car – driver and Public transport (PT) Puebla (1993)

Source: Household Origin-Destination Surveys.
3. CASE STUDIES PRESENTED

We will present 3 case studies representing various levels of motorization: 2 in North America, Juarez and Puebla in Mexico, representing two levels of motorization in an emergent economy. The third case study is Lille, in France, which can be compared to Juarez, two international cities with a population in a range of 1 to 2 million inhabitants. These cities were chosen for their interest but also because of the availability of comparable Household Origin-Destination Surveys.

Juarez is located in the north of Mexico bordered to the north by the city of El Paso Texas in the United States. Juarez and El Paso meet to create North America’s largest border community with a combined population of 2.4 million people and is the most important site of the international commerce that links Mexico and USA. Indeed Juarez is still considered one of the most important hubs of the manufacturing industry in the United States-Mexico border despite the effects of the world economic crisis, violence and social problems in the city that began in 2008.

Overall, by 1996 Juarez had a population of 1.1 million and an estimated population of 1.2 million in 2006. The transportation infrastructure projects implemented in the last decades in Juarez were only highway construction and no public transport projects, which made Juarez a car-dependent city over time. Two Origin-Destination surveys are available: 1996 and 2006.
Puebla is an urban area of 2 million inhabitants, located in the centre of Mexico and much less motorized, representative of a more traditional life-style. Two Origin-Destination surveys are available: 1994 and 2011. In Mexico, population growth is still very rapid (averaging 1.58% per year between 1990 and 2010) but can be expected to slow down. According to CONAPO national projections of the annual growth rate should average roughly 0.67% between 2010 and 2030, with rapid and substantial ageing (the proportion of people aged 65 or over was 3.4% in 1950, 4.2% in 1990, 6.4% in 2010 and is forecasted to be 12.5% in 2030 and 22.0% in 2050). In the cities, growth should be slightly more rapid because of a continuing rural exodus.

The Urban Community of Lille has a population of 1.1 million. It is located in northern France close to the Belgium border. Like most millionaire French cities it has a good public transit with a metro and trams.

4. THE TRAVEL DEMAND FORECAST MODEL USED

In an intent to forecast travel distance and isolate structural factors in the trends of an apparent saturation of urban mobility, we extrapolate distance travelled, applying the Age-Cohort projection model developed by INRETS (now IFSTTAR) which is used here in four types of simulations. Simulations 1 to 3 focus on the decoupling of behaviour and aging changes by showing distance travelled per capita and the fourth is intended mostly to identify the impact of population growth and age pyramid evolution on Total Demand (i.e. total distance). The mobility variables measured are (km/day/person) for the simulations 1 to 3 and total distance (km/day) for simulation 4. All four simulations have been conducted for: All Modes (including walking, etc...), Car Driver, Car Passenger and Public Transport.

(1) Fixed behaviour: only changes in the age structure of the population are taken into account (Ageing AC model),

(2) Fixed age structure: only mobility is changing over time, (i.e. a simulation with population fixed) (Behaviour AC model),

(3) Full Age-Cohort model (distance per capita): A more realistic simulation where population forecasts are used and behaviour changes are taken into account. (AC model) and,

(4) Full Age-Cohort model (total distance): In addition to per capita distance projections from model (3) and in order to decouple the magnitude of contribution of population growth from age pyramid evolution over total distance we ran also full age-cohort models based on two different demographic projections (Figures 11, 13...
and 15). The first scenario considers an increasing population and age pyramid changes year after year (model a). This scenario better recreates demographic projections that are more likely to be observed in the future. The second demographic scenario (model b) has a total population fixed at year 2000 but changing age pyramid over the years. Having these two demographic forecasts models allows us to better identify the contribution of population growth in travel demand by making the following subtraction: [Model (a)] – [Model (b)].

For clarification it should be emphasized that we considered in all models travel activity and population forecasts exclusively within the same area of study over the years in order to mitigate geographic selection bias (Krakutovski, 2004). In fact, we decided to control for geography since the models could be sensitive to the changing geographies over two time periods (Zegras 2012). Another reason is that despite the possibility in developed countries to know a couple of decades in advance where new developments are going to be built and with a good approximation of the total population living in these new areas; in developing countries is very difficult to predict it due to lack of systematic urban planning and strong political power over existing urban master plans. Therefore all results shown do not take into account urban sprawl. We would probably expect greater travel distances if urban sprawl was included in the forecasts. A promising path of research could be taking into account different levels of urban sprawl and population densities.

4.1 Description of the Age-Cohort Model

The projection of mobility (daily kilometers) for an individual of zone of residence (z), level of motorization (v) and gender (s) at the date (t) is given by:

\[ t = a + k \] (a is the age of the individual reflecting the life-cycle and k his generation, defined by his date of birth);

\[ a_a : \text{measures the behavior of a generation of reference at the age a. This allows us to calculate a «Standard Profile» of the life cycle;} \]

\[ g_k : \text{measures the gap between the cohort k and the generation of reference Y} \]

Since the gaps between cohorts for recent generations tend to disappear we took the last observed cohorts gap for future generation [Madre & al., 1996]. The mobility for the population at the date t is estimated as follows:

\[
M_t = \frac{\sum_{z=1}^{3} \sum_{v=1}^{2} \sum_{s=1}^{2} (p_{a,t}^{z,v,s} \times m_{a,k=t-a})}{\sum_{z=1}^{3} \sum_{v=1}^{2} \sum_{s=1}^{2} p_{a,t}^{z,v,s}}
\]
Where $M_{iz}$ is the population projection of zone of residence $z$, level of motorization $v$ and gender $s$ at the date $t$ (Krakutovski, 2004).

5. RESULTS

5.1 Lille

The results presented here are based on a calibration of the model with the two most recent O-D surveys of 1998 and 2006 to capture the Peak travel effect (Figure 14 and 15). The simulation over the period 2000-2030 measuring the sole impact of ageing of the population with fixed behaviour shows a monotonous tendency of diminishing mobility. If we keep the age structure of 2000 to measure the sole impact of changing behaviour, this diminution is postponed for Auto Driver and All Modes and stops the renewal of Public Transport use, which would stagnate starting in 2015. For Auto Passengers the projection at fixed population structure of 2000 (behaviour effect only) would be lower than the projection of ageing only, a result opposite than for the other modes. This could mean that there are more drivers (and less passengers) in the new cohorts of elderly who keep their car as long as they can drive it. For Public Transit use, ageing alone induces a decrease, because students use them more than elderly due mainly to decrease of mobility. The behaviour model gives a diminution of use until 2010 then a decrease, and the complete Age Cohort model gives an increase in Public Transportation use which reflects all the factors (including a strong cohort effect among young adults), where population growth is important.

5.2 Puebla and Juarez

We applied the Age-Cohort approach over the period 2000 to 2050 for Puebla, based on 1994 and 2011 surveys (Figures 10 and 11); and for Juarez, 1995-2050 using 1996 and 2006 surveys (Figures 12 and 13). In Puebla, in order to compare the results from the 1994-2011 calibration with the precedent simulation (of Figure 9) we made a simulation calibrated on 1994 only where the Auto Driver simulation shows a strong increase until reaching a peak around 2030 and then diminishing, matching the forecast made previously for this city. The behaviour model shows a downward trend, which reflects the results of the O-D Surveys of 1994 and 2011 showing a decrease in personal motorization. This trend might not be structural since the O-D survey in 1994 was made in a peak economic activity and the 2011 O-D survey in a low economic context. Per capita Auto Passenger distance decreases and Total Auto Passenger distance increases and peaks at 2030 when calibrating with the base year 1994 and also with the calibration of 1994/2011, then decreases. This means that total distance increases mainly because of demographic growth. Public Transport sees a negative impact with ageing (students use them more than the
elderly) but a strong impact with behaviour (students and young adults use more and more PT), which reflects the results of the O-D surveys, which may reflect different stages in the economic cycle (Puebla is the only case study surveyed before the economic crisis of 1994 and after the economic crisis that began in 2008). For All Modes, veh-km reaches a peak around 2035 and then stabilizes.

For Juarez we chose a slow demographic growth scenario given the current context of violence (Morales et al., 2013) (projected average annual growth rates of 1.60% from 2006 to 2012 and 1.06% from 2015 to 2030). For All Modes in Juarez we would see a stable demand in veh-km, the positive impacts of behaviour being compensated by the negative impacts of ageing, in a context of slow demographic growth. For Car Driver, the ageing factor is very different from the one observed in Puebla. It has a negative effect for all the period of forecast, but the Behaviour Model gives a strong positive impact, reaching a peak around 2020. The Auto Passenger reaches a peak in 2005 and then diminishes constantly. Public transit with the ageing model sees a downward trend for all the period. The Behaviour Model gives a peak in 2015 and then diminishes constantly. The inflection point for car-driver use appears in 2020, which could not be explained by population ageing, since only 5.4% will be aged 65 or over in 2015, but probably by a beginning of saturation of individual car ownership, with 72% of households having cars, as compared with 84% in France in 2007-08, and 36.4% of households having more than one car, as compared to 38% in France in 2008 (Kolli, 2012) and in contrast to other major non-border Mexican cities, where this percentage of households with at least one motorized vehicle hardly goes over 45%.

In Mexico City for example, only 37% of the households have a vehicle available (INEGI, 1994). Here, also, average vehicle age is increasing, rising from 11.7 years in 1996 to 13.8 in 2006, due possibly to multiple ownership, the persistence of relative poverty and the proximity of the US border, which facilitates lightly taxed imports of vehicles aged ten years or more. According to the latest data from the Urban Observatory of Security and Safety, the total amount of private vehicles in Juarez was approximately 750,000 which, considering the 1,332,131 inhabitants reported in the population census of 2010, this result in a rate of 0.6 vehicles per capita (Hernández, 2012).

In spite of the disparities that two different economies might cause to urban commuting behaviour, the percentage of private vehicle use in the modal choice seems to be almost the same in Lille and Juarez (Table 1). In general occupancy rates in private vehicle trips are higher in Juarez and Puebla (1.7 pas/veh in Mexican cities/surveys) than in Lille (1.35 pas/veh in 2006) and the double number of daily trips per person in Lille in comparison with Juarez and Puebla. The main difference between these contrasted urban areas could be in fact a result of the important gap in terms of income between developed and developing countries (Pison, 2011).
Nevertheless in Juarez both the occupancy rates (1.7 pas/veh) and the private car share (50%) appear to be stabilized between 1996 and 2006 showing a strong automobile dependency for a Mexican city (for example only 27% in the Guadalajara Metropolitan Area in 2007) (Tapia-Villarreal et al. 2013). This is due mostly to poor public transportation infrastructure, sprawled urban form and the availability of cheap used cars imported from the U.S. Public transport share decreased from 24% to 22% between 1996 and 2006 showing that in Juarez private auto users could be seen as captive users who are generally unable to change to other travelling alternative modes due to structural reasons. In 2011 in Puebla the occupancy rate was 1.7 pas/veh but the private car share was down to 13% from 20% in 1994 and public transit use rose from 48% to 56%, a surprising result according to the 2011 O-D Survey, which may be explained by persistent poverty and a possible underestimation of motorization due to the difficulty to survey gated communities and economic cycle phenomena mentioned above.

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<tr>
<td>Trips/pers/day</td>
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<td>4.39</td>
<td>4.14</td>
<td>1.99</td>
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<td>1.71</td>
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<td>0.54</td>
<td>0.51</td>
<td>0.50</td>
<td>0.50</td>
<td>0.20</td>
<td>0.13</td>
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<td>Average distance/driver trip (km)</td>
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<td>4.10</td>
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<tr>
<td>Average distance/PT trip (km)</td>
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<td>4.67</td>
<td>6.67</td>
<td>8.00</td>
<td>5.03</td>
<td>5.25</td>
</tr>
</tbody>
</table>

Source: O-D Household Surveys and calculations by IFSTTAR.

Table 1: Indicators of mobility in Lille, Juarez and Puebla

The importance to model a highly motorized city such as Juarez lies in the necessity to observe and predict the trends of the most pollutant mode, which is the private car. In the year 2001 in the Metropolitan Area of Paris 90% of the total CO2 emissions from transport were caused by only 44% of the total modal share (private cars) (Tapia-Villarreal, 2011). In the "Juarez Auto Driver Model" the impact of changes of population age pyramid and mobility behaviour seems to slow down the private vehicle trend observed in the past (increase only of 10% from the base index to 2050) showing some evidence of saturation or peak car in developing countries.
5.3 Discussion of Findings

Is there a common pattern of development in terms of transportation trends in urban areas in France and Mexico? A way to identify relative trend patterns is to make abstraction of all results by creating an Age-cohort model trend matrix (Table 2). The purpose of this matrix is to identify relative trend effects of the different full Age-cohort models developed, when taking into account the most recent survey into the models and comparing it to the previous trends that included only the surveys developed in the 90’s. A pattern of travel trend development clearly separates the Mexican cities from the pattern of Lille.

Indeed, the main difference is the strong decline of “All modes” models in the French city showing noticeable saturation or peak travel, while in the Mexican cities there is still a relative positive influence for overall mobility when taking into account latest surveys. The contribution of population growth on total distance forecasts is greater in Puebla than in Lille and Juarez due to a strong increase of population in this city. Two modes of transportation seem to have similar relative trends with different calibration periods in the French and Mexican cities. The first one is “Public Transportation” with an increasing relative influence with most recent survey. The reasons could be very different from one country to another, as we expect for instance rapid and sooner aging of the population in coming years in Lille, which might promote the shift to public transportation mode. On the other hand in the Mexican cities we expect aging of the population later in comparison to Lille; and since there were no major public transportation projects implemented in between surveyed years (in Puebla after 1994 a perimeter highway was constructed, which should have stimulated car use), we could link the increasing use of Public Transportation mostly to poverty. The second mode that have similar trends pattern of development in both countries is “Auto Passenger” which has a decreasing relative influence when taking into account most recent surveys. Possible hypotheses that can be tested for viable explanation for having directionally similar trends in these three different cities are listed below, having in mind that it is not in the scope of our study to attempt to quantify shift in mode of transportation over the years. Instead our methodology is to some extent comparable to the analysis done by Kuhnimhof et al., (2013) in the sense that “It does not include the effects of individuals changing from one group to another”, because each mode was projected separately and refers to within-group travel demand evolutions only (Krakutovski, 2004). Possible hypotheses for Puebla’s downstream trend of “Auto Passenger” could be that people might have shifted from “Auto Passenger” towards “Public Transport” due to poverty, a shift probably amplified by the economic crisis started in 2008. Besides this probable shift from “Auto Passenger” to “Public Transport” due to generational or behavioral changes, in Juarez an additional possible hypothesis that needs to be tested for this city is the probable shift from “Auto Passenger” towards “Auto Driver”. A decrease in “Auto Passenger” mode in
developing countries is not good news, because the rate of occupancy of vehicles is an important factor of their energy efficiency per passenger*km.

In France per capita car use had a decreasing trend after 90’s (Kuhnimhof et al., 2013). Our methodology confirms this decreasing trend for Lille. “Auto Driver” mode in Puebla experiences also a decreasing relative trend only when taking into account the most recent survey implemented in 2011 so it has to be observed in the context of an economic downturn that could have amplified the downstream trend of “Auto Driver”. Opposed to the case of Puebla and Lille “Auto Driver” mode in Juarez has a strong positive trend. Urgent political action is needed for the purpose of diminishing vehicle pollution emissions.

In Juarez peak car is not clear since the last survey shows a strong use of private vehicle, and ageing is not strong enough to slow down motorization trends in following years. In spite of the complexity of having different observations and models to compare, the analysis of relative trends shows different patterns of development between France and Mexico. However we expect also travel activity to have a peak in these Mexican cities but decades later compared to Lille. It is also clear that even if relative trends tend to be similar in Juarez and Puebla there is sufficient evidence indicating that there is no general pattern in Mexican cities and mobility behaviour can vary considerably from one city to another.

6. CONCLUSIONS

To summarize with respect to France, the main findings are as follows: the same trend towards a decline in mobility can be found here as in most other developed countries, starting in the early 2000s, whilst the average distance travelled by households was levelling off and dropped slightly thereafter, with cyclical variations probably linked to fuel price variations, a drop in the percentage of young people holding driving licences in the most densely populated urban areas (elsewhere, the opposite can be seen), the social distribution of car ownership, which is attaining its limits, with the decline in inequalities of automobile ownership and the widespread increase in second cars, an ageing of the cars on the road, a saturation of car ownership. In addition, there can be seen significant growth in the use of public transport.

In our case studies in Mexico, we can also perceive a saturation phenomenon that could take place in roughly 20 years in the most traditional cities and slightly earlier in more developed cities, provided there is a slowdown in population growth. The car fleet is old, however, and is not tending to get any younger, for lack of purchasing power, but also due to policies that encourage ownership of old vehicles, such as the annual vehicle tax from which cars aged 10 years or older are exempt - a tax that was recently abolished at the national level (federal tax) and in certain states (Puebla and Tlaxcala in 2011). Given the finding that overall mobility as well as
urban car mobility has reached a saturation point, or at the very least has been slowing in the developed countries, along with the probable appearance of a similar tendency in emerging economies, but only in about 20 years after intense pressure for individual car ownership, what can be concluded in policy terms? With respect to developed countries, in which the growth of cities is changing, there is an encouraging sign that it will be easier to shift the focus of urban transport planning: restrict car usage in the city, while promoting the use of public transport and soft modes; find ways to control urban extension by making suburbs denser; rethink the construction of toll roads at the periphery of metropolitan areas, which are perhaps no longer useful nor worthwhile economically; rethink our conception of quality-of-life in the city, with less emphasis on the fluidity of car travel; introduce various measures to manage demand in order to diminish the number of trips and car travel within cities. It would also be necessary to address the technology by imposing stricter standards on manufacturers; nevertheless, the impact on the production cycle and the renewal of cars on the road could take another two decades. The transition must therefore be accelerated (Schipper, 2011).

With respect to emerging economies, despite the great disparities from one country to another, and from one city to another, the example of Puebla and Juarez can give us an idea of the magnitude of the challenge to be taken up in the years ahead: a determinant factor is population growth which will remain relatively strong for at least another one or two generations; it is likely that cities will expand in a way that is disordered and staggered; and socio-economic equality between households in terms of car ownership is only beginning, the great majority of transport policies favour the use of automobiles, along the lines of the US model from the 1970s, at least in Mexico and elsewhere in Latin America; most public transport is fairly rudimentary and not very competitive in relation to travel by car, and the absence of redistributive taxation makes it difficult, except in very large cities, to modernize it and introduce operating subsidies to make it more competitive; the public's lack of awareness of environmental issues; security problems complicate the introduction of non-motorized modes, which cities in the north are promoting. What, therefore, would be the most appropriate policies?

First, existing facilities must be strengthened. Many Mexican and Latin American cities built on the European model still have high population densities comparable to European cities. Policies should be oriented to maintain the density of city centres and avoid constructing ring roads without complementary measures to avoid population migration from the centre to the periphery; modernizing public transport to make it more competitive relative to cars and to change its image from a mode of transport for poor people to a mode of transport for everyone; to foster the introduction of pedestrian areas in city centres and in suburbs; foster continued use of bicycles in many cities where it has not yet disappeared; promote expansion of bicycle use for utilitarian and recreational purposes; regulate the fleet of cars to make
it younger, with cleaner vehicles; disseminate information and facilitate procedures to have access to carbon vouchers that could finance these measures.

Yes, the trend towards ever-greater urban mobility, which seems to be reversing in the developing countries, can be expected to spread to a number of emerging economies, but only in a couple of decades. The challenges for sustainable transport are as great as ever.

7. FIGURES

Figure 10. Age-Cohort model simulations, Puebla 2000-2050. Average distance travelled per day per person in veh-km by mode (base index=1 in 2000).
Figure 11. Age-Cohort model simulations, Puebla 2000-2050. Total distance travelled per day in veh-km by mode (base index=1 in 2000).

* (Pop. a) Increasing population and age pyramid changes
* (Pop. b) Total population fixed at year 2000 but changing age pyramid
Figure 12. Age-Cohort model simulations, Juarez 2000-2050. Average distance travelled per day per person in veh-km by mode (base index=1 in 2000).
*(Pop. a) Increasing population and age pyramid changes
*(Pop. b) Total population fixed at year 2000 but changing age pyramid

Figure 13. Age-Cohort model simulations, Juarez 2000-2050. Total distance travelled per day in veh-km by mode (base index=1 in 2000)
* (Pop. a) Increasing population and age pyramid changes
* (Pop. b) Total population fixed at year 2000 but changing age pyramid

Figure 14. Age-Cohort model simulations, Lille 2000-2030. Average distance travelled per day per person in veh-km by mode (base index=1 in 2000).
*(Pop. a) Increasing population and age pyramid changes
*(Pop. b) Total population fixed at year 2000 but changing age pyramid

Figure 15. Age-Cohort model simulations, Lille 2000-2030. Total distance travelled per day in veh-km by mode (base index=1 in 2000).
<table>
<thead>
<tr>
<th>Mode</th>
<th>Puebla, Mexico</th>
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<th>Lille, France</th>
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<tr>
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<tr>
<td>Total Dist. (a)</td>
<td>2030</td>
<td>2040</td>
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<tr>
<td>Auto Driver</td>
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<td>Total Dist. (a)</td>
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<td>Total Dist. (b)</td>
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<td>Total Dist. (b)</td>
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(+) Increasing change when taking into account latest survey. (-) Decreasing change when taking into account latest survey.
(a) Increasing population and age pyramid changes. (b) Total population fixed at year 2000 but changing age pyramid.
Note: Having an increasing (+) and decreasing (-) influence means that the last survey had a positive (+) or negative (-) relative impact by mode and model in relation to the first survey. For instance negative influence could go from 1.4 to 1.1 (base index 1 in 2000), while positive influence could go from 0.7 to 0.9

Table 2: Age-cohort models trends by mode
ACKNOWLEDGEMENTS

We would like to thank: the Cuerpo Académico de Economía Urbana y Regional of the Faculty of Economics of the Benemérita Universidad Autónoma de Puebla, the Mexican National Council on Science and Technology (CONACYT) (subsidy CB-2011-01 No.168388) for their support; Dr. Salvador González-Ayala (IMIP) for providing Juarez's urban mobility surveys. First author thanks the Mexican National Council for Science and Technology (CONACYT) for its support during his Ph.D. studies. We are also grateful to our colleagues from the associated research team to IFSTTAR DEST lab. (ERA-MOB), especially to Mathieu Rabault and Bernard Quetelard (CETE Nord-Picardie) for their advice on Lille Household Travel Surveys, as well as to LMCU (Lille Métropole Communauté Urbaine) for allowing to use these outstanding data.

REFERENCES


INEGI (1994). OD Study for the Mexico City Metropolitan Area".


Urban Accessibility and Affordability: A Case Study for Istanbul

Prof. Dr. Haluk GERÇEK ¹ and Research Ass. Sabahat TOPUZ KİREMİTÇİ ²

Abstract

With 14 million population in 2013, Istanbul is not only the centre of economic and social activities in Turkey, but also is one of the largest and highly urbanized cities in the world. As a result, Istanbul is now overwhelmed by a flood of people and vehicles, an inadequate road network and a public transport system that has been slow and expensive to develop. Thus, recently sustainable transportation policies have gained considerable importance to plan the future transport infrastructure in this megacity. This study focuses on economic and social goals of sustainable transportation by searching relations between urban accessibility and affordability. Accessibility refers to the ease of reaching goods, services, activities and destinations, which together are called opportunities. Transportation affordability means that user financial costs of transport are not excessive, particularly for basic access.

A joint logit model using a utility based accessibility measure is proposed to analyse mode and destination choices of individuals for home-to-work trips. The aim of this study is to investigate the combined role of affordability and accessibility to make an emphasis on transport related equity by means of income distribution and to present an accessibility measure for comparing different transportation infrastructure schemes in Istanbul. Transportation budgets and monthly household incomes of public transportation and private car users are taken into consideration in the utility function. Home-to-work trips data were gathered from the Household Travels Surveys conducted by the Istanbul Metropolitan Municipality in 2006.

1. Introduction

Transport and infrastructure development enables economic and social development but is often detrimental to sustainable development due to congestion, accidents, air pollution as well as greenhouse gas emissions. (Bakker at al., 2014). Thus, decisions and policies about transport and transport related infrastructure investments should be made with great precision, especially in developing countries with tighter budgets. However, there are no specific or solid indicators to measure how these investments can contribute to promoting better access to opportunities particularly for the most vulnerable segments of the population (Bocarejo & Aviedo, 2012).

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This paper aims at presenting a new approach (perspective) to accessibility in evaluation of transport investments, focusing on sustainability related social elements such as equity and transportation affordability.

Within this scope, Istanbul is chosen as the case city because of it is a megacity trying to cope with income inequalities, irrepressible transport related problems and extensive transport infrastructure investments.

The next section of the paper gives brief information about the study area. Section 3, describes accessibility and transportation affordability, and explains data and method used in the analysis. Concluding section discusses the results and further studies that have to be done.

2. About Istanbul

Istanbul is a unique megacity with over 14 million inhabitants spread both Asian and European sides of the Bosphorus. North of the city is mostly rural and forest areas. Population densities are higher on the southern of the city (Figure 1). On the other hand, distribution of working people seems more widespread (Figure 2). Districts with highest number of working people are close to the districts with highest number of employment, which are generally industrial areas (Figure 3).

Distribution of household income does not present a distinctive geographical pattern (Figure 4). It is often possible to spot a high income zone surrounded by low income zones and vice versa. Car ownership distribution (Figure 5) of the city has shown similar characteristics with income distribution, i.e., zones with highest car ownership values are the zones of higher income groups.

Despite its relatively large area and massive population, mostly road-based public transportation system is not sufficient to meet the demand and this causes one of the most significant problems of the city. As shown in Figure 6 and Figure 7, transportation network of the city is road dominated. Railway system is inadequate and although city is divided by the Bosphorus, the share of sea transport is dramatically low.

Currently two highway bridges crossing the Bosphorus Strait carry road traffic between Asian and European sides of the city. Relatively higher number of job places are located in the European side (73 % of jobs and 65 % of inhabitants) and this creates a high travel demand in the east-west direction in the morning and opposite direction in the evening peak hours. The bottlenecks created by the bridges and unbalanced travel demand causes long queues and traffic congestion not only in morning and evening peaks but almost all day long.
Figure 1. Population density in Istanbul

Figure 2. Number of working people in Istanbul
Figure 3. Number of employment in Istanbul

Figure 4. Household income distribution
Figure 5. Car ownership distribution

Figure 6. Road network of Istanbul
3. Methodology

Transportation affordability means that user financial costs of transport are not excessive, particularly for basic access. The terms, sustainability and affordability require improving public transport, cycling and walking. Affordability is also important for transport related social exclusion and transport equity, especially for low income groups.

On the other hand, accessibility is a term often used by transportation experts from both academic and practical backgrounds. It has many definitions in literature such as: the potential of opportunity for interaction (Hansen, 1959), overall benefits provided by a given transport system (Ben-Akiva & Lerman, 1985) and, the ease of reaching goods, services, activities and destinations, which together are called opportunities (DfT, 2004). (For more detailed information about accessibility concept, see Geurs & van Wee, 2004). According to Geurs and Van Wee (2004) accessibility measures can be categorized according to their components which are land-use, transport and individual elements. A utility based approach is used in this study because of its capability of representing all these three components.

There are several utility based accessibility measures available in the literature such as multinomial logit, joint logit (Anas, 1981; Niemeier, 1997; Limanond & Niemeier, 2002) and nested logit models (Daly, 1987). In order to estimate both destination and mode choices of travellers, joint logit models and nested logit models are applicable. Nested logit has a sequential tree structure but joint logit model estimates destination
and mode choices together. A joint logit model has been preferred in this study due to its relatively simpler choice structure.

3.1 Data

Home-based work trips data from household travel surveys that were carried out in 2006 have been provided by Transportation Planning Department of Istanbul Metropolitan Municipality. The data contains information of approximately 20,000 home-based work trips from 451 traffic analysis zones of Istanbul. In this study, private car and public transport trips of about 8,000 individuals have been used.

3.2 Joint Logit Model

Suppose that a multidimensional choice set \( C_n \) for individual \( n \), whose elements are defined as mode and destinations. Let us define \( U_{dm} \) as the total utility of the element of \( C_n \) consisting of mode \( m \) and destination \( d \). It is assumed that some elements \( C_n \) share common observed elements as a consequence of their sharing the same mode or destination. By extension of the partition of the total utility into systematic and random components, it can be written as,

\[
U_{dm} = V_d + V_m + V_{dm} + \varepsilon_{dm}, \forall (d,m) \in C_n
\]

where,

\( V_d = \) the systematic component of utility common to all elements of \( C_n \) using destination \( d \),
\( V_m = \) the systematic component of utility common to all elements of \( C_n \) using mode \( m \),
\( V_{dm} = \) remaining systematic component of utility specific to the combination \((d,m)\),
\( \varepsilon_{dm} = \) the random utility component.

Our model has the following variables for alternative \( i \) \( \in C_n \)

\( x_{i1} = \) travel time for mode/destination combination \( i \),
\( x_{i2} = \) the out-of-pocket cost for mode mode/destination combination \( i \) divided by monthly household income,
\( x_{i3} = \) the employment ratio at the destination included in alternative \( i \),
\( x_{i4} = \) a gender-specific constant defined as \( x_{i4} = \begin{cases} 1 & \text{if male} \\ 0 & \text{otherwise} \end{cases} \)
\( x_{i5} = \) car availability defined as \( x_{i5} = \begin{cases} 1 & \text{if household owns 1 auto} \\ 0 & \text{otherwise} \end{cases} \)
\( x_{i6} = \) car availability defined as \( x_{i6} = \begin{cases} 1 & \text{if household owns more than 1 auto} \\ 0 & \text{otherwise} \end{cases} \)
\[ x_{i7} = \text{mode specific constant} \]

Here, first two variables \( x_{i1} \) and \( x_{i2} \) would be part of \( V_{dm} \) because they vary across both the mode and destination. Variable \( x_{i3} \) would be part of \( V_d \) because its value do not vary across elements of \( C_n \) using \( d \); any mode and destination combinations having the same destination have the same values of \( x_{i3} \). Finally \( x_{i4}, x_{i5} \) and \( x_{i6} \) vary only across modes.

Thus,

\[
V_{dm} = \beta_1 x_{i1} + \beta_2 x_{i2} \tag{2}
\]

\[
V_d = \beta_3 x_{i3} \tag{3}
\]

\[
V_m = \beta_4 x_{i4} + \beta_5 x_{i5} + \beta_6 x_{i6} + \beta_7 \tag{4}
\]

The distribution of the \( \epsilon_{dm} \)'s across the alternatives and across the population defines the choice probabilities. Multinomial logit model has been used for the joint choice of destination and modes, assuming these disturbances are independent and identically Gumbel distributed (with the scale parameter \( \mu \) normalized to 1) as follows:

\[
P_n(d, m) = \frac{e^{V_m + V_d + V_{dm}}}{\sum_{(m,d) \in C_n} e^{V_m + V_d + V_{dm}}} \tag{5}
\]

Equation above is called the joint logit model.

Let \( i \) denote \((d,m)\) destination/mode choice combination, natural logarithm of equation (5)'s denominator is used as accessibility measure for individual \( n \).

\[
A_n = \ln \sum_{i \in C_n} e^{V_m + V_d + V_{dm}} \tag{6}
\]

4.1. Results of the Joint Logit Model

N-logit software has been used to estimate the coefficients of the joint logit model. Estimated coefficients and t-statistics of the joint logit model are given in Table 1.

According to t-statistics, the variables are significant and the pseudo-\( R^2 \) (\( \mu^2 \)) value, which is 0.21, for the model also suggests a moderate model on the basis of overall goodness-of-fit.
Table 1. Estimation results of Joint Logit Model

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>t-stats</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \beta_1 )</td>
<td>-0.04504802</td>
<td>-37.402*</td>
</tr>
<tr>
<td>( \beta_2 )</td>
<td>-5.26844073</td>
<td>-20.415*</td>
</tr>
<tr>
<td>( \beta_3 )</td>
<td>4.53209045</td>
<td>16.245*</td>
</tr>
<tr>
<td>( \beta_4 )</td>
<td>0.95696531</td>
<td>13.712*</td>
</tr>
<tr>
<td>( \beta_5 )</td>
<td>2.40162860</td>
<td>42.050*</td>
</tr>
<tr>
<td>( \beta_6 )</td>
<td>2.80048098</td>
<td>29.593*</td>
</tr>
<tr>
<td>( \beta_7 )</td>
<td>-3.32058474</td>
<td>-40.286*</td>
</tr>
</tbody>
</table>

*Significant at 95% confidence level

4.2 Elasticities

A disaggregate elasticity represents the responsiveness of an individual’s choice probability to a change in the value of the selected attribute (Ben-Akiwa & Lerman, 1985).

Let \( E_{x_i}^{P_n(i)} \) be the elasticity of the probability of an individual choosing alternative \( i \) with respect to a change in some attribute \( x_i \) which is an independent variable in the model.

\[
E_{x_i}^{P_n(i)} = \frac{\partial P_n(i)}{\partial x_i} \frac{x_i}{P_n(i)} = \frac{\partial \ln P_n(i)}{\partial \ln x_i} = [1 - P_n(i)]x_i \beta_k
\]  

Likewise, the disaggregate cross elasticity of the probability of an individual choosing alternative \( i \) that is selected with respect to a change in alternative \( j \) is,

\[
E_{x_j}^{P_n(i)} = \frac{\partial \ln P_n(i)}{\partial \ln x_j} = -P_n(j)x_j \beta_k
\]

In order to calculate elasticities, individuals have been categorized into 18 groups according to their gender (male, female), household income level (low, middle, high), and car availability of the household (no car available, one car available, more than one car available). An origin-destination zone pair is selected and changes in utilities are calculated for each of 18 categories and for 2 cases: In Case 1, private car users costs are increased 10% and 15%. In Case 2, public transportation travel times are reduced 10%.

In Base Case (no change in auto travel cost and in public transport travel time), categories 5, 6, 8 and 9 choose private car. People in these categories are male, in middle or high income groups, and own one or more than one auto. In Case 1, private car users costs are increased 10% at first and as a result none of the categories changed their choices. Then private car users costs are increased 15% and only the people in Category 5 shifted from private car to public transportation. Elasticities for
Case 1 and 2 are shown in Table 2. For Case 2, individuals in Category 5 chose to shift from private car to public transportation.

As it can be seen from the elasticities of Category 5, 6, 8 and 9, private car users are inelastic to travel cost increase (Case 1). Effect of travel time changes on mode choice is higher (even elastic for Category 5) than the effect of the travel cost.

Table 2. Elasticities for Case 1 and for Case 2

<table>
<thead>
<tr>
<th>Category</th>
<th>Gender</th>
<th>Income</th>
<th>Car Ownership</th>
<th>Base Case</th>
<th>Case 1</th>
<th>Case 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(P_A)</td>
<td>(P_{PT})</td>
<td>(P_A)</td>
</tr>
<tr>
<td>1</td>
<td>Male</td>
<td>Low</td>
<td>0</td>
<td>0.01</td>
<td>0.99</td>
<td>0.01</td>
</tr>
<tr>
<td>2</td>
<td>Male</td>
<td>Low</td>
<td>1</td>
<td>0.13</td>
<td>0.87</td>
<td>0.08</td>
</tr>
<tr>
<td>3</td>
<td>Male</td>
<td>Low</td>
<td>1+</td>
<td>0.18</td>
<td>0.82</td>
<td>0.11</td>
</tr>
<tr>
<td>4</td>
<td>Male</td>
<td>Middle</td>
<td>0</td>
<td>0.09</td>
<td>0.91</td>
<td>0.08</td>
</tr>
<tr>
<td>5</td>
<td>Male</td>
<td>Middle</td>
<td>1</td>
<td>0.53</td>
<td>0.47</td>
<td>0.49</td>
</tr>
<tr>
<td>6</td>
<td>Male</td>
<td>Middle</td>
<td>1+</td>
<td>0.63</td>
<td>0.37</td>
<td>0.59</td>
</tr>
<tr>
<td>7</td>
<td>Male</td>
<td>High</td>
<td>0</td>
<td>0.13</td>
<td>0.87</td>
<td>0.12</td>
</tr>
<tr>
<td>8</td>
<td>Male</td>
<td>High</td>
<td>1</td>
<td>0.61</td>
<td>0.39</td>
<td>0.60</td>
</tr>
<tr>
<td>9</td>
<td>Male</td>
<td>High</td>
<td>1+</td>
<td>0.70</td>
<td>0.30</td>
<td>0.69</td>
</tr>
<tr>
<td>10</td>
<td>Female</td>
<td>Low</td>
<td>0</td>
<td>0.01</td>
<td>0.99</td>
<td>0.00</td>
</tr>
<tr>
<td>11</td>
<td>Female</td>
<td>Low</td>
<td>1</td>
<td>0.05</td>
<td>0.95</td>
<td>0.03</td>
</tr>
<tr>
<td>12</td>
<td>Female</td>
<td>Low</td>
<td>1+</td>
<td>0.08</td>
<td>0.92</td>
<td>0.05</td>
</tr>
<tr>
<td>13</td>
<td>Female</td>
<td>Middle</td>
<td>0</td>
<td>0.04</td>
<td>0.96</td>
<td>0.03</td>
</tr>
<tr>
<td>14</td>
<td>Female</td>
<td>Middle</td>
<td>1</td>
<td>0.30</td>
<td>0.70</td>
<td>0.27</td>
</tr>
<tr>
<td>15</td>
<td>Female</td>
<td>Middle</td>
<td>1+</td>
<td>0.39</td>
<td>0.61</td>
<td>0.36</td>
</tr>
<tr>
<td>16</td>
<td>Female</td>
<td>High</td>
<td>0</td>
<td>0.05</td>
<td>0.95</td>
<td>0.05</td>
</tr>
<tr>
<td>17</td>
<td>Female</td>
<td>High</td>
<td>1</td>
<td>0.38</td>
<td>0.62</td>
<td>0.36</td>
</tr>
<tr>
<td>18</td>
<td>Female</td>
<td>High</td>
<td>1+</td>
<td>0.48</td>
<td>0.52</td>
<td>0.46</td>
</tr>
</tbody>
</table>

4. Conclusions

The role of transport policies for sustainable living environment is undeniable. Policies such as improving public transportation, promoting walking and cycling, managing travel demand not only reduce the share of private cars, traffic congestion and air pollution, but also increase accessibility and create more liveable cities.

There are several outcomes of this study which can be summarised as follows:

- Effects of gender, income and car availabilities on mode choices are significant.

- A small portion of people, which are male, belong to middle or high income groups and own one or more private cars choose to travel by car on their
home-based-work trips. It is difficult to change their mode choices by only reducing public transportation travel time or increasing costs of private car. Improving public transportation network, creating more convenient and comfortable systems may be a better option.

Despite the fact that most people prefer public transport system for home-based work trips, public transport network, particularly rail transit system, is still far from being sufficient to meet the increasing demand.

As a continuation of this study, accessibility and affordability measures will be aggregated on zonal basis to make spatial analyses of Istanbul’s districts.

5. References


Development of a Rural Accessibility Index for South Africa

Marianne Vanderschuren ¹ Sekadi Phayane ² and Simon Ssekabira ³

Abstract

On 25 September 2013, the President of the UN General Assembly hosted a special event to follow up on efforts made towards achieving the Millennium Development Goals (MDGs). At the Special Event towards achieving the MDGs, UN Secretary-General Ban Ki-moon presented to Member States his report entitled “A Life of Dignity for All”.

A Life of Dignity for All in the rural context of Africa is dependent on accessibility. In an effort to better understand the current accessibility levels in rural South Africa, the South African Department of Transport employed SMEC South Africa (supported by the University of Cape Town) to carry out an accessibility index using an elaborate questionnaire on the access to: food, shopping, utilities, education, employment, medical and social services in 26 rural districts in South Africa.

Using a special sampling technique, an accessibility index is calculated for the various areas. Findings are presented in a GIS system, providing the possibility for verified extrapolations. This paper presents a summary of the findings for one area.

1. Introduction

South Africa has many achievements since the first democratic elections in April 1994. Poverty has been significantly reduced in terms of income, access to social services and assets. Over 12 million people have benefited from government’s social security assistance programs. The number of people with access to electricity and water services has dramatically increased. More than three million South Africans have been assisted through housing subsidies. Almost 10 million South Africans now have a place they can call home; and more than half of all households are headed by women (www.ruraldevelopment.gov.za).

There are, however, some significant challenges still facing our country. Progress in urban areas is in stark contrast to the often extreme levels of poverty that many South Africans in rural areas still endure. Social deprivation and under-development continues to haunt too many rural areas (www.ruraldevelopment.gov.za).

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Improving accessibility can reduce poverty by facilitating community interaction with social services and their participation in political and economic activities. Accessibility can be defined in various ways. The ‘potential of opportunities for interaction’ was the definition given by Hansen (1959), while Dalvi and Martin (1976) identify the ‘ease with which any land-use activity can be reached from a location using a particular transport system’. Burns (1979) speaks of the ‘Freedom of individuals to decide whether or not to participate in different activities’, and the ‘benefits provided by a transportation/land-use system’ were provided as a definition by Ben-Akiva and Lerman (1979). Even if the definitions from author to author differ, they all identify the possibility to participate in activities and gaining the benefit of services as the core of accessibility.

The South African government realises that accessibility is a key indicator for the well-being of inhabitants, in general, and rural inhabitants in particular. The Department of Transport’s Public Transport Action Plan (Phase 1: 2007 – 2010) identified key district municipalities in various parts of South Africa that became part of Governments Integrated Sustainable Rural Development Programme (ISRDP). The aim was to assess these areas using a Rural Accessibility Index – which measures the number of rural people who live within two kilometers of an all-season road with active public transport services.

Although the described analysis would provide an indication of access for rural inhabitants, it does not provide a value of how good or bad access is in the areas that are positioned beyond 2 km. Furthermore, the time it will take, using the quality infrastructure available to reach a service or opportunity, is also not indicated.

In this study, data was collected in 26 rural district municipalities. Using interpolation and extrapolation techniques, an accessibility value is calculated for every m² in each particular area. This paper provides an overview of the accessibility calculation for one of the 26 areas, i.e. uMzimkhulu in the province of Kwazulu Natal.

2. Methodology

A complex process of 10 steps was carried out in this study for each of the 26 rural areas. These steps were (see Figure 1):

1. A literature was carried out to identify Key Performance Indicators (KPIs), identify the establishment of an Accessibility Index (AI), identify the best sampling method, and inform the development of the questionnaire.
2. The key performance areas, within which the KPIs fall, were identified as being: spatial, temporal/time, travel mode, infrastructure, opportunity and cost aspects.
3. The overall AI was developed based on an aggregation of the scores of the various key performance areas.
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3. The overall AI was developed based on an aggregation of the scores of the various key performance areas.
4. Based on the literature and South African statistics, a sample of rural areas was identified. Based on statistical and geographical requirements, the number of HouseHold (HHs) per rural area was selected.
5. The literature review also informed the questionnaire development.
6. Through a pilot, data collection, processing, analysis and mapping challenges were identified and problems corrected.
7. The actual data collection was carried out over a 6 month period.
8. In parallel, data coding happened.
9. As soon as coded data was validated and corrected, the data analysis and mapping started.
10. For each of the 26 areas, a report was created, as well as an overall summary report.

![Figure 1 Study Methodology](image-url)
3. Questionnaire Development

The data collection tools (i.e. the questionnaires) primarily aim is to collect information that improves the insight into rural accessibility deprivation. By collecting personal information about the respondents, and the households they head, a better understanding of social challenges is gained.

Individual Household Questionnaires (IHQ) were compiled as the best tool for data collection. The advantage of IHQ is that they are close-ended. Close-ended questionnaires are highly structured. This means that data is collected on the variables that have been shown to be linked to the construct under investigation.

This contributes to heightened construct validity. Secondly, IHQs allow for data to be collected at the household level. This is an advantage in that it allows for analysis to be done at the level of a household with a higher degree of certainty than, for instance would, be the case with Focus Group Discussions (FGD).

The questionnaire focused on the last trip made, from home to a specific destination. Destinations were predetermined in the Domains and Destinations section. The questionnaire had the following aspects:

- Information Leaflet for respondents and interested parties: In this section, the following aspects were covered: background, procedures, benefits, confidentiality and contact person.
- Consent and Assent sheet for the interview: This section covered the informed permission of the potential participant to be part of the Pilot Project.
- Administrative and Background information: Information about the Pilot Project, as well as the background of the respondent representing the Household, was collected here.
- Household demographics: Information on the Household was collected in this section.
- Domains and Destinations: Possible and predetermined destinations were outlined in this section.
- Travelling to and from destinations: The detail of the travel experience was captured in this section.
- Other destinations: Information on the destinations that the Household would want to travel to, within the District Municipality, but are unable to, was collected in this section. This question relates specifically to the Household’s access to transport that will allow them to be able to reach other desired Domains.

The questionnaire was administered at the Household level, to individual Households, and the Head (or Acting Head) of the Household was interviewed. A Household is defined as: “a person, or a group of persons, who occupy a common dwelling (or part of it) for at least four days a week and who provide themselves jointly with food and other essentials for living ... People who occupy the same dwelling, but who do not share food or other essentials, are ... separate Households” (www.statssa.gov.za/census2011/faq).
4. The Data Collection Process

It is essential that data collection processes were streamlined. Fieldworkers, who spoke the local language, were hired in each of the Provinces. The fieldworkers were trained for one day. The training included role-play and detailed explanations of the data collection tool. A team leader was appointed to streamline the communication with the fieldworkers, as well as the project team.

The project team announced the arrival of the fieldworkers to the Local or District Municipality. The population of each village was reviewed, leading to a determination of a ratio of how many Households should be interviewed in each village. This was done in order to guarantee the statistical and geographical sampling requirements. This then led to the identification of the households to be approached. Having identified a set number of households (number of Households in each village divided by number of sections to determine number of Households in each section to be visited), the households were approached, following convenient sampling. Interviews were then conducted in each Household by the Fieldworkers. Data was collected on the printed questionnaires and captured onto an Excel spread sheet. Data analysis and reflection on the process was then undertaken.

5. The Sampling Process

Compared with complete enumeration, a statistically based sampling process has great advantages. It leads to reduced costs, higher speed, greater scope and a loss of accuracy that is negligible compared to complete enumeration (Cochran, 1977). The confidence level and margin (accepted) of error are the statistical tools used to identify the required sampling size. Confidence levels allow concluding that the answer of any inhabitant will be the same as the average answer calculated based on the respondent’s answers. The lower the confidence level, the smaller the sample, and vice versa. For human and financial reasons, a 60% confidence level was accepted for this study. The accepted margin of error was set at 5%. Following this, a minimum number of 71 households in each sampled ward were sampled, based on the calculation provided in Equation 1.
\[ n = \frac{z^2 p(1-p)}{a^2} = \frac{0.84^2 p(1-p)}{0.05^2} = 70.56 \]

Multiple villages were sampled in each Local Municipality. Samples were drawn from the spatial frame over the entire Local Municipality. A stepwise stratified and random spatial sampling was used for the selection of villages.

The aim of the first step was to identify settlements that generated the largest geographical spread within the Local Municipality. Google earth was used to identify the settlements. Over the whole of the Local Municipality the settlements were evenly spread (informed by the actual settlement location). This is called stratified geographical sampling. Stratification is the process of dividing members of the population into homogeneous sub-groups before sampling. The strata should be mutually exclusive: every element in the population must be assigned to only one stratum. In this study the strata is based on the geographical location.

The aim of the second step is to apply random sampling within the strata identified in step 1. Within the settlements the geographical location of household is random. The number of households per settlement depends on total number of settlements identified in the Local Municipality with a minimum of 3 (required to do the intended geographical modelling).

6. Case Study Identification

Kwazulu Natal was previously identified as the most deprived province (STATSSA, 2006). Although not the most deprived, the selected district municipality of uMzimkhulu is expected to have high levels of poverty and limited access to opportunities and services. Figure 2 provides an indication of the position of Kwazulu Natal as a province and the uMzimkhulu district municipality within the province. For the purpose of this paper, this area in Kwazulu Natal was selected as the case study.

As indicated, the questionnaires had various sections, including domains and destinations. The accessibility indicator is the time it takes to reach the domains is an accessibility indicator. Some 15 domains were included, i.e. food shopping, other shopping, education, work, work seeking, medical facilities, traditional healer, municipal offices, home affairs, welfare offices, tribal authorities, police stations, post offices, social and utilities.
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Using ArcGIS (version 10.0), access (through the use of travel times) to all domains was mapped. Due to the fact that only limited samples of households were interviewed, it was required to calculate values for other locations. The complete district municipality was mapped using interpolation and extrapolation procedures. In the final mapping, values for agricultural land were omitted.

7. Accessibility Mapping

Accessibility mapping was carried out using ArcGIS. All 26 areas are rasterised into cells that are 0.05 km². For each cell a value, Accessibility Index per cell (AIc), calculation is carried out. This value is based on the 12 closest measurements (HH questionnaire results) and the distance to the cell (see Equation 2).

\[
AIc = \sum_{n=1}^{12} (\alpha AV_n \times \beta f(L_n))
\]

Where:
AIc = Accessibility Index per cell
AV_n = Accessibility Value for a specific domain measured for the 12 closest HHs
f(L_n) = Function of the distance to the cell
F(L_n) = function of the distance (L) to the 12 HHs, longer distances have reduced influence.

During the mapping procedures it was found that access to the different domains varies substantially. As an example, Figures 3 and 4 provide the access maps for food shopping and education. The mapped values vary between 15 minutes and 180 minutes to reach the domain.

Food shopping (Figure 3) is clearly more difficult in the western part of the uMzimkhulu district municipality (red areas, indicating long travel times). In the eastern part, access to food shopping is deemed acceptable (blue areas).

Access to medical facilities shows a very different map (Figure 4) to the one generated for food shopping. In the north-western and southern part of the uMzimkhulu district municipality access to medical facilities is possible within acceptable travel times. In the middle of the district municipality travel times to medical facilities are long, even though some areas include facilities. However, a local clinic may not be able to provide the services required, and access to appropriate medical facilities is far. Due to space limitations in this paper, not all 15 generated maps are provided.
8. Infrastructure Investment Decision Support

As indicated, an overall AI was developed based on an aggregation of the scores of the various key performance areas. The key performance areas, within which the KPIs fall, were identified as being: spatial, temporal/time, travel mode, infrastructure, opportunity and cost aspects. In theory, various combinations can be used to develop the AI. For the purpose of this paper, only the mapping principle was explained and not the various combinations and weightings of KPIs.

Access to opportunities and services is not the only criteria for government to decide that investment in an area is needed. If the number of inhabitants is small, then large investments are not warranted, even if accessibility levels are low. In the mapping exercise carried out in this project, the accessibility value (calculated for every 0.05 km²), is multiplied with the total population. The calculated value provides an Accessibility Investment Index (AII) that can be used to make investment decisions. As an example, the AI for education is provided in Figure 5.
The higher the accessibility value in combination with the population size, the more important it is to invest in infrastructure, i.e. improve the transportation system or bring opportunities and services (in this case education) closer to the people. Again it can be seen, for example in Ibisi that, despite the presence of schools, the AII for the area is indicating a need for investment. A possible reason is the level of schooling provided at the two local schools. Many rural schools only provide limited grades (up to grade 5 or 7 is common).

Besides the identification of an AII for the 15 domains included in this study, an overall AII can be calculated. In this case, all AIs would be added together and be multiplied by the overall population (see Equation 3).
$$AII_{tot} = \sum_{k=1}^{15} AII_c \times Pop_{tot}$$  \hspace{1cm} (3)$$

Where:
AII$_{tot}$ = overall Accessibility Investment Index  
AII$_c$ = Accessibility Index per cell per domain  
Pop$_{tot}$ = total population per sub area

Figure 6 provides the AII$_{tot}$ map for uMzimkhulu district municipality. Part of Idawana, Zwelethu, Nqozama, Umzimkulu/Clydesdale and Ibsi have the most deprivation. In other words, further analysis on how to address the lack of opportunities and services in these areas is required. The feasibility of improved transport infrastructure and services versus improved local opportunities (i.e. schools, clinics etc.) needs to be reviewed. If the actual values for the mentioned areas are compared, the area with the highest value needs to be reviewed first.
9. Reflection

For rural communities, the time travelled to opportunities and services is not the only aspect to consider. Given the poverty levels, the cost of travel is important. International literature (Vasconcellos, 2001) indicates that, due to the lack of financial possibilities, the poor often pay in time (walking long distances, as motorised transport options are too expensive). Theoretically, more sophisticated equations could be used to incorporate not only time travelled, but also the information regarding the cost of a trip, mode used etc. Moreover, a weighting would be possible (i.e. is time more important than cost or vice versa?). Further research into this area is likely to provide interesting findings. However, including more variables does not necessarily provide better results, as the contribution of each added variable is less than the previous one. Moreover, more data adds a risk of increased errors during the data collection, processing and analysis.

Weighting could also be applied to the AI per domain. In other words, is access to food more important than access to education or medical services? This is a relevant question that would require discussions with government (at a national level, as well as locally) and other stakeholder engagement and, possibly, further research. From an academic point of view, an equal weighting was chosen as no reliable information was available that could justify a different weighting of AI per domain.

10. Concluding Remarks

A Life and Dignity for all, as called for in the Millennium Development Goals (MDGs), can only be achieved if people have access to services and opportunities. The Development of Accessibility Indices (AIs) for rural South Africa identifies current gaps.

Single, or even combined and weighted AIs, cannot be used for investment purposes. To decide an investment budget, a consideration of population volumes is required.

In any study it is required to balance data collection costs versus statistical reliability. In this study, 60% reliability was accepted, as funding did not allow for more. However, by adding geographical stratified sampling, the collected data proved to be valuable, reliable and significant.

Geographical Information Systems (GIS) are a useful tool in analysing data. This study proves that investment decision support is possible based on limited data collection. For the African continent, where investment funding is scarce, these tools should be considered.

Actual AI and AII values can be used to prioritise investments within a district municipality and between district municipalities. Theoretically, the most deprived area in South Africa could be identified.
ArcGIS calculated its own values, based on the actual data collected. If the user considers a weighting, then a standardisation of AI results is recommended. As this is an academic paper and no weighting was carried out, this is not demonstrated in the presented results.

11. References


URBAN LANE REDIRECTION METHODOLOGY 
BASED ON AN OVERALL AVERAGE ACCESSIBILITY 
ANALYSIS

Diego Escobar-Garcia¹, Juan Duque-Cañas ² and Carlos Cadena-Gaitán³

Abstract

This investigation uses a methodology based on transport infrastructure supply. With the use of GPS data from automobile vehicles it is possible to determine the characteristics of a network, and the conditions for urban accessibility. The aim of the methodology is to propose structural lane modifications though the use of proper geostatic calculations. The results of this investigation are currently being applied within its population. The primary objective of the investigation is to define optimal lane directions for the Municipality of Riosucio (≈approx. 60,000 inhabitants, Colombia, South America). The main hypothesis is that proper lane direction improves the mobility characteristics of different modes of transport, as well as the quality of life of the inhabitants concerned; in addition, accident probability will decrease due to less flow in certain convergent areas of the city. Calculations are based on the compilation of over 3 million GPS data points, across different transport modes. The overall average accessibility analysis was done for nine (9) scenarios, the first being the current lane situation, and the other eight (8) different lane redirection proposals within the city. Each proposal is evaluated in relation to the change in two variables: average travel time and population coverage. The effects of each lane direction proposal are determined, and a conclusion is reached based on population coverage, reduction of average travel times and land use of the sectors that benefit from the proposal.

1. Introduction

The objective of transportation infrastructures is that they serve the purpose for which they were built, allowing for mobility with high standards in terms of promptness of communication, security, economy and commodity. This investigation can be seen as a methodological proposal for the application of transportation model offers; in which the overall average accessibility analysis is able to technically define the best option for lane redirection in a network of transportation infrastructures.

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The applied methodology is described as well as the results obtained by investigation which was carried out in the city of Riosucio (Colombia, South America), located at 5° 24’ north latitude and 75° 40’ West latitude. At an altitude of 1783 meters above sea level (5849.74 feet) (Mayor’s office of the municipality of Riosucio, 2003). Total area of 422 Km² (Caldas Governor’s office, 2009).

Research related to the analysis of accessibility address primary concepts of the network and graph theory (Petrus, J. and Segui, J., 1991). Through a morphometric study of these theories, and based on a sample of data, the general aspects of a network can be known using quantitative and geospatial methods (Geostatistics). In spite of the fact that the origin of the term “accessibility” can be traced back to the decade of the 90’s, and is involved with studies related to regional economic planning (Batty, 2009) and the localization theory; the concept has been emphasized over the past five decades in both regional and urban territorial planning. The term is jointly analyzed from the mere physical possibilities of accessing a location, to its geographic dimension.

The first technical definition of the concept was given by Hansen (1959, 73) “… the potential of opportunities for interaction.” Notwithstanding, other definitions of the term have been developed (Pirie, 1979; Jones, 1981; Martellano et al., 1995) from the geographic dimension, which is defined as a measurement of the ease of communication between activities and human settlement using some mode of transportation (Morris et al., 1978; Zhu and Liu, 2004).

We must highlight the fact that accessibility analysis is increasingly prominent in the evaluation of infrastructure projects and territorial planning (Gutiérrez et al., 2010), and that finding an improvement in the levels of accessibility in most cases is one of the criteria used in the evaluations. It is also valid to say that one of the main variables leading to low accessibility in a territory is the deficient offer and operation of transportation infrastructures. In view of this, accessibility has become one of the main assets of a sound urban transportation system. (Bocarejo and Oviedo, 2012).

At present, it’s possible to find different types of analysis and studies of accessibility that have allowed to relate the term with varied criteria such as: demography (Kotavaara et al., 2011); social cohesion (Schürman et al., 1999; López et al., 2008; Farrington and Farrington, 2005); Economic development (Rietveld and Nijkamp, 1993; Vickerman et al., 1999; Holl, 2007; MacKinnon et al., 2008; Ribeiro and Silva, 2011); Provision and localization of services (Calcuttawala, 2006; Park, 2012; Higgs et al., 2013); Acces to public parks (Wang et al, 2013); Sustainability (Cheng et al., 2007; Vega, 2011; Escobar et al., 2013); operation of modes of transport (Escobar and García, 2012); Analysis of coverage (Straatemeier, 2008).

A study of lane redirection must obey the results of a serious analysis that guaranties the selection of sound decisions. Because of this, overall urban average accessibility analysis can be applied to establish the impact generated by the modifications done to operational and or physical structure of a lane network. Having finished the
introduction, in the second section the methodology proposed by this investigation for the study of lane redirection will be addressed. In the third section the main results obtained will be presented, and finally in the fourth section the main conclusions will be shown.

2. Methodology

The investigation is carried out in six stages. a) determination of the physical characteristics of the network; b) Validation and georeference of the network of transportation infrastructures; c) determination of the operational characteristics of the network with GPS equipment; d) Calculation of the average operation velocity of each of the arcs that compose the network; e) calculation of the overall average accessibility offered by the network of infrastructures, and f) Calculation of the percentages of population coverage covered by the isochrone curves obtained from the accessibility analysis.

2.1 Determination of the physical characteristics of the network

The aggregation of nodes and arcs (segments of a lane) make up the so-called network of infrastructures of transport. In this case, the network is composed of more than 650 arcs and over 460 nodes, which together are the fundamental base for the respective overall average accessibility analysis.

With cartography given by the municipal administration, and with routes done directly in the field, it was possible to collect the data of the physical characteristics of the transport network infrastructures of the city. Aerial photography was a fundamental support for the recollection of this information, making it possible to establish points at which, for example, there was a change in the number of lanes or in the type of tread surface, etc.

2.2 Validation and Georeference of the network of transportation infrastructures

With the use of monitoring equipment (GPS) installed in different automotive vehicles (cars, taxies, motorcycles and collective urban public transportation), it was possible to store satellite positioning data, allowing the detection of possible inconsistencies in the lane network that had initially been georeferenced.

During the process of validation an inventory is carried out in which the routes registered by the GPS are superimposed onto the existing lane network, thus identifying the elements of the lane that require confirmation. In Figure 1 the superimposition of some GPS data onto the lane network is shown, verifying that the arcs aren’t displaced with respect to the obtained data. This is usually due to the fact that it is the actual lane that’s erroneously positioned on the study graph, possibly because of the reticular (flat) cartography provided.
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Fig. 1. Superimposition of the GPS data for the verification process of the lane network. Source: Personal elaboration.

The validation process of the information is complemented by the verification of the coordinates, the structure of the data base, the foreseen precision, the time between units of data, the data sequence, the file format, etc. Of the previously mentioned variables, the identification of the data sequence of a certain route is a complex process, because some GPS equipment temporarily lose their signal or report completely incoherent information.

2.3 Determination of the operational characteristics of the network

For this investigation operational velocity data was taken from the following modes of transport: Motorcycles, Taxies, collective urban public transportation and private vehicles, with the use of GPS equipment.

The operational velocities were calculated from the real monitored datum, and they reflect the true operational characteristics of the arcs that conform the lane network, which is quite significant because in many cases they assume velocities according to the lane category (Burns, 2007). However, in the last few years accessibility investigations have been done that measure the real velocities of some vehicles, for example: Taxies. (Li et al., 2011).

2.4 Calculation of the average operation velocity of each of the arcs

The operational velocity was calculated with the information obtained by the GPS, which registered the date, time, event, velocity and coordinates of each of the vehicles they were in every second. This allowed the generation of a database of the routes of the vehicles. Information was taken from over 75% of the arcs of the lane network of the city; with multiple passes at different times of day.
The processing of the information required the application of different calculations according to the development of the investigation, with a special reference to the analysis of operational velocity. This is because this variable determines the general behavior of the network and it becomes a key element for accessibility calculations (Geurs and Ritsema van Eck, 2001). Most of the precision and veracity of the results that are obtained depend on this variable’s recollection (Herce, M. y Magrinya, F., 2002). Operational velocity was determined for each arc of the network from the time information obtained continuously from the GPS equipment. Three parameters were analyzed:

a) The operational velocity of the vehicle within an interval of time between two points (Ec.1), where, $v_i = \text{velocity in Km/h}; x_1, y_1 = \text{coordinates of point 1 in meters}; x_2, y_2 = \text{coordinates of point 1 in meters}; t = \text{the interval of time in seconds between points 1 and 2}$. This parameter is used to know the variability of the velocity in a specific arc, also known as the instant velocity of the vehicle.

$$v_i = 3.6 \sqrt{(y_2 - y_1)^2 + (x_2 - x_1)^2} \quad (1)$$

b) The average operational velocity of a vehicle over the Nth arc (Ec.2), where, $v_i^a = \text{velocity i in the arc at (km/h)}; l_a = \text{longitude of the arc in meters}; t_1 = \text{passing time in the initial node}; t_2 = \text{passing time in the final node}$. This velocity is calculated with the relationship between the longitude of the arc and the difference in the passing times in the initial and final nodes.

$$v_i^a = 3.6 \frac{l_a}{t_2 - t_1} \quad (2)$$

c) The average operational velocity for each arc i of a determined route. (Ec.3), where, $V_a = \text{Average operational velocity of arc a}; n = \text{number of velocity units of data registered in the arc a for a given period of time}$. This velocity was used to establish the impedances of the network, and was used as prime data to develop a prediction model for average route times.

$$\bar{V}_a = \frac{n \sum_{i=1} V_i^a}{n} \quad (3)$$

The operational velocity data was loaded onto the lane network graph using SIG, which in turn allowed a more detailed knowledge of the characteristics of the overall average accessibility offered by a mode of transport in particular and the network of infrastructures. An advantage of the use of the SIG is that they permitted an understanding of the behavior of the networks (Gutierrez et al., 2010), which was analyzed using algorithms (i.e.: minimum paths) (Zhang and Gao, 2009).
2.5 Calculation of the overall average accessibility offered by the network of infrastructures

In this stage the desired knowledge is how the vehicles can access the different sectors of the city according to the operational and physical characteristics of the network. The overall average accessibility is calculated with the average route time vector (Tvi), which represents the average route time from node i to the rest of the nodes in the network of the study. To obtain said variable a SIG algorithm allowed us to find the shortest path between a specific node and the rest of the nodes in the network. This conformed a unimodal matrix of impedances. With the minimum distance matrix, and the knowledge of the average operational velocity of each arc, an average minimum time matrix was calculated. In this matrix the route time is minimized between all the nodes of the network.

With the previously mentioned matrix, it’s possible to calculate the average route time vector (Tvi, Ec.4), where, Tvi = average route time between node i and the rest of the nodes in the network; tvi = minimum route time between node i and the rest of the nodes in the network.

\[
\bar{T}_vi = \frac{\sum_{j=1}^{m} t_{vi}}{(n \cdot 1)} \quad i = 1,2,3,...,n \quad ; \quad j = 1,2,3,...,m
\]  

(4)

The average route time vector (n x 1), relates to the geographic coordinates (longitude and latitude) of each node to generate a matrix in the order of (n x 3). With this matrix the isochrone curves of average route time are obtained by the application of a geostatic model. For this investigation the ordinary kriging with a linear variogram was used as a prediction model for the average route times.

This accessibility indicator tends to favor the points located towards the center of a network of infrastructures, due to the fact that the route times from those nodes to the rest are shorter because of their geographic location. The overall average accessibility analysis was carried out for nine (9) scenarios, the first being the current lane situation, and the other eight (8) different lane redirection proposals within the city. Each proposal is evaluated in relation to the change in two variables: Average travel time and population coverage.

2.6 Calculation of the percentages of population coverage

After knowing the results of each of the eight (8) lane redirection proposals from the average route time variable, it was possible to relate the isochrone curves of each case with the population data. The comparisons are made in terms of percentage of population covered by the different average route time curves, which has a necessary premise of a uniform population density, given the inexistence of disaggregate
population information. Similar applications of coverage have been carried out in other contexts. (Straatemeier, 2008).

3. Main Results

The lane network of the city of Riosucio has a longitude of 60km, distributed as follows: 22% main, 12% secondary, 49% toll free 4, 14% regional, and 3% pedestrian. In terms of the average operational velocity, results showed that all along the regional lanes there were higher average velocities, with the exception of the highest velocity that was registered on a main lane at 50.8 Km./h.

The maximum velocities for the different categories are high, considering their functional characteristics, with the exception of the pedestrian lanes. The minimum velocities found are considered normal and could not be related to possible vehicular congestion, but rather to the modes of transport themselves. The average velocities found are as follows: Main: 31 Km./h., secondary 22 Km./h., toll free 19 Km./h., regional 33 Km./h.

The lane redirection proposals are evaluated taking into account the change generated in the average route time variable, which is directly influenced by the modifications of the direction of some lanes that form part of the network. In the next section of the investigation the current situation scenario, the scenario that has the most adequate proposal, and a comparative analysis of the results of each proposal that was analyzed will be presented.

3.1 The “current situation” scenario

The Fig. 2 shows the current situation scenario lane network of the city of Riosucio. The arcs highlighted in red are the lanes that are currently one way. In Fig. 3 the average route time curves that were obtained can be seen. Currently, the operational characteristics of the city’s’ lane network allows a complete crossing from one side to the other if a maximum of 20 minutes are invested at the average velocity of all the modes of transport. Although, in a general sense, the city can be crossed in average route times of between 5 and 17 minutes.

The center of the municipality registers the best conditions of overall average accessibility (the sector with the lighter colors). The curves clearly expand all along the main lanes, that is to say, there is a larger expansion of the average route time curves going north than going west-east, and vice versa. In the southeast sector the accessibility conditions are different than those found in the CBD or the commercial center of that same sector.

4 “Via colectora” In Spanish is a road that runs parallel to a highway and has less lanes. One could assume that the equivalent in most English speaking countries would be a toll free service road. Their use is, however, mostly inter-urban.
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3.2 Comparative analysis of redirection proposals based on population coverage

In this stage of the investigation all the particular results of each of the eight (8) lane redirection proposals are understood from the point of view of the average route time variable. This makes it possible to relate the isochrone curves obtained for each case with demographic information, with the finality of comparing population coverage according to certain isochrone curves for each redirection case. It’s important to point out that the comparisons are made in terms of the percentage of population coverage which has a necessary premise of a uniform population density given the inexistence of disaggregate population information.
In Fig. 4 the comparative results of population coverage according to the different isochrone curves obtained for each proposal of lane redirection.

Fig. 4. Percentage of population coverage Vs Average route time. Comparison between current situation and proposals. Source: personal elaboration

From the previous comparison of results it is possible to conclude the following points:

a) The proposals 3, 4, 6, and 8 are the only ones that refer some population coverage by a average route time curve of 4.5 minutes. That being said, the proposal N°3 is the one that offers the greatest percentage for that isochrone curve.

b) Analogically, observing the percentages of coverage for the 5 minutes curve, all proposals offer some coverage for that average route time curve. The proposals 1, 2, and 8 report the highest percentages at over 30%.

c) When analyzing the superior extremity, one can observe that the only proposal that makes a reference to coverage for the 11.5 minute curve is N°7.

d) An analysis of the current situation shows that this scenario reports the highest percentages in the 7, 8, and 8,5 minute curves. This shows that the redirection proposals that have been studied, to a certain proportion, improve the average route times in the urban zone of the municipality.

On the other hand, it is possible to obtain the percentage ogives of the relation between the isochrone curves and the percentage of population coverage, so as to understand in detail the behavior of the population coverage in each one of the lane redirection proposals studied.
In Fig. 5 we can observe the results obtained concerning this point. The further right the percentage ogive is from the center means the more average route time that must be invested for a certain percentage of coverage.

Fig. 5. Percentage ogives of the relation between average route time and % of population coverage. Comparison of redirection proposals. Source: personal elaboration.

From the previous comparison of results we can conclude the following points:

a) Of all the redirection proposals, N°7 is the most deficient in terms of percentage of population coverage, and the average route time curve. This is due to the fact that it’s mostly located to right of the “current situation” percentage ogive. The rest of the proposals show an improvement in relation with the current situation scenario.

b) There are three proposals that are located farthest left of the current situation, these are the proposals 3, 4 and 8.

c) Looking specifically at the average route time that related to 20% population coverage, one can observe a time of 4.68 minutes for the proposals 3 and 4, 4.78 minutes for proposal 8, and a time of 4.88 minutes for proposal 6. The rest of the proposals refer to times over 5 minutes for that coverage.

d) Looking specifically at the average route time that related to 50% population coverage, one can observe a time between 5.47 and 5.67 minutes amongst the proposals, whereas the current situation made reference to a time of over 6 minutes.
e) It’s clear that for 10.5 minutes, all proposals show a 100% coverage, which shows that the average times of displacement within the city of Riosucio are quite short. This only reinforces the necessity to know the real characteristics of mobilization, to propose mobility corridors according to mobility preferences.

It is possible to carry out the same analysis between the percentage of average route time saving curves, and the percentage of population coverage as shown in the results obtained in Fig. 6.

Fig. 6. Percentage ogives of the relation between % of average route time saved and % of population coverage. Comparison between proposals and the “current situation” scenario. Source: personal elaboration

From the previous comparison of results we can conclude the following points:

a) It can be observed that the proposals 3, 4, and 8 are the only ones that refer to a saving of 2% with respect to the initial average route time at 100% coverage. And so, for example, for the case of proposal 7, less that 50% population coverage refers to the same amount of saving.

b) For a saving of average route time of 12%, the only proposals that would impact over 10% of the population would be 3, 4, and 8. The same can be seen with a saving of 8%, in which the same proposals are the only ones able to impact over 30% of the population.

c) The proposals that report most benefits in terms of improving accessibility are 3, 4, and 8, in that order. It is necessary, however, to make a decision as to which
proposal can be defined as the best. These results must be related to the spatial configuration of the isochrone curves.

d) The proposals that are located closer to the origin are the ones that present a more deficient performance with respect to the current situation. This can be seen, for example, in the 40% coverage zone where proposal N°7 is the most deficient and then is followed by 5, 2, 6 y 1, 8, 4 y 3 respectively.

e) There are only three proposals that make reference to a saving percentage of 14% with respect to small coverage percentages, namely N°3, 4 and 8.

3.3 The redirection proposal that was selected.

As a result of the preliminary analysis of the redirection proposals, proposition N°3 was profiled as the optimal choice taking into account the percentage of average route time saving. It was, however, necessary to make some small modifications to the proposal when verified through field implementation. This ended up creating the lane redirection proposal N°8 (see Fig. 7), which was finally selected as the most adequate.

![Fig. 7. Lane redirection proposal N°8. Source: personal elaboration.](image)

In Fig. 8 one can observe the results of the isochrone curves obtained by applying this proposal; the shortest average time curve is 4.5 minutes and it covers a small sector of the center of the city. The average route time curves then vary in that range between approximately 4.5 and 15.5 minutes.

In a general sense, the behavior of the curves that was obtained was similar to the previous redirection proposals. In these, the sector with the most deficient accessibility conditions is the northwest, and the time curves expand more going from north to south and vice versa than going east to west. This is due to the spatial configuration of the transportation infrastructures as such.
In Fig. 9 the result of comparing the average route time curves of proposal N°8 and the average route time obtained for the current situation. The result of this comparison is expressed as the saving percentage of the average route times.

It’s important to highlight that only a small area in the southwest of the CBD shows a null percentage of saving. Notwithstanding, the CBD in the municipality shows percentages of saving from 2% to 8% with regards to the initial average route time. Towards the north of the city saving in some cases reaches 14% with respect to the average route time of the current situation. The curves with the highest percentages of saving are covering residential lands, healthcare attention point such as the Hospital, or security such as the police station. This is a great point in favor of the proposal.
In Fig. 9 the result of comparing the average route time curves of proposal N°8 and the average route time obtained for the current situation. The result of this comparison is expressed as the saving percentage of the average route times. It’s important to highlight that only a small area in the southwest of the CBD shows a null percentage of saving. Notwithstanding, the CBD in the municipality shows percentages of saving from 2% to 8% with regards to the initial average route time. Towards the north of the city saving in some cases reaches 14% with respect to the average route time of the current situation. The curves with the highest percentages of saving are covering residential lands, healthcare attention point such as the Hospital, or security such as the police station. This is a great point in favor of the proposal.

This proposal was selected because of the combination of three variables:

a) The percentages of saving of the average route time. This variable clearly showes that between the proposal and the current situation there are significant percentages of the population that benefit.

b) Possibilities of field implementation. This variable gave proposal N°8 an advantage over proposal N°3, due to the fact that the later encountered significant problems in terms of implementation, because of the topography of some arcs in which redirection was to take place.

c) Configuration of the percentage saving of the average route time curves. It is clear that the northern sector of the urban settlement in the municipality is where
there are the highest saving percentages. This is where most of the population is settled, adding to the benefits the land use of this sector.

The proposal comprehends a lane direction unification of 5.1 kilometers of the central area of the city. The implementation of this new lane direction has to be done gradually. This being said, it is our recommendation that the change of direction of the lanes and or unification be done over a long period of time, the minimum being a year. This is so that the population can assimilate the changes slowly.

4. Conclusions

During the investigation the citizens commitment to search for the improvement of mobility conditions stood out. A clear and active participation of transportation companies, the administration, and the community was evidenced.

We highlight the inexistence of the “Local lane” as described in the Basic Plan of Territorial Order (Plan Básico de Ordenamiento Territorial, Acuerdo 145 de 2003)\(^5\). This must be corrected with the purpose of achieving an adequate relation between the definition of a lane, and its corresponding functionality.

Whilst analyzing the behavior of isochrone curves, we found that when going from north to south there is a larger expansion of the curves, especially towards the north. This is due to this direction having the best lane characteristics in the municipality. The same expansion is present when going west to east and vice versa, the west presents major difficulties, probably due to the steep gradients present in the sector. The previously mentioned characteristics where the common denominator in all the lane redirection proposals.

The results of the proposals N°5 y 6 simply show that the lane direction proposals evaluated make it so that, towards the central sector of the city, people that use an automotive medium for displacement don’t experience any saving in their average route time. We consider that these techniques are used more in situations in which there is a desire to demotivate the use of motorized modes in a specific sector of the city. For this particular case, what is being sought is the generation of a culture of organization of vehicular flow in the city, without having to use direct demotivation of automotive vehicles.

The gradual implementation of the lane direction proposal N°8 over time is recommended. Of all the proposals that were studied, this one has the most benefits as seen in the previous section.

\(^5\) This is a juridical agreement proliferated by regional legislative organs to systematize lane networks and other infrastructures.
It’s important to mention that every proposal for lane unification must be accompanied with a very strong dissemination and socialization campaign of the interventions to take place. This can be achieved through radio and community television programs, as well as the installation of proper signs, distribution of propaganda alluding to the change to take place, and a general educational and communicational champagne that all allow the community to adapt to the new lane directions.

The methodology proposed in this investigation has proven to be a powerful tool for decision-making. It positions itself as a purely technical support that allows one to know the impact generated by the modification of lane directions, in a network of infrastructures. In addition, this methodology could be key to the analysis of the impacts that the insertion of a certain infrastructure or a given intervention in the sector of a city, given the changes in the operational characteristics of the network.

5. References


TRANSPORT GOVERNANCE OF THE ‘INTERNATIONAL BEST PRACTICE’: PARALLELS BETWEEN BRT DEVELOPMENTS IN AHMEDABAD AND BOGOTÁ

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ABSTRACT

The city of Ahmedabad has recently become a model of transport planning both in India and overseas. The Bus Rapid Transit –BRT- system of the city, ‘Janmarg’, has been in operation since 2009 as a result of top-down planning involving strong political will and high-level technical assessment. Particularly, the project profited from involvement of international partners in its design, drawing insights from previous experiences with BRTs over the world. These included that of Bogotá (Colombia), another international example of best-practice in implementation of a bus-based system in a development context. Despite large geographical and socio-demographic differences, Bogotá and Ahmedabad share interesting common ground for analysing planning processes and governance of transport provision. Technically speaking, ‘Janmarg’ adopted most features from Bogotá’s ‘Transmilenio’; and both projects benefited from political leadership driving transport policy when they were conceived and implemented. These features allowed a smoother adoption of bus-based systems in both cities, strengthening the idealization of BRTs as expedite and efficient transport solutions for developing cities.

However, this success is not to be generalized. Although Ahmedabad was effective in adopting Bogotá’s model so far, its system is still halfway developed, falling short on several aspects. ‘Janmarg’ not only has exhibited an apparent lack of integration with the structure of the city and other transport modes, it also has affordability issues and relatively low levels of ridership. In this context, we compare the cases of Bogotá and Ahmedabad reflecting on common elements that allowed the production of specific BRT models in each city and raising awareness on the dangers of “BRT Prescriptions”. We analyse the governance of trending transport solutions and the implications of adopting models from different geographies, questioning whether their role as transport solutions and planning tools is overthrown by their potential as mechanisms for expedite policy delivery and increasing visibility of urban development.
Infrastructure is widely recognised as a driver of development. Transport in particular relates directly to economic growth, which places it at the centre of mainstream urban development agendas (Willoughby, 2002). In addition, transport infrastructure has the capacity of transforming urban structures in relatively short timespans, being one of the most visible policy instruments available for achieving meaningful urban transformations (Dávila, 2013). This feature attaches considerable political significance to transport interventions and policy, particularly in cities facing problems of efficiency in mobility of goods and services. Interactions and opportunities resulting from mobility have made public transport development a central concern in policy and planning (Lizarrraga, 2006). However, political economy if these interventions is still what places them in priority spots in the agendas of many governments seeking short-term delivery of visible interventions.

Increasing awareness of local and global environmental challenges has progressively led to a pursuit of sustainable development agendas that include transport as one possible mechanism to help changing urban structures (Jones and Lucas, 2012). During the past decade, public transport policy has acquired newfound importance in southern cities focusing on the implementation of new technologies for increasing coverage, reliability and quality of public transport services. These features are often translated into infrastructure-intensive and technology-based interventions seeking to replace traditional, and often informal, services. The latter are often characterized by high inefficiencies and negative externalities (i.e. Curitiba, Santiago, São Paulo, and Bogotá), which increases considerably economic, social and environmental implications of their removal. This context has led to the pursuit of high-capacity transport systems that can serve as basis for the re-organisation of public transport in large cities. In Colombia, the construction and operation of Bogotá’s Bus Rapid Transit –BRT-, Transmilenio, has contributed to significantly improving mobility and reframing urban public transport policy in throughout country.

Bogotá’s success summed up to those of several cities in South and Central America, Asia and Africa in the last twenty years have turned BRT into a revolutionary urban transport instrument in much of the developing and developed world. According to Rodriguez and Mojica (2008), the rapid evolution of BRT worldwide took it from a fringe transportation option used in a few Brazilian and Australian cities to an appealing mass transport alternative capable of rivalling carrying capacities of even heavy rail-based systems. Ahmedabad, in the south of India has followed this series of successes in the process of implementing BRT as transport solution in 2009. This, as many previous cases of BRT implementation entailed strong political will and high-level technical assessment. The project profited from involvement of international partners drawing insights from international experiences including Bogotá’s.

This paper analyses the cases of Bogotá and Ahmedabad, paralleling features and implications that allowed the production of specific BRT models in the developing world. We analyse the governance of trending transport solutions and the
implications of adopting models from different geographies, questioning whether their role as transport solutions and planning tools is overthrown by their potential as mechanisms for expedite policy delivery and increasing visibility of urban development. Despite large geographical and socio-demographic differences, Bogotá and Ahmedabad share interesting common ground for analysing planning processes and governance of transport provision. In this regard, we overview the process of implementation of the systems in each city, reflecting on transnational policy dialogues and raising awareness on implications of “BRT Prescriptions”.

Transport policy and the role of infrastructure: from Colombia to India

Developing cities share tendencies of hastened growth of motorization and the need of shaking off accumulated inefficiency in transport practices, institutional weakness, and consolidated power of privately managed public transport with very weak regulation. Mainstream response to these challenges has entailed structural institutional changes and implementation of modern high-capacity public transport (Gakenheimer, 1999).

Transmilenio, Colombia’s first Bus Rapid Transit system, was planned for a city that at the time had 6.4 million inhabitants (1999), and represented 15.2% of the country’s population with one of the highest densities in the country (210 people per hectare) (Transmilenio, 2004). In 1999, 1 million cars carried 19% of Bogotá’s population, while 30,000 buses transported 72% of the city's inhabitants at an average speed in the morning peak of less than 10 Km/hr; an equivalent to 2 hours 20 minutes daily as average travel time by public transport (Transmilenio, 2004). This represented a huge challenge for a local government deep in debt and limited by national regulations for investment support from the national government (Acevedo et al., 2007). These conditions led to the development of Transmilenio as mass public transport solution for a city that had been promised a metro already 4 times in its recent history (Acevedo et al, 2007).

With Transmilenio, Bogotá followed the path paved by Curitiba and other Brazilian cities adopting hybrid-managed bus systems with a more active role of authorities in determining the structure of transport network, levels of service and frequencies, forcing a separation between revenue collections and operating activities (Estache, 2005). Not only did Transmilenio represent an unprecedented change in urban transport policy in terms of technology, infrastructure and operation. It entailed a restructuring of longstanding weaknesses in local and regional transport management institutions and the organization of private actors in the provision of public transport services.

The required regulation and policy changes for the implementation of Transmilenio influenced greatly national urban policies. This opened the door to new regulatory framework originated in the national urban development policy, and defined based on the very principles of the political constitution of the country. This requires the national government to "....intervene to give full employment of human resources and ensure that all people, especially those of lower income, have effective access to basic goods and services ... " (Colombian
Political Constitution, 1991). The Urban Development Policy seeks optimization of cities from the notion of a densified city model that encourages the concentration of activities, reduce travel between residential areas, urban services and employment. This involves an encouragement of infrastructure development and reuse of existing structures, promoting the use of public transport and other alternative means for travel, and reducing urban sprawl and pressure on conservation areas (Master plan of mobility for Bogotá, 2005).

The National Policy to Improve Public Urban Passenger Transport Services was launched in 2002, two years after Transmilenio started operating. It provided policy guidelines aiming at improving urban public transport services through application of innovative financial techniques and management tools. Following Bogotá’s experience, the national government aimed at strengthening decentralization and increasing productivity of large and medium-sized cities using public transport as an instrument of urban management and development (CONPES, 2002).

According to national policy documents (CONPES, 2002), the objectives of the National Urban Transport Policy encompass physical, economic and institutional interventions aiming to achieve sustainable and inclusive mobility. The ambitious policy framework set by the government aimed to institutionally strengthen cities in the planning, management, regulation, and control processes of traffic and transport. It encourages implementation of public transport systems that could respond to travel needs of the population under criteria of operational, economic and environmental efficiency. Ambitious as it may seem, this marked the official change in paradigm from the late 80's and early 90's car-based city to a more collective-sensitive set of policies aiming to holistic improvements in both mobility and sustainability.

One of the central issues in post-Transmilenio urban policy is an explicit aim to break the inertia motivating local governments to continue expanding capacity of road infrastructure. This encouraged the implementation of BRT systems in 5 large metropolitan areas in the country, and the conceptual development of thoroughly integrated transport systems that would eliminate most atomised operation of traditional public transport. However, other transport policies and conceptual definitions of further transformations of urban public transport that could benefit from the initial re-organization expected from BRT’s were identified as an additional requirement for achieving the objectives set on the national policy.

The need for additional policies and interventions, however, evidenced the limitations of infrastructure-related policies and interventions. BRT’s in 3 of 5 metropolitan areas where these systems have been implemented experienced many difficulties in terms of implementation, contracting and even underuse and low performance (DNP, 2013). Lack of adequate regulations and control has led several systems to be overthrown by traditional transport and rise of the use of private vehicles, particularly motorcycles. This has led local and national authorities to seek policies encouraging efficient use of private vehicles in urban areas while offering alternatives under assumptions of availability of adequate
public transport. It has also been made clear that large-capacity bus systems are only effective when implemented on scale, which has also led to strengthening of public transport projects based on the use of either preferential or exclusive bus routes, provided according to the population size and levels of demand. Colombia has faced both the success and failures of the BRT under a variety of circumstances related to local, metropolitan and national levels. However, it is clear that Transmilenio and the change of mind-set following its rapid success have been fundamental for the development of urban policies in both Bogotá and the rest of Colombia. Although the effectiveness of large-capacity buses in other cities of the country is still a matter of debate, it is clear that Transmilenio and the local conception of the BRT has influenced greatly approaches to urban transport and infrastructure policy in the country.

Urban India has registered similar dynamics to those depicted by official figures in Bogotá at the end of the 1990’s. Very high increase in motorized vehicles, associated externalities and serious difficulties for provision of public transport have been longstanding issues in cities in the country. The NUTP, 2006\(^1\) states that “while the population of India’s six major metropolises increased by about 1.9 times during 1981-2001, the number of motor vehicles went up by over 7.75 times during the same period (pp. 1-2). From the population census of 2011, at least 35 per cent (27.76 million) urban households had a motorized two wheeler and 9.7 per cent (7.65 million) urban households had a motorized four-wheeler. While, on the whole, the registered motor vehicles increased by 2.4 times during 2002-2011 period or at the rate of 10.2 per cent per annum, in 19 metropolitan cities for which the two time point data is available, registered an increase at 8.8 per cent per annum in the decade (Transport Research Wing, 2012, pp. 3-4). In spite of such a rapid vehicular growth in India, the number of vehicles per thousand population is still low at 117 in comparison to USA (828), UK (544), Brazil (275) or South Africa (170). However, continued high economic growth would increase vehicle density in India in the coming years.

The public transport system in the cities in India have not kept pace with increase in demand and hence people have turned to either personalized modes or the IPTs (WSAPL-MoUD, 2008), creating congestion and air pollution. Bizarre still, solutions to the problems have been found in road widening and flyover construction and not improving the public transport system till the NUTP, 2006 advocated for the same. There have also been no comprehensive attempts at supporting the municipal or the state run urban bus services which are often struggling with erratic services, depleting and ill-maintained bus fleet, lack of financial and human resources. The public transport fares are kept low and other revenue opportunities are not explored, making it difficult to afford even routine maintenance and vehicle replacement, let alone system modernization and expansion\(^{\text{Pucher et al., 2005}}\). This explains low share of public transport in the overall modal share in the cities in India.

Realising the importance of public transport in the cities and equity concerns in the same, the NUTP, 2006, spelt out the following objectives: (i) to bring about a more equitable allocation of road space to various users with people, rather than vehicles, as its main focus; (ii) to encourage greater use of public transport and
NMT modes by offering central financial assistance for this purpose and (iii) to enable the establishment of multi-modal public transport systems that are well-integrated, providing seamless travel across modes (MoUD, 2006). Under the JNNURM’s Urban Infrastructure and Governance (UIG) component, 24.2 per cent of the total allocations are for transport related projects. However, 13.3 per cent of the transport related project were road widening and flyover building and only 8.66 per cent for transport projects were mass transit development and the rest for parking and other small transport projects (Mahadevia 2011). In spite of the clearly written NUTP objectives, the largest portion of the transport related funds in JNNURM were spent on road-building instead of allocating them to the mass-transit projects.

Successful BRT projects internationally have organised the whole right of way as an urban design or street design project instead of just motorised traffic-based design, and this approach is suitable for Indian cities on account of the 42 per cent share of walking and cycling (WSAPL-MoUD, 2008). In particular, BRTSs have advantage in Indian context because of multi-nuclei urban form, mixed land use and trips distributed in multiple directions making average trip length low. This kind of urban form and land use system also make it difficult to find high ridership corridors for efficient metro rail services. With this learning, the NUTP recommended mandatory integration of NMT infrastructure with the BRT projects proposed in the cities. Twelve cities in India have BRT corridors at various stages of development and operation, with 50 per cent of the cost as financial assistance from the national government under the JNNURM. While, the Ahmedabad BRTS has taken off, other BRTSs in India - Pune, Indore and Jaipur - have been totally subverted and some sacrificed at the alter of metro-lobby (Mahadevia, Joshi & Datey, 2013).

Transmilenio and the revolution of BRT

Transmilenio, has contributed greatly to improving mobility and has marked the beginning of a process of renewal of public transport in Bogotá. The city’s BRT has helped significantly in improving mobility conditions for the users of public transport, which by 2005 represented approximately 60% of motorized trips. Since its start, the system has increased the speed from 10 km/h during the decade of 90’s to 26 km/h in the first phase of the project. Likewise, it has increased connectivity of public transport, facilitated reduction of fleet size, reduced emissions of greenhouse gases and led to positive changes in land use and organization of city.

Operationally, there are some elements of the system that have contributed to achieve improvements in local mobility. On the one hand, there is a re-formulation of Bus Rapid Transit systems. TransMilenio is “a flexible, rubber-tired rapid transit mode that amalgamates stations, transferences, accommodations, and driving lanes, into an integrated system.” (Lleras, 2003). This system, designed initially for 35,000 passengers per hour per direction, covered 42.4 kilometers of exclusive bus lanes along three of the main transit corridors in its first phase. It currently has a measured maximum capacity that goes beyond 45,000 passengers...
per hour per direction and covers approximately 87 km as shown in Figure 1 (Transmilenio S.A., 2007).

**Figure 1 – Transmilenio’s phase 1-3 BRT network**

Source: Transmilenio S.A., 2007

In these corridors, central lanes are exclusively set for the operation of Transmilenio’s buses, and passengers at the stations are the only customers. Stations are located in the middle of the road facilitating transfers between buses, mimicking the metro system. The system currently has 150 stations, located in distances between 700 and 1000 meters of each other. These are equipped with pay booths, registering machines, surveillance cameras, and infrastructure such as bridges, pedestrian crossings and traffic lights designed to facilitate access of passengers to the system. Terminals are located in both ends of the corridors that operate as meeting point for feeder buses, and buses from the traditional system that work in the neighbouring municipalities. Feeder bus passengers have an integrated tariff so riders do not have to pay twice for utilizing the feeder and trunk services (Transmilenio S.A, 1999).

Since the late 1990’s one of the most representative figures of urban policies in Latin America is Enrique Peñalosa, former mayor and current international
planning consultant. During his mandate, Bogotá’s landscape was transformed radically through city-wide transport investments that had Transmilenio as the cornerstone of the transport system. The BRT was complemented by large-scale public space transformation that included new spaces devoted to pedestrians and bicycle users (Cervero, 2005).

Transmilenio system was intended to transform public transport in the city as Ex-Mayor Peñalosa’s eventual answer to the sedulously assiduous demands for a metro in the nation’s capital. The development of Transmilenio and the subsequent adoption of high-capacity buses in the city was preceded by local, and national initiatives to build a metro in Bogotá. When Enrique Peñalosa stepped in as elected mayor of the city, he did so with presidential approval of funding for the construction of what at the moment was conceived as the only available alternative for public transport, a metro (Gómez, 2004, Gilbert, 2008).

Existing limitations for financing and the experience with the only existing metro system in the country up to date, Metro of Medellín, had made difficult for large cities to access support of national government for large public transport systems (Acevedo, 1993). According to Gilbert (2008), the ex-mayor always believed in buses as he kenned that the country could not afford to build a metro in Bogotá. However, he followed national proposal for financing a metro project, considering that both the Council and current President were convinced of the merits of a metro.

Only when a new national administration took office, Peñalosa accepted that resources were insufficient to build a metro and presented Transmilenio as an alternative solution (Bermúdez and Carvajal, 2000; Gómez, 2004). The comprehensive structuring of the system allowed it to be approved despite the reluctance of national officials. A central argument in the development of these political decisions was that Transmilenio was affordable enough for aiming for nearly entire coverage of the city in a relatively short span in comparison with rail systems.

While Transmilenio’s main features were developed long before Peñalosa, his greatest achievement is to have built the system in three years, efficaciously (Gilbert, 2008). Moreover, the Transmilenio endeavour managed to involve historically difficult stakeholders with great influence in the city as bus owners and drivers organisations, making them part of the core of the structure of the system. In a city where transport plans are seldom implemented congruously and where even minute amendments customarily take years, this was a hugely impressive achievement (Gilbert, 2008).

One of the most highlighted features of Transmilenio is its cost of construction. While the infrastructure investment was considerable, it results frugal in comparison with the costs of a metro. In addition, the operation scheme of the system allows it to cover operation costs and benefit longer trips through crossed subsidies between users. These characteristics allow for the implementation of three phases and financially sustainability in running costs. Moreover, the system has been integrated from its conception with other public spaces and forms of
mobility, which has allowed the development of other essential urban infrastructure for sustainable transport. The past two decades Bogotá has taken important steps forward in the development of active travel. The city has undergone significant transformations such as the creation of a network of segregated cycling lanes covering 376 kilometres and the pedestrianisation of central corridors and districts (Alcaldía de Bogotá, 2013). Cycling policy in the city has been supported by significant investments of the order of hundreds of millions (USD) invested in the past decade (the ciclorutas programme used about $180 million between 1992 and 2002) (Cervero 2005). These urban interventions were mainly the result of a top-down approach to urban development led particularly by Peñalosa (1998-2001) and have continued intermittently by subsequent administrations.

Bogotá has increased non-motorized infrastructure and public spaces across the city. These interventions cover from cycling pathways to the transformation of central corridors and commercial streets for pedestrian use that have influenced considerably the approach of citizens to the bicycle as a realistic transport alternative. The current network of Ciclorutas is connected to Transmilenio providing not only pathways but complementary facilities as Cycle Parking, pedestrian overpasses, public spaces and recreational facilities. High densities in the city also allow for lower travel distances and a higher relative competitiveness and efficiency of cycling over motorized modes (Universidad de los Andes, 2012).

However, despite progress achieved so far, many problems that urban transport policy in Bogota seek to solve are still present today, showing mainly problems of inequity in access to opportunities and difficulties to use the system by the most vulnerable segments of the population. In average, Bogotá’s citizens make 1.5 trips per day and the average travel time exceeds 50 minutes per trip. Similarly, a serious problem of access to transport in both its physical and economic component is evidenced since there are several households that spend more than 20% of their income conducting only mandatory trips, in addition to elevated walking times for accessing public transport.

The Ahmedabad BRT and its promises

The city of Ahmedabad is the seventh largest urban agglomeration (and fifth largest municipal area) with population in 2011 was 6.35 million\(^6\) registering a growth rate of 3.5 per cent per annum in the decade of 2001-11. The city has received second largest per capita grant for JNNURM projects among the metropolitan cities (Kundu & Samanta, 2011).

The Ahmedabad Municipal Corporation (AMC) decided to construct a BRT system in 2006, coinciding with the launching of the Jawaharlal Nehru National Urban Renewal Mission (JNNURM) and the National Urban Transport Policy (NUTP) in 2005 and 2006 respectively and the willingness of the central government to fund, in part, BRTs in all the cities. Ahmedabad was again among the first to seize this opportunity and submitted a DPR (detailed project report) to the JNNURM. The project was approved in the year 2006 and the work started in 2007. The
sanctioned length of the project is 88.8 km and it is divided into two phases. The first phase is of 58.3 km and the second phase is of 30.5 km. At the city level, there were expectations, and optimism, of getting well-laid roads, creation of road space for pedestrians, bicyclists and vendors, management of on-street parking and mainly, the provision of an efficient and reliable bus system as promised in the DPRs of 2006 and 2008. This project was named ‘Janmarg’ (meaning people’s pathway) by the AMC and the first phase was opened in October 2009.

The Ahmedabad BRT system stands out amongst the Indian cities in having about 58 km of rapid transit network, which continues to expand. Janmarg was the first BRT Project in India, which aimed at creating a city-wide network in the first proposal itself, rather than delineating a few isolated corridors like in cities such as Delhi, Pune and Jaipur¹ (Mahadevia, Joshi & Datey, 2012). It was decided to create a project on the lines of Bogotá’s Transmilenio, with bus stops in the middle of the median bus lanes and using a physically segregated busway with BRT buses running exclusively on them.

**Figure 2 - Ahmedabad BRT network and phases**

![Ahmedabad BRT network and phases](image)

*Source: From Suzuki, Cervero & Luchi (2013) pg. 98 attributed to COE UT CEPT (2012)*

¹ Co-author Rutul Joshi along with others have studied this system in detail and evaluated it for its social accessibility.
Figure 3 - Ahmedabad BRT corridor

The first BRT corridor was designed by following the idea of connecting ‘busy places but avoiding busy roads’ so as to minimize resistance from the private vehicle users, as had occurred in Delhi and Pune. The first corridor in Ahmedabad did not create any visible problems of congestion for the private vehicle users when it started operations because it returned back a similar amount of road-space. Most of the operational BRT corridors have been placed on roads of 30 m or more in width, and maximum road space has been left for the mixed traffic, sometimes at the cost of cycle tracks and footpaths. On the road widths of less than 30 m, the BRT runs on single, one-way, uni-directional corridor.

The other important points which planners of Janmarg had in mind were “completing a network and not a corridor”. Janmarg was the first BRT Project which aimed at creating a city-wide network in the first proposal itself, rather than delineating a few isolated corridors. This approach also helped to realize the project in the context of the city, rather than specific roads. It was clearly decided to create a project on the lines of Bogotá’s Transmileno, with bus stops at middle of the median bus lanes and closed corridor with exclusive BRT buses running on them.

The Janmarg team has remained conscious of the importance of branding and social marketing of the project, especially amongst the vocal middle-classes, who mainly drive private vehicles. This also fits into the larger politics of the state government of showcasing ‘development’ in the city and giving credit to the incumbent Chief Minister. Janmarg could be said to be one of the highly publicised government projects in Gujarat, through advertisements in the newspaper, special
articles extolling its successful use during festivals and national holidays, and above all, free use of the system for the first 3 months following its launch between October to December 2009. Local media frequently reported about the system, for example on future plans, facilities introduced on the corridors, opinions of well-known people, etc. All these have added favourably to the system’s image locally, nationally and internationally. The BRT of Ahmedabad has attracted global as well as national awards as a prime example of best practice in the field of public transport (Suzuki, Cervero & Luchi, 2013). Four years have passed since the opening of the first corridor, and BRT is now carrying about 0.15 million passengers with daily revenues of about Rs. 0.9 million (NIUA, 2011).

The public bus systems in India are generally associated with poor services, and Janmarg worked hard to remove this image. The “Janmarg” worked towards achieving some glamour quotient for the project similar to the Metro rail project in Delhi. The public bus systems in India are generally associated with poor services, and Janmarg worked hard to remove this image. Although there are differential experiences of the services in the East and the West Ahmedabad. This distinction is being made here because, East Ahmedabad is a working class segment of the city and West Ahmedabad has residences of the elites of the state.

The branding of the ‘Janmarg’ also created a schism between the two bus services, the AMTS and the new BRT, owned and operated by the same entity, the AMC. The BRT was getting associated with the new, swanky services whereas the AMTS services began to be more irregular, financially depleted and facing slowed speeds due to increasing mixed traffic. In a detailed study of organisational behaviour, Parikh (2011) depicts how the BRT is operated by a public sector ‘special purpose vehicle’ (SPV) with corporatised bureaucrats as its office bearers whereas the AMTS is still operated as a conventional government agency with political representatives and employee’s trade unions. On the corridors where the BRT is operated, the AMTS services have been stopped otherwise the two bus services would compete for the same routes. The growth of BRT did not improve the condition of public transport in general given the weak institutional and physical integration with the AMTS bus service. There are no plans, at least in the public realm, to integrate the two in terms of road space and resource sharing, fares and ticketing or even creating one branding for public transport in the city.

One another conflict seen consistently across the cities in India, and also in Ahmedabad, is on-street parking. The new facilities created, whether footpaths, cycle tracks or increased road width, were encroached by roadside parking. Parking is seen as a ‘right’ of the motorist instead of being seen as an act of ‘privatising the public space’. Much of this parking on the BRT corridors is long-term parking and not short-term and dynamic parking. All the parking on the BRTS corridors continues to be free barring a few spots where paid-parking sign boards hang without round-the-clock implementation. This has become the major obstruction in efficient street management marginalising the pedestrians and the cyclists. This means that the future BRT plans should include the paid parking policies as demand management tools to be part of an integrated approach to sustainable mobility.
Mahadevia et al., 2012 looked at two aspects of the Ahmedabad BRT project: one, building of corresponding infrastructure of walking and cycling along the BRT corridors to view the project in totality and two, the socio-economic profile of the BRT users to understand the social outreach of the project. BRTS is intended to be not only the exclusive bus services being run on the central verge but also it is a comprehensive system benefitting various users of public transport, cyclists and pedestrians (Deng & Nelson, 2011). However, in the entire BRT system the non-motorised transport (NMT) infrastructure is not given its due attention as was promised and claimed in the detailed project reports. The footpaths and cycle tracks are not designed and built on all corridors, compromising safety and access for pedestrians and cyclists. As per the study (Mahadevia, Joshi & Datey, 2012), only 26.2 per cent of the BRT route length had bicycle tracks, of which only 65 per cent were unobstructed. In the case of footpaths, 83.7 per cent of the BRT track had footpaths, but only 52.5 per cent of these were unobstructed. Even to access the central median bus stops from the sides of the roads by walking is difficult and unsafe for pedestrians. The lost opportunity of building walking and cycling facilities along the BRT corridors would have been another way of facilitating the travel of the urban poor. Comprehensive walking and cycling plans would have connected the poor households to the large range of services and livelihoods. Without a good network of walking and cycling, the BRT corridors in Ahmedabad are reduced to a bus system running on the central median lanes, which in itself is the subversion of the very idea of BRT.

Mahadevia, Joshi & Datey (2012) also surveyed the BRT user-profile to prove that although the BRT system is promoted as low-cost public transport in Indian cities, it is not yet accessible to the urban poor and in particular women among them. This is especially clear where there are large numbers of slum squatters and low-income group settlements in close vicinity to the BRT corridors. The cost of the BRT system in Ahmedabad is prohibitive to improve the accessibility of low-income households and in particular poor urban women. For majority of the urban poor, BRT is an expensive option and AMTS become attractive for the long distance commute within the city. The AMTS services are depleting as BRT has taken lots of focus of the authorities. In spite of lot of rhetoric about providing for the NMT infrastructure (footpaths and cycle lanes), nothing much has been
achieved. It seems that all the modes favourable to the poor (walking, cycling, public bus) are either not being planned for or are not being implemented properly in Ahmedabad city.

The BRTS run by Ahmedabad Janmarg Limited also saw the eviction of 2,600 families along its routes, mostly in Wadaj - Nava Wadaj, Chandola Lake, Dani Limda, Khodiyar nagar, Shah Alam, Jamalpur, and Soni ni Chali. The BRTS also entailed evictions around BRTS terminuses, near Gita Mandir in the center of the city for the building of the Maninagar station, and also near Kota Nagar on the edge of ring roads. However, officially the BRT project was never accepted as the reason for the evictions. The official reason cited for the evictions were the implementation of the city’s development plan. It is rather curious that the road widening proposals of the city’s development plans were only activated after the BRT project was conceived. The evictions were carried out citing the development plan but the road development along the eviction sites was funded under the BRT project.

**Figure 5 - Forced evictions for the road widening on the BRT corridor**

![Satellite images of Nava wadaj area in Ahmedabad in Feb and May 2010](image-url)

**Note:** Satellite images of Nava wadaj area in Ahmedabad in Feb and May 2010

**The role of transport governance – reflecting from the case studies**

The case of Transmilenio in Colombia holds some lessons for the development of infrastructure projects for public transport, particularly when contrasted with a city like Ahmedabad. Several main features can be identified from the case of Bogotá: operation, flexibility, effectiveness, and political support. In relation to the first three it is clear that the system, within utility-driven ideals of public
transport, has been overall successful. Technical innovations that allowed increase in capacity were possible within a consolidated framework for institutional development and independence in decision making processes. However, the dexterity and commitment within the local government are some of the most remarkable features of the Colombian case, which allowed the expedite development of the system and the start of operation of at least the first phases.

Involvement and flexibilization of the local environment for policy decisions and financing was in the end what made the system possible. However, the existence of restrictions for national financing, the lack of continuity of local leaders promoting the project and a rigid framework for adjustment and expansion of the system beyond its geographical and administrative boundaries, as well as beyond technologies considered in the existing framework pose challenges for the continuous evolution of the system.

The adaptability of Transmilenio to challenges posed by significant increases in its demand have increased its reputation as a competitive alternative for providing public transport in large urban areas of the developing world. The involvement of local stakeholders belonging to particularly problematic groups in the system allowed for a rapid acceptance and acknowledgement of the system as an essential change in urban development in the city. Public acceptability drives political acceptability, and Transmilenio in first stages was very successful in gaining adepts supporting its functioning and development. Sufficient public support for change allowed endeavours like Peñalosa’s to take place and influence policies at a larger scale in following stages.

The need for additional policies and interventions evidenced the limitations of infrastructure-related policies and interventions. Lack of adequate regulations and control on competition pose dangers for the sustainability of BRT systems. Large-capacity bus systems are only effective when implemented on scale, which limits their transferability to other realities. Although the effectiveness of large-capacity buses in the country is still a matter of debate, Transmilenio and the local conception of the BRT has influenced greatly approaches to urban transport and infrastructure policy in the country.

Transmilenio has entailed significant transformations that go beyond infrastructure and transport. The reformulation of policies at the national level and the strengthening of local governments for the pursuit of adequate transport investments in relation to their supply and demand are a reflection of a change in paradigms in relation to infrastructure-intensive solutions and the idealization of development in southern countries being associated with technology. Transmilenio has not been the solution to all Bogotá’s transport problems and should not be interpreted like it from any perspective. The limitations of the system in affordability, security and even capacity, among other features, make it an imperfect, and especially incomplete, system that requires additional integration with the rest of the transport network and more holistic policy packages. However, the development of policy frameworks and the consolidation of a general concern on public transport development and sustainability are Transmilenio’s greatest achievements.
In recent years, the city of Ahmedabad is spending huge sums on urban infrastructure and transportation. The municipal budget is increasing every year and partly so with the grants from the JnNURM (Jawharlal Nehru National Urban Renewal Mission). In the 2013-14 budget of Ahmedabad with the size of US$ 460 million, about US$ 152 million will be spent on ‘roads and bridges’ and the expenditure on public transport is less than half of that amount. Recently approved projects under the last phase of JnNURM show that the JNNURM in Ahmedabad funded a project of Rs. 1500 million for about 60 kms of the BRT corridors. In addition to the public transport facilities made available by the Ahmedabad Municipal Transport Services (AMTS), this JNNURM funded BRTS project is seen as a strategic intervention that seeks to improve the transit options for the city. Ahmedabad witnessed a growth of 9 to 10 % of private vehicle ownership per year, with a simultaneous deterioration of the public transport situation provided by the AMTS. Ahmedabad sought to create and Integrated Public Transit System in three phases, with the proposed BRTS, metro rail and the upgradation of roads on the agenda. The BRTS was tabled with the intention of introducing a network of 155 km, with Phase 1 developed in the Ahmedabad Municipal Corporation (AMC) area alongside the Ahmedabad Urban Development Authority, of 58 km, attempting to induce modal shifts and improve road and infrastructure. It was also the first big project working for the poor after the communal riots in 2002.

Unfortunately, the unintended message that goes out from Ahmedabad BRT is that it is alright to neglect walking and cycling, overlook the parking chaos or not have affordable fares as long as the buses run regularly on the central median lanes. The Ahmedabad BRTS raises a very pertinent concern, of treating public transport as a technological fix rather than a wider urban or social solution. It treats the BRTS as a metro on the road with exclusive characteristics. While such exclusivity does bring a good brand image, it does not necessary attain the objectives for which the system is designed, of providing mobility to all. This raises a question whether we have truly ‘an international best practice of BRT in the country’?

Finally, the top-down transportation planning approach has not really taken into account the needs of the urban poor in the city of Ahmedabad, in spite of all the rhetoric about including the low-income groups in the proposed project reports. It has also not achieved a significant shift away from the private motorised modes. Both the goals of low-carbon mobility and social inclusion still remain important challenges for the Ahmedabad BRTS project. Since the project is still in implementation phase, there is still scope for reforming its key components and making it more inclusive, and thus sustainable. If the BRTS of Ahmedabad has to remain a ‘best practice’ then it has to widen its social reach and attract more users from private motor vehicles; it has to develop well-designed footpaths and cycle tracks, implement paid parking regime and effectively integrate both systems of buses in the city.

References:


Departamento Nacional de Planeación (2013), Estructuración de síntesis de evaluación de SITM en el país. Bogotá


Parikh, M. (2011) Evolution of AMTS and the Challenges It Faces : A Study into Implications for Organizational Effectiveness. CEPT University, Ahmedabad.


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INTEGRATED ROAD PRICING AND BUS RAPID TRANSIT: 
THE EFFECT OF HABITUAL BEHAVIOUR AND CAPTIVE ATTITUDE

Sittha Jaensirisak ¹ and Sermsak Pongmesa ²

Abstract

This paper presents the possibility of using Bus Rapid Transit (BRT) and road pricing policies to reduce private vehicle use in Chiang Mai, Thailand. The assessment is made in terms of level of effectiveness of the integrated policies to shift the use of private vehicles to BRT. Habitual behaviour and captive attitude of private vehicle users were observed. A total of 1,200 private vehicle users (car and motorcycle), was randomly surveyed by a Stated Preference (SP) exercise and attitudinal questionnaire. Two situations were designed including: (1) development of Bus Rapid Transit (BRT) system alone, and (2) development of BRT system with road pricing. The factor analysis was used to classify habitual behaviour and captive attitude, while Logit model was used to analyse the effects of the BRT and road pricing. The study found that most private vehicle users believed that private vehicles were important for their daily lives and would still be essential even if a comprehensive public transport system had been implemented. They felt that using private vehicles had great benefit and they had intention of using private vehicles even for short distances. The study also showed that utilising BRT system development together with road pricing is more effective than BRT system development alone. Therefore, improvement of BRT system would be more effective if it is integrated with restraint measures (e.g. road pricing) that can reduce habitual behaviour and captive attitude.

1. Introduction

In Thailand, traffic congestion is a critical issue for not only Bangkok, but also for other major cities such as Chiang Mai, Khon Kaen, and Nakorn Ratchasima. It has a number of negative impacts on travellers, environment, health, as well as the economy. In order to alleviate traffic congestion, the cities have been mainly focused on traffic management. Currently, they are interested in public transport development particularly bus rapid transit (BRT). Restraint measures (e.g. parking and pricing policies) are less considered. The cities have not clearly understood and well planned in integrated policies. Therefore, there is no sign of sustainable transport development. Numbers of cars and motorcycles have been still increasing steadily.

Due to its cost and flexibility, BRT is known to be able to provide an alternative for commuters, instead of using private vehicles. However, it can only reduce some portions of private car use (Pickrell, 1990; Mackett and Edwards, 1998).

Road pricing has been suggested for several years as an appropriate technique for managing travel demand in order to alleviate traffic congestion and pollution, and to provide a potential source of revenue to finance services supporting the public transport system. However, road pricing is not readily acceptable to the public, particularly among private vehicle users (Jaensirisak et al., 2002, 2005)

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One factor that makes the issue of sustainable transport in major cities without success is the attitude and behaviour of travellers which encourages the use of a private vehicle without considering the real benefits (Steg, 2005; Pongmasa and Jaensirisak, 2013). Behaviour and learning patterns of private vehicle users are repetitive. The causes include habitual behaviour and captive attitude in the choice of a private vehicle for travel. Such factors affect the travel behaviour of private vehicle owners. They feel that travelling by bus or other modes of public transport is going to be difficult. It is expected to have an impact on the success in resolving transport problems, especially on ideas for improvement and development of public transport.

There was a study attempting to investigate the potential of adapting communicative transportation measures to reduce car use in Thailand (Choocharukul et al., 2006). This study was based on attitudinal image variables for cars and public transport, including: symbolic affective, instrumental and social orderliness attitudinal aspects. It was found that fewer attitudinal-aspects of car use had significant effects on a moral obligation to reduce car use, thus it might not be easy to reduce car use in Thailand by utilising strategies to change the image of car and public transport (“pull” measure). This is also as Gardner (2009) found that information-based driving reduction initiatives which target attitude and belief change may have only limited impact on habitual behaviour.

Moreover, Chen and Lai (2011) explore the effects of rational and habitual factors on mode choice behaviours in a motorcycle-dependent region in Taiwan. They found that habit behaviour increases choice probability for motorcycle use, revealing that the stronger the habit, the higher likelihood motorcycle is chosen. They suggest that effective “push” and “pull” strategies should be carefully designed and implemented in disrupting motorcyclists’ habitual action and modifying the structure of the decisional environment.

So, this study aimed to investigate the possibility of integrating road pricing (“push” measure) with Bus Rapid Transit (BRT) to alter mode choice behaviour. An assessment was made in terms of effectiveness of the policies to reduce the use of private vehicles (both cars and motorcycles).

In this study, habitual behaviour and captive attitude of private vehicle users were observed. Two situations were included in the observation: (1) development of BRT system alone, and (2) development of BRT system integrated with road pricing. A total of 1,200 private vehicle users (cars and motorcycles), were randomly surveyed in Chiang Mai (Thailand). The data was gathered during November 2011 and February 2012. The factor analysis was used to classify the habitual behaviour and captive attitude, while Logit model was used to analyse the effects of BRT and road pricing.

2. Effects of captive and habit factors on mode choice behaviour

One factor that makes the issue of sustainable transport in major cities of the country not successful is the attitude and behaviour of road users, which encourage the use of private vehicle travel without considering the real usefulness (Steg, 2005; Pongmasa and Jaensirisak, 2012). Behaviour and learning to use a private car through repetitive actions and satisfaction vary with time. Habitual behaviour and captive attitude identified in the choice of private vehicle travel influence these actions. Such factors affect the selection changes on travel patterns of users of private cars, and whether travelling by bus or other public transport system is going to be difficult. Past research (e.g. Piriyawat, 2010; Jinhua, 2011; Matthew et al., 2012) has a number of clues on the approach to measure habitual behaviour and captive attitude of those travelling by private vehicle, in various forms using different words, phrases such as car dependence, habit, and auto dependence etc. There are also some psychological research (e.g. Goodwin, 1995; Garling, 2003) that have described the phenomenon of habitual behaviour since the alternatives were based on satisfaction (preference-based) and prudence. The achievement of a positive attitude to learn, recognise and develop the data is saved in one’s memory. When a jurisdiction of choice is in its original form, one will have to recall these back and to serve as a basic reference in the decision (script-based) as a result of receiving information or to consider new options.
Habitual behaviour is expressed in response to stimuli with the same approach to achieve the goal, of course, often until it becomes an automatic response to the situation under the old environment (Verplanken and Orbell, 2003; Verplanken, 2004). Bargh (1996) classifies that behaviour is automated or not automated which can be determined by the four aspects: what they are doing, the ability to control the behaviour, psychological effectiveness and showing an intention. Garling (2003) refers to past behaviour as “intentions and circumstances that cause a major component in behaviour”. Habitual behaviour may be associated with variation in repetitive behaviours in the past, as may be inversely correlated with intention. However, Huff and Hanson (1986) have suggested that frequency of a repeated behaviour may not be identified as a habitual behaviour. The reason may come from a mistake or having carefully thought through, such as the landing of the aircraft, cooking intention, medical treatment of patients, and the intention of driving to work, etc.

To evaluate habit strength, Veplanken and Orbell (2003) and Verplanken (2004) introduced indicators called the Self-Report Habit Index (SRHI), which scores habit according to reflections on behavioural automaticity (e.g. ‘Behaviour X is something I do without thinking’) and performance frequency (‘Behaviour X is something I do frequently’). The indices include; for example: frequency of behaviour, action automatically, action by a lack of awareness of what the action is, action without thought, action on something that does not rely on the efforts, actions performed regularly, starting doing before you realise what you’re doing, the action is not hard, not thinking about the need for action, and doing this act for a long time.

Therefore, captive and habitual behaviour in this study is referred to private vehicle users’ behaviour which attaches to the use of private vehicles, and not allows themselves to consider any other mode of travel.

3. Methodology

3.1 Case study

Chiang Mai is a hub of transport, economy and tourism for the Northern region of Thailand. Chiang Mai urban area is 430 km², covering the entire space on Muang Chiang Mai district (Chiang Mai city) and adjacent seven district-level municipalities. There are 630,591 people in the urban area (in 2012). The major activity areas attracting frequent trips include 144 education centres, 254 religion centres, and 108 government and public utility offices.

Major networks of roads in the urban area employ the radial and ring road system, with lateral roads spreading out in different directions serving as connections between urban centre and sub-urban areas or rural districts. Currently, traffic congestions on the main roads within the inner ring system are common, especially in the areas surrounding education institutes or other major activity areas. The main public transport system is the shared taxi (known as Songtaew or Red-cap), which is a pickup truck with seats and cap installed. The service route is unregulated. The Red-cap drivers drive around to pick up passengers with the same destination. Fare in the city is fixed at 20 Baht, but for outer area it is up to agreement between individual driver and passenger. Other types of public transport are motored tri-cycle (known as Tuk-tuk), pedalled tri-cycle (Samlor-tee) and metered-taxi.

Planning of BRT system in Chiang Mai (Chiang Mai University, 2007) was done in 2006 with the main objective to develop a public transport system to cope with current travel demand and prevent future problems in traffic congestion, energy and the environment. The Chiang Mai BRT masterplan designs that the system consists of four route networks with accumulate distance of 100 kilometres. The system has its dedicated bus ways, right-of-way and stations that are independent of the road surface, and has its own controlling system. The masterplan did not consider integrating the system with road pricing or any other restraint policy. Until now, the BRT system in Chiang Mai has not been implemented because of lack of financial support from the central government.
Therefore, this research intends to study further if the BRT system is integrated with road pricing. Scope of the study covers the urban area of Chiang Mai within the inner ring road. The study target group includes those who drive cars or ride motorcycles to work or study in the areas of Chiang Mai city where vehicle users are expected to be affected by the road pricing policy.

3.2 Stated preference (SP) exercise

Stated preference techniques are based on the presentation of hypothetical scenarios to respondents. These scenarios need to be plausible and realistic for respondents. Each scenario represents a package of different attributes. The design process of an SP experiment can be summarised in four steps.

1. Selection of a set of attributes. The characteristics of the hypothetical scenarios are represented by attributes that influence preferences.
2. Specification of the number and magnitude of attribute levels. Variations of attribute values across scenarios need to be large enough for respondents to trade-off, otherwise they may be ignored.
3. Experimental design: combination of the attribute levels. Design of the hypothetical scenarios is based on an experimental design, which is usually fractional factorial rather than complete factorial. A complete factorial design contains all possible combinations of attribute levels. A great advantage of the fractional factorial design is that the number of scenarios can be dramatically reduced from the full factorial design, while it still ensures that the main effects of attributes are independent from the significant interaction effects, so that the main effects can be estimated efficiently.
4. Design of response measurement. Respondents are asked to state their preferences towards each scenario by choosing. These responses are able to provide information based on how individuals evaluate the attributes in the designed scenarios.

In addition to the SP experiment, other components are also needed in a survey, e.g. questions gathering individuals’ actual travel situations, which are relevant to the study context, questions about the attributes of existing choice alternatives, questions about attitudes to alternatives and personal details. These additional data are useful in analysis of SP data and explanation of the behavioural responses.

In the study, total cost of private vehicle use, road pricing, travel time on BRT, and BRT fare were used as attributes in the SP experiment. Levels of the attributes were selected according to possible road pricing levels and values of travel time in BRT and BRT fare. A combination of the attribute levels included nine scenarios presented to respondents. For each observation, respondents were asked to choose their current travel mode or BRT. Two SP experiments were designed for car and motorcycle user groups. The scenarios included both development of BRT system without road pricing (level of charge = 0), and development of BRT system integrated with road pricing (varying levels of charge). Moreover, a set of attitudinal questions was included to observe attitudes to private vehicle use, which could reflect habitual behaviour and captive attitude of private vehicle users.

3.3 Data collection

The main data collection was conducted by personal interview at major places such as government offices, private sectors, academy, department stores and markets during November 2011 to February 2012. The data set available for modelling purposes (removed those who have not fully completed the questions) contains 600 private car users and 600 motorcycle users, in a total of 1,200 individuals with 10,800 SP observations. Respondents characteristic are shown Table 1.
Table 1 Characteristics of Respondents

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Vehicle users</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Private car (PC)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>Mean 28.8</td>
</tr>
<tr>
<td>Personal income per month (Baht)</td>
<td>Mean 14,211</td>
</tr>
<tr>
<td>Household income per month (Baht)</td>
<td>Mean 57,103</td>
</tr>
<tr>
<td>No. of members in the household (person)</td>
<td>Mean 3.4</td>
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<tr>
<td>No. of private cars (vehicle)</td>
<td>Mean 2.3</td>
</tr>
<tr>
<td>No. of motorcycles (vehicle)</td>
<td>Mean 2.4</td>
</tr>
<tr>
<td>Gender</td>
<td>Male 313 (52%)</td>
</tr>
<tr>
<td></td>
<td>Female 287 (48%)</td>
</tr>
<tr>
<td>Residential location</td>
<td>Inner city (inside ring road) 390 (65%)</td>
</tr>
<tr>
<td></td>
<td>Outer city (outside ring road) 210 (35%)</td>
</tr>
<tr>
<td>Career</td>
<td>Students 225 (38%)</td>
</tr>
<tr>
<td></td>
<td>Government officers 70 (11%)</td>
</tr>
<tr>
<td></td>
<td>Enterprises 74 (12%)</td>
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<tr>
<td></td>
<td>Employees 173 (29%)</td>
</tr>
<tr>
<td></td>
<td>Others 58 (10%)</td>
</tr>
</tbody>
</table>

Note: 1 US Dollar = 30 Baht (in July 2014)

4. Results

Results of the study are presented in three parts. Firstly, results of attitudinal questions were reported in Section 4.1 to reflect habitual behaviour and captive attitude of private vehicle users. Secondly, in Section 4.2, the factor analysis was used to classify habitual behaviour and captive attitude. Finally, Logit model was used to analyse the effects of the BRT and road pricing, as well as habitual behaviour and captive attitude on mode choice behaviour.

4.1 Attitudes to private vehicle use

A set of attitudinal statements was presented to respondents. There were four groups of statements including belief, feeling, intention and behaviour (in total 11 statements). Individuals were asked how much they agree with each statement. The results are shown in Table 2.

The study found that most private vehicle users believed that private vehicles were important for their daily lives and would still be essential even a comprehensive public transport system had been implemented. They felt that using private vehicle had great benefit and they had intention of using private vehicles even for short distances. These attitudes reflect that private vehicle users have some degree of captive to their personal vehicles or having habit to use their personal vehicles even there is public transport available or when travelling for a short distance. This would be a barrier for modal shift to public transport.
Table 2: Attitudes to private vehicle use

<table>
<thead>
<tr>
<th>Attitudinal questions</th>
<th>Travel Mode</th>
<th>Totally not agree</th>
<th>Not agree</th>
<th>Neither</th>
<th>Agree</th>
<th>Totally agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Belief</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Private vehicle is necessary for living now and in the future. (q1)</td>
<td>PC</td>
<td>0</td>
<td>4</td>
<td>10</td>
<td>63</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>MC</td>
<td>0</td>
<td>1</td>
<td>11</td>
<td>54</td>
<td>34</td>
</tr>
<tr>
<td>The use of a private vehicle is still needed, even public transport is perfect. (q2)</td>
<td>PC</td>
<td>1</td>
<td>17</td>
<td>12</td>
<td>51</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>MC</td>
<td>0</td>
<td>7</td>
<td>13</td>
<td>46</td>
<td>34</td>
</tr>
<tr>
<td>2. Feeling</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I feel difficulty of travel if not using a private vehicle. (q3)</td>
<td>PC</td>
<td>0</td>
<td>13</td>
<td>18</td>
<td>45</td>
<td>24</td>
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<td></td>
<td>MC</td>
<td>0</td>
<td>5</td>
<td>21</td>
<td>38</td>
<td>36</td>
</tr>
<tr>
<td>I feel difficulty in changing travel mode from private vehicles to public transport. (q4)</td>
<td>PC</td>
<td>1</td>
<td>12</td>
<td>21</td>
<td>37</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>MC</td>
<td>1</td>
<td>6</td>
<td>18</td>
<td>38</td>
<td>37</td>
</tr>
<tr>
<td>3. Intention</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whenever I am travelling, I intend to use private vehicle only. (q5)</td>
<td>PC</td>
<td>0</td>
<td>20</td>
<td>15</td>
<td>42</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>MC</td>
<td>0</td>
<td>7</td>
<td>13</td>
<td>51</td>
<td>29</td>
</tr>
<tr>
<td>Despite travel distance of only 375 meters, I intend to use private vehicle only. (q6)</td>
<td>PC</td>
<td>3</td>
<td>21</td>
<td>18</td>
<td>35</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>MC</td>
<td>0</td>
<td>10</td>
<td>17</td>
<td>44</td>
<td>29</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Attitudinal questions</th>
<th>Travel Mode</th>
<th>Very low</th>
<th>Low</th>
<th>Neutral</th>
<th>Much</th>
<th>Very high</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. Behaviour</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I specialise in car driving. (q7)</td>
<td>PC</td>
<td>0</td>
<td>4</td>
<td>8</td>
<td>53</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>MC</td>
<td>21</td>
<td>9</td>
<td>13</td>
<td>38</td>
<td>19</td>
</tr>
<tr>
<td>I specialise in motorcycle riding. (q8)</td>
<td>PC</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>34</td>
<td>61</td>
</tr>
<tr>
<td></td>
<td>MC</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>53</td>
<td>43</td>
</tr>
<tr>
<td>Despite traffic congestion, I still insist on using private vehicle. (q9)</td>
<td>PC</td>
<td>0</td>
<td>8</td>
<td>22</td>
<td>46</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>MC</td>
<td>0</td>
<td>0</td>
<td>12</td>
<td>57</td>
<td>31</td>
</tr>
<tr>
<td>Despite the convenience of public transport, I still insist on using private vehicle. (q10)</td>
<td>PC</td>
<td>0</td>
<td>1</td>
<td>19</td>
<td>54</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>MC</td>
<td>0</td>
<td>2</td>
<td>16</td>
<td>53</td>
<td>29</td>
</tr>
<tr>
<td>Although there is road pricing in the area, I will use private vehicle, anyway. (q11)</td>
<td>PC</td>
<td>0</td>
<td>7</td>
<td>31</td>
<td>43</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>MC</td>
<td>0</td>
<td>4</td>
<td>26</td>
<td>43</td>
<td>27</td>
</tr>
</tbody>
</table>

Note: MC = Motorcycle users, PC = Private car users

4.2 Analysis of habitual behaviour and captive attitude

These results of attitudes to private vehicle use (in the previous section) were analysed by factor analysis to reflect habitual behaviour and captive attitude of private vehicle users. The initial analysis found that the KMO (Kaiser-Meyer-Olkin measure of sampling adequacy), which was used to measure the suitability of the information, was 0.89. It was greater than 0.5 and approached 1, therefore, the data are suitable for factor analysis when modelling could explain at 89.1%.

Table 2 shows factor loadings from exploratory factor analysis. Eleven indicators can be classified into two groups of latent factors. One factor consists of q7 and q8, while the rests are indices of the other factor. The percents of variance were equal to 10.71% and 49.27% respectively. The latent first factors can be named "habitual behaviour" (P_BEH), while the second factor can be called "captive attitude" (ATT).
Table 2 Factor loading of the indices after rotation of factors

<table>
<thead>
<tr>
<th>Attitudinal questions</th>
<th>Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I feel difficulty of travel if not using a private vehicle. (q3)</td>
<td>P_BEH: .120</td>
</tr>
<tr>
<td>2. I feel difficulty in changing travel mode from private vehicles to public transport. (q4)</td>
<td>ATT: .825</td>
</tr>
<tr>
<td>3. Despite travel distance of only 375 meters, I intend to use private vehicle only. (q6)</td>
<td>P_BEH: .149</td>
</tr>
<tr>
<td>4. Although there is road pricing in the area, I will use private vehicle, anyway. (q11)</td>
<td>ATT: .808</td>
</tr>
<tr>
<td>5. Whenever I am travelling, I intend to use private vehicle only. (q5)</td>
<td>P_BEH: .080</td>
</tr>
<tr>
<td>6. The use of a private vehicle is still needed, even public transport is perfect. (q2)</td>
<td>ATT: .807</td>
</tr>
<tr>
<td>7. Despite the convenience of public transport, I still insist on using private vehicle. (q10)</td>
<td>P_BEH: .142</td>
</tr>
<tr>
<td>8. Despite traffic congestion, I insist on using private vehicle. (q9)</td>
<td>ATT: .790</td>
</tr>
<tr>
<td>9. Private vehicle is necessary for living now and in the future. (q1)</td>
<td>P_BEH: .038</td>
</tr>
<tr>
<td>10. I specialise in motorcycle riding. (q8)</td>
<td>ATT: .782</td>
</tr>
<tr>
<td>11. I specialise in car driving. (q7)</td>
<td>P_BEH: .019</td>
</tr>
<tr>
<td>Eigen values</td>
<td>ATT: .769</td>
</tr>
<tr>
<td>Percent of Variance</td>
<td>P_BEH: .079</td>
</tr>
<tr>
<td></td>
<td>ATT: .749</td>
</tr>
<tr>
<td></td>
<td>P_BEH: .028</td>
</tr>
<tr>
<td></td>
<td>ATT: .744</td>
</tr>
<tr>
<td></td>
<td>P_BEH: .042</td>
</tr>
<tr>
<td></td>
<td>ATT: .644</td>
</tr>
<tr>
<td></td>
<td>P_BEH: -.783</td>
</tr>
<tr>
<td></td>
<td>ATT: -.008</td>
</tr>
<tr>
<td></td>
<td>P_BEH: .747</td>
</tr>
<tr>
<td></td>
<td>ATT: .099</td>
</tr>
<tr>
<td></td>
<td>P_BEH: 1.178</td>
</tr>
<tr>
<td></td>
<td>ATT: 5.420</td>
</tr>
<tr>
<td></td>
<td>P_BEH: 10.71</td>
</tr>
<tr>
<td></td>
<td>ATT: 49.27</td>
</tr>
</tbody>
</table>

The relationship between “captive attitude” and “habitual behaviour” was confirmed by the confirmatory factor analysis as shown in Figure 1a. The analysis found that the chi-square = 1,084.340, degree of freedom = 43, chi-square per degree of freedom = 25.217, root mean squared residual (RMSEA) = 0.142, Goodness of fit index (GFI) = 0.857. That is, the analysis of the structural equation model was not consistent with the data. (Note that RMSEA value equal or less than 0.06, and CFI and GFI values greater than 0.90 indicate a good fit to data (Tabachnick and Fidell, 2000)).

Thus, the model was adjusted by connecting two-headed arrows between the deviation of variable indices, which relied on the consideration of the Modification Indices pairs. Analyses were done after adjusting the model until the results of the analysis have been established. Data analysis results after adjustment for the new structure are shown in Figure 1b. It was found that the structural equation model was consistent with the data by considering the chi-square (at degrees of freedom equal to 20 and the number of 1,200 samples) is equal to 36.201, chi-square per degree of freedom = 1.810, RMR = 0.012, GFI = 0.995, AGFI = 0.983 and RMSEA = 0.026. This explains the “captive attitude” and “habitual behaviour” factors associated with positive correlation (0.34). The directed arrows from the two latent variables to the 11 observed variables indicate the loadings of the variable on the proposed two latent factors. Therefore, it is confirmed that the captive attitude and habitual behaviour can be explained by the 11 observed variables.
4.3 Mode Choice Model

Mode choice behaviour affected by the system features (travel time and cost) with captive attitude and habitual behaviour was analysed by the logit model. Each of the 1,200 respondents, who were private car and motorcycle users, was presented nine scenarios and was asked to choose his/her own private vehicle (personal car or motorcycle) or BRT for their journeys to work or education. The utility functions for these responses were set as Equation 1.

\[
V_{PC} = ASC + t \times (Total\ Travel\ Time)_{PF} + c \times (Total\ Travel\ Cost)_{PF} \\
+ r \times (Charg e)_{PF} + ha \times P_{BEH} + ca \times ATT \\
V_{BRT} = t \times (Total\ Travel\ Time)_{BRT} + c \times (Total\ Travel\ Cost)_{BRT} \\
\]

The utility of private vehicle use \(V_{PC}\) is a function of total travel time, total travel cost, and charging of private vehicle use (road pricing), habitual behaviour \(P_{BEH}\) and captive attitude \(ATT\). The utility of BRT use \(V_{BRT}\) is a function of total travel time and BRT fare.

The data gathered from personal car (PC) users and motorcycle (MC) users were separately analysed. The model results are presented in Tables 3 and 4, respectively. (Greater detail of the model development and discussion is presented in Pongmesa, 2013). For each group, two models were developed. One is the model without captive and habit variables, and the other one is the model with captive and habit variables. The captive and habit variables are the latent variables, which were analysed by factor analysis in the previous section. These models are to demonstrate the effects of captive and habit behaviour on mode choice behaviour.
The results show that private vehicles (both car and motorcycle) are much more preferable to private vehicle users than BRT (ASC is positive sign), when everything else is equal. The charge has a significant negative effect, as expected, indicating that when the road charge increases, preference of private vehicle use falls.

The analyses also show that the model with captive and habit variables are significantly better than the one without the variables. Captive and habit variables have positive significant effects, confirming that those who are captive to their private vehicles and/or have habit to use their personal vehicles are less likely to switch to use the BRT. Therefore, the model with captive and habit variables would predict mode shift to BRT less than prediction from the model without captive and habit variables. This means that prediction from the model without concerning captive attitude and habit behaviour tends to overestimate mode shift from private vehicles to the alternative, as shown in Tables 5 and 6.

Comparing the scenarios with and without road pricing, the prediction show that the higher level of charge, the more car and motorcycle users switch to use BRT, as expected. Mode shifts to BRT without charging private vehicles (charge = 0) are rather low, compared to the development of BRT integrated with road pricing.

Without charging motorcycle use (see Table 6), motorcycle users rarely switch to use the BRT. This is because using motorcycle is very convenient and cheap. The higher level of charge increases, the more BRT users switch from Motorcycle, particularly with higher levels of charge. This show that road pricing is an effective strategy to break captive attitude and driving habit behaviour. However, Chen and Lai (2011) concern that implementing road pricing to reduce motorcycle use behaviour may be difficult in practice, particularly more complicated in a motorcycle-dependent area than in a car dependent one. Thus planning to implement road pricing for motorcycle users should be further studies in more details.

Table 3 Parameters of mode choice model for car users

<table>
<thead>
<tr>
<th>Variables</th>
<th>Model without captive and habit variables</th>
<th>Model with captive and habit variables</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
<td>t-ratio</td>
</tr>
<tr>
<td>ASC</td>
<td>1.3086</td>
<td>4.51</td>
</tr>
<tr>
<td>Travel time (t)</td>
<td>-0.0389</td>
<td>-5.45</td>
</tr>
<tr>
<td>Travel cost (c)</td>
<td>-0.0271</td>
<td>-3.81</td>
</tr>
<tr>
<td>Charge (r)</td>
<td>-0.0288</td>
<td>-23.39</td>
</tr>
<tr>
<td>Habit (ha)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Captive (ca)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Observations</td>
<td>5,400</td>
<td></td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.0862</td>
<td></td>
</tr>
<tr>
<td>Log Likelihood</td>
<td>-3,385.696</td>
<td></td>
</tr>
</tbody>
</table>

Table 4 Parameters of mode choice model for motorcycle users

<table>
<thead>
<tr>
<th>Variables</th>
<th>Model without captive and habit variables</th>
<th>Model with captive and habit variables</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
<td>t-ratio</td>
</tr>
<tr>
<td>ASC</td>
<td>1.0791</td>
<td>2.93</td>
</tr>
<tr>
<td>Travel time (t)</td>
<td>-0.1519</td>
<td>-8.59</td>
</tr>
<tr>
<td>Travel cost (c)</td>
<td>-0.1164</td>
<td>-6.57</td>
</tr>
<tr>
<td>Charge (r)</td>
<td>-0.1735</td>
<td>-26.80</td>
</tr>
<tr>
<td>Habit (ha)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Captive (ca)</td>
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<td>-</td>
</tr>
<tr>
<td>Observations</td>
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</tr>
<tr>
<td>$R^2$</td>
<td>0.3351</td>
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</tr>
<tr>
<td>Log Likelihood</td>
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</table>
Table 5 Prediction of car users switching to BRT

<table>
<thead>
<tr>
<th>Road charging</th>
<th>Model without captive and habit variables</th>
<th>Model with captive and habit variables</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BRT fare</td>
<td>BRT fare</td>
</tr>
<tr>
<td></td>
<td>10 Baht 20 Baht 30 Baht</td>
<td>10 Baht 20 Baht 30 Baht</td>
</tr>
<tr>
<td>0 Baht</td>
<td>30% 20% 20%</td>
<td>24% 19% 15%</td>
</tr>
<tr>
<td>30 Baht</td>
<td>50% 40% 37%</td>
<td>44% 37% 30%</td>
</tr>
<tr>
<td>60 Baht</td>
<td>70% 64% 58%</td>
<td>65% 59% 52%</td>
</tr>
<tr>
<td>90 Baht</td>
<td>85% 81% 76%</td>
<td>82% 78% 72%</td>
</tr>
</tbody>
</table>

Table 6 Prediction of motorcycle users switching to BRT

<table>
<thead>
<tr>
<th>Road charging</th>
<th>Model without captive and habit variables</th>
<th>Model with captive and habit variables</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BRT fare</td>
<td>BRT fare</td>
</tr>
<tr>
<td></td>
<td>10 Baht 20 Baht 30 Baht</td>
<td>10 Baht 20 Baht 30 Baht</td>
</tr>
<tr>
<td>0 Baht</td>
<td>2% 1% 0%</td>
<td>1% 0% 0%</td>
</tr>
<tr>
<td>15 Baht</td>
<td>24% 10% 3%</td>
<td>20% 7% 2%</td>
</tr>
<tr>
<td>30 Baht</td>
<td>78% 55% 29%</td>
<td>74% 50% 25%</td>
</tr>
<tr>
<td>45 Baht</td>
<td>98% 93% 82%</td>
<td>97% 92% 80%</td>
</tr>
</tbody>
</table>

5. Conclusions

This paper presented the possibility of integrating Bus Rapid Transit (BRT) with road pricing to reduce private vehicle use in Chiang Mai, Thailand. A total of 1,200 private vehicle users (car and motorcycle), was randomly surveyed by a Stated Preference (SP) exercise and attitudinal questionnaire. Two situations were designed including: (1) development of Bus Rapid Transit (BRT) system alone, and (2) development of BRT system with road pricing. The factor analysis was used to classify habitual behaviour and captive attitude, while Logit model was used to analyse the effects of the BRT and road pricing.

Habitual behaviour and captive attitude of private vehicle users were observed. The obtained results have shown that most private vehicle users believed that private vehicles were important for their daily lives and would still be essential even if a comprehensive public transport had been implemented. They felt that using private vehicles had great benefit and they had the intention of using private vehicles even for short distances. Private vehicle users perceived difficulty when being asked to reduce their vehicle trips, even if their city has Bus Rapid Transit system. These reflect that private vehicle (car and motorcycle) users are likely to be captive to their vehicles and/or have habit to use their vehicles with less considering alternative modes. Therefore, development of public transport system needs to consider personal psychology factors affecting mode choice behaviour.

The study also showed that utilising BRT system development together with road pricing is more effective than BRT system development alone. Therefore, improvement of BRT system would be more effective if it is integrated with restraint measures (e.g. road pricing) that can reduce habitual behaviour and captive attitude.

REFERENCES


AN OPTIMIZATION MODEL FOR BRT SYSTEMS: ISTANBUL METROBUS CASE

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1 IETT General Directorate, Transportation Planning Department, Turkey

Abstract

In this presentation, route optimization studies which aimed at increasing the capacity of the metrobus system in order to increase the comfort of public transportation will be described. First chapter primarily focuses on metrobus example following a brief information on the current transportation system, and then Capacity Expansion of Metrobus Project, made in collaboration with TUBITAK TÜSSIDE and IETT, will be detailed. The stages of project are as follows: Analyzing journey details, establishing a model and implementation. In conclusion, an assessment will be made on the implementation of the outcomes and what could be done in the future.
Appropriate operating environments for Feeder-Trunk-Distributor or Direct road based public transport services in cities of developing countries.

ABSTRACT

Bus Rapid Transit projects are being actively promoted internationally. They require the replacement of many direct services by Feeder-Trunk-Distributor services. Often city officials champion these projects on the basis of their success in other countries, without due regard to the existing trip making conditions in their own city.

The objective of the paper is to provide guidance on where Feeder-Trunk-Distributor road based public transport services should replace existing Direct services.

Methodology:

A model was developed to estimate the cost, travel time, energy consumption and CO2 emissions of Direct and Feeder-Trunk-Distributor road based public transport services for a wide variety of operating environments described in terms of peak hour public transport trip production density at the origin, peak hour public transport trip attraction density at the destination, route length, percentage of trips generated from the origin distributed to the destination, and the number of routes distributing public transport trips at the destination.

Data:

Data on the performance of road based public transport modes have been collected over many years from many cities in South Africa as well as on the range in the parameters used to describe urban environment in which public transport operates.

Expected conclusions:

A statement of which combinations of operating conditions make Feeder-Trunk-Distributor service more advantageous, Direct service more advantageous, and where neither type of service is advantageous in respect of cost, average passenger travel time, energy consumed and CO2 emitted per passenger.

KEY WORDS
direct, feeder-trunk-distributer, public transport, cost, travel time, energy, emissions
INTRODUCTION

Bus Rapid Transit (BRT) has become increasingly fashionable in recent years and is being vigorously promoted in developed as well as developing countries. The immediate image of a BRT is one or more dedicated lanes in each direction, with very well designed stations and a promise that it will at least cover operating costs.

There are many examples where this has been accomplished but the operating conditions that have allowed this to be achieved is seldom factored into the thinking of elected and appointed officials that return from their pilgrimages to examples of BRT, such as Bogota; and previously Curitiba.

This paper describes an analysis to determine the conditions where Feeder-Trunk-Distributor (FTD) services would outperform Direct Services in respect of cost, passenger travel time and energy consumption of the public transport service. The study is limited to road based services, because in the main, rail services need feeder and distributor services to aggregate sufficient passengers. The model, developed for the study takes account of peak hour public transport volume, route length, percentage of trips generated from the origin distributed to the destination, peak hour public transport trip generation density from the origin and to the destination, and the number of routes distributing public transport trips at the destination.

LITERATURE REVIEW

The popularity of BRT

Bus rapid transit is often the published image of FTD public transport services. The image is one of efficiency and modernity with its well designed stations, dedicated roadways and modern vehicles that will achieve greater capacity, speed and operational efficiencies that promise better services without operating subsidy from government (Viva 2007).

Menckhoff (2005) cites the economic experience of BRT services in South American cities as “BRTs described in this paper (with the exception of Quito’s Trole and Ecovia) cover operating costs including vehicle acquisition and depreciation from passenger revenues – different from almost all urban rail systems in Latin America and elsewhere”. This expectation, without mention of the possibility that operating costs might, in some cases, not be fully covered by fare revenue is often repeated by consultants in other countries where trip making and vehicle operating conditions could be quite different; such as the following that refers to Johannesburg and eThekwini (Durban) in South Africa:

The use of high-quality dedicated infrastructure and a planning process to optimize operations have allowed cities to significantly reduce subsidies. The Operational Plan for Phase I of Johannesburg’s Rea Vaya project projects a 34% net profit for the system. By contrast, eThekwini is projecting to increase subsidies from R 280 million per year to R 1.1 billion per year, a four-fold increase ($40 million to $ 157 million). (Viva, 2007)
Elected and appointed officials visit successful BRT systems and return with enthusiasm to embark on BRT projects rather than to apply the lessons learnt by identifying the most appropriate public transport solutions for their own cities. What constitutes “success” needs to be defined for each circumstance. The goals for a public transport solution and the importance of each could be vastly different than those of the visited cities. The realism of expectations of no operating subsidy can then be reviewed in light of the system performance required to meet these goals. As an example, high crowding levels would produce higher revenues, but are unlikely to attract riders out of automobiles. Similarly, providing a frequent off-peak services will incur costs but is essential to attract choice riders. One final example is the assumed level of fares – if the new system must charge far more than the previous alternatives in order to break even, it may actually fail in the goal of improving mobility.

There is evidence that some BRT systems purported self-sufficiency comes at the expense of poor performance in some respects. In 2012, there were riots in Bogota centered around the Transmilenio BRT. Specifically, riders complained of high fares, chronic overcrowding even in the off-peak and delays caused by this crowding (Sequera and Bajak, 2012). Support for the feeder network with free transfers necessitates a higher fare than the previous system and fare increases have been frequent and above the average inflation rate (Gilbert, 2008).

**Feeder-Trunk-Distributor and Direct services**

*Operations*

The often high capital cost of BRT routes and the political implications of providing road space for public transport instead of private motor vehicles can only be justified by high passenger volumes. In many parts of most cities, residential density translated into public transport passenger density is insufficient to produce the volumes required to begin to achieve the economies of scale achievable by BRT from passengers that can walk to BRT stations. This is resolved by developing feeder systems to and distributor systems from BRT terminals and transfer stations (Figure 1).

**Feeder-Trunk-Distributor (FTD) versus Direct Services (DS)**

The choice between using a FTD or a DS has a long history of discussion. The intention of this paper isn’t to repeat this discussion as the appropriate decision seems to be very case specific. It depends upon the corridor’s physical characteristics, the ridership profile, the demographics of the current and potential ridership, the performance and purchase price of the available vehicles, the local operator and maintenance labour costs, the ability to maintain reliable service schedules, availability of shelters, and various other factors. Furthermore, whether investment capital is available for the upgrade will also affect the potential relative performance of each option.
The Institute for Development and Transport Policy (IDTP, 2007) lists travel time, operational efficiencies, infrastructure, vehicle types, capacity, and system image and customer friendliness as a basis to compare FTD and DS. These exclude two major aspects; namely cost of delivering the service and the energy consumption / gas emission.

**Potential Advantages of Feeder Trunk-Distributor**

The obvious advantage of FTD is the division of the trip into three components; namely feeder, trunk and distributor. Each of these components will carry different volumes of passengers; for which different public transport modes might be more appropriate.

Services are expected to be more efficient with vehicles being able to operate on ways that permit less external interference in the flow of public transport vehicles. As such an HOV lane will provide some improvement over conditions with mixed traffic; and a BRT will be even better.

Referenced, hourly capacities of public transport modes vary considerably. For example, the City of Ottawa (2007) indicates hourly passenger capacities per direction of 8000, 10000, 14000 and 14000 for buses, street car and light rail transit (LRT) and BRT respectively; while IDTP (2007) shows the capacity of BRT as 45 000 passengers/hour/direction. Evidence is quoted that “TransMilenio’s double-width busway on Avenida Caracas even accommodates 35,000 pphpd with a mixture of all-stop and express bus services” (Menckhoff, 2005). On very busy corridors in congested areas where land is at a premium (e.g. the CBDs of cities) being able to achieve such high capacities might be the most important factor. However, caution is advised in interpreting such numbers as multilane capacities often confuse way capacity with station capacity. The former is important for running multiple routes
over express sections or for running on motorway but irrelevant for services stopping along a particular route. A two-lane BRT roadway might also be limited by the time allocated to public transport on the traffic signal timings.

It can be expected that vehicle speeds will be higher on dedicated lanes. For example, the Insurgentes corridor in Mexico City with median busway was expected to achieve “a commercial speed of 21 km/hour, compared to 14 km/hour achieved by the bus services currently serving the corridor” (Menckhoff, 2005).

Other advantages

A second advantage is that FTD services have the potential to provide more frequent off-peak services than DS. While demand may be sufficient during peak periods to provide direct links, FTD allows connections throughout the day. This theoretical advantage requires space and facilities for connecting terminals and introduction of timed-transfer discipline.

The authority and city would also benefit from the higher capacity of the trunk route, which could reduce the land take required to carry people to and from high density areas; such as CBDs.

The transport authority could benefit from FTD from the reduction in the cost of delivering the service through the economies of scale from bigger vehicles and higher speeds. However, if there is an integrated fare structure this improvement must be large enough to compensate for the additional costs of the feeder services.

Potential disadvantages

There are two major disadvantages of FTD. The first is the penalty incurred in changing modes at the terminals. The penalty lies in the time taken to alight from a vehicle, walk to the next stop and wait for the next vehicle and board. The penalty is more than just time. It includes the inconvenience of interchanging between vehicles. The travel time penalty needs to be made up as much as possible by the improved travel speeds on the trunk route. If the aforementioned economies of scale are not sufficient, it may also translate into higher fares to cover the extra vehicles and kilometers incurred.

The second disadvantage lies in the fact that from a passenger’s point of view, the feeder vehicles have to travel to the terminal at the feeder end of the trip and after travelling on the trunk section, then travel from the terminal at the distributor end of the trip; with these components amounting to a greater distance than the direct route. From an operator’s point of view, the lower cost resulting from the improved efficiencies and economies of scale of the trunk component may not be sufficient to cover the extra cost of the combined system from the total distance traveled and time consumed per day by the fleet.
Towards an analysis model

For the purposes of the present paper it suffices to note that there is both theoretical and empirical evidence to suggest that trunk/branch networks can outperform direct networks under some circumstances. Bruun (2007) describes the theoretical pros and cons between three possibilities: direct service to and from a CBD terminal, the merging of direct services onto a trunk as they near the CBD terminal, and the introduction of a higher capacity mode along the trunk section with the requirement of all passengers from the branches to transfer. He concludes that the best choice depends upon the particular site and objectives of the planning authority. For example, if the primary objective is only serving commuting trips to/from the CBD during peak hours, direct service will usually cost the least. On the other hand, for all day service between multiple origins and destinations, the third possibility is likely to be the best.

Some empirical evidence is also available on the before/after results for LRT systems built in the United States. Thompson and Matoff (2003) compared before/after ridership based on conversion to a timed-transfer system between local buses and LRT from a largely direct to CBD bus system and found substantial ridership increases without large operating cost increases for the corridor. They also found that older peer combined rail and bus systems that did not convert to trunk/feeder experienced relatively stagnant ridership. Clearly, labor costs are much higher in the U.S. and traffic conditions much different, so it doesn’t follow that the results would be similar, but there is enough evidence to suggest that trunk/branch could be promising for developing countries.

The model presented in this paper is capable of including the impacts from changes to most of the relevant variables usually discussed in the literature. Specifically, factors that affect the relevant advantages of FTD versus DS include:

a) Public transport trip production and attraction rates and the proportion of trips distributed to the destination;
b) Route catchment area which depends on the stop spacing and acceptable walking distance;
c) Feeder, trunk and distributor modes and their operating characteristics.
d) The number of routes feeding to the origin terminal;
e) The distance between origin and destination;
f) Distributor catchment area which depends on the stop spacing and acceptable walking distance;
g) The number of routes distributing from the destination terminal.

The issue of reliability is not included as this would require the introduction of stochastic variations in travel times; an enhancement that could be added in the future.
METHODOLOGY

The Conceptual Spatial Model

The spatial arrangement has been simplified to an origin area served by one or more routes; a trunk service; and a destination area served by one or more routes as shown in Figure 2. Trips are produced in the origin area which is composed of one or more catchments of routes that feed the origin terminal. At the origin terminal, trips produced by the origin area are distributed to destination areas through one or more trunk routes. At the destination terminal, trips arriving from one or more trunk routes are distributed through one or more routes that feed the destination area.

FIGURE 2: Spatial schematic of analysis

The Computational Model

Overall structure of the computational model

The computational model estimates the public transport passengers travelling on the feeder, the trunk, the distributor and the direct route and the lengths of these routes for all the combinations of the variables listed in Table 1. These values are fed to a public transport model to calculate the cost, travel time and energy used to travel each segment of the FTD trip and the DS trip for six public transport modes (Table 2). These outputs are then used to determine the minimum cost, travel time and energy per trip for the FTD and DS alternatives; which are the data used in the analysis.

Input variables to the model

Table 1 shows the values of the input variables used to determine the number of trips and route lengths used to compare FTD and Direct services:
TABLE 1 Trip making conditions used in the analysis

<table>
<thead>
<tr>
<th>VT</th>
<th>LL</th>
<th>PO</th>
<th>DO</th>
<th>DD</th>
<th>RD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>11</td>
<td>15</td>
<td>5</td>
<td>20</td>
<td>1</td>
</tr>
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<td>20000</td>
<td>40</td>
<td>(-)</td>
<td>(-)</td>
<td>(-)</td>
<td>(-)</td>
</tr>
</tbody>
</table>

(-) Only three levels of each variable used in analysis

Where:

VT is the peak hour volume on the trunk route between the Origin and the Destination (PT pax/hr);
LL is the distance between the end of the Origin and the end of the Destination (km);
PO is the percentage of trips generated by the Origin that are distributed to the Destination (%);
DO is the peak hour PT trip production density from the Origin (PT pax/hr/ha) (1ha = 2.47 acres);
DD is the peak hour PT trip attraction density to the Destination (PT pax/hr/ha);
RD is the number of routes distributing PT trips at the destination.
SO, SD are the stop spacings on the feeder and the distributor services respectively (assumed to be 1000m (3300 ft) and 500m (1650 ft) respectively).
Os, Ds are the number of stops on the feeder route (assumed to be 10) and the distributor route (assumed to be 5).

In this analysis it is assumed that all the passengers produced by the origin are distributed to the destination will travel between the terminals of the trunk route. The model does not account for passenger alighting or boarding on the route; although the public transport model assumes time lost due to vehicles stopping at stations assumed at 1km intervals. In cases where there is very high demand along the trunk, it would shorten wait times at terminals through higher frequency or reduce trunk operating costs through larger vehicles.

Input to the public transport model

The values given in Table 1 produced 1296 cases of trip making conditions. Each case produced values for feeder, trunk, distributor and direct services. These values were input to a previously developed public transport model (Del Mistro and Baloyi, 2000; Del Mistro and Aucamp, 2000, Kingma, Hugo and Del Mistro, 2002) used to calculate the cost, travel time and energy consumed per passenger.

The transport model

Assumptions were made in the model with respect to the distribution of trips throughout the day, minimum service frequency, vehicle speeds over different types of road, etc. The following six modes were considered:

a) 16-Seater minibus in mixed traffic or HOV lane operation.
b) 25-Seater midibus in mixed traffic or HOV lane operation.
c) 66-Seater bus in mixed traffic or HOV lane operation.
d) 80-Seater articulated bus in mixed traffic or HOV lane operation.
e) 66-Seater bus with a BRT way (lateral separation but at-grade intersections),
f) 80-Seater articulated bus with a BRT way (lateral separation but at-grade intersections),

Table 2 shows the values for the most important operating parameters used by the public transport model. Cost data has been updated to 2013 and the operating parameters are typical of South African public transport operations. All the factors are necessary to determine the cost, travel time and energy consumption to service a route. The model was also run for both current and high labor costs to address the argument that is often leveled that low salaries in developing countries makes smaller capacity vehicles more competitive than in developed countries.

### TABLE 2 Public Transport Model: Important Operating and Cost Parameters

<table>
<thead>
<tr>
<th>MODE</th>
<th>16-Seater Minibus</th>
<th>25-Seater Midi Bus</th>
<th>55-Seater Articulated Bus</th>
<th>66-Seater Articulated Bus</th>
<th>80-Seater Bus</th>
<th>BRT</th>
<th>Artic Bus BRT</th>
<th>HOV mini</th>
<th>HOV Bus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel speed Destination in peak (km/h)</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>30</td>
<td>25</td>
</tr>
<tr>
<td>Travel speed Arterial in peak (km/h)</td>
<td>45</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>50</td>
<td>45</td>
</tr>
<tr>
<td>Travel speed Origin in peak (km/h)</td>
<td>35</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>45</td>
<td>45</td>
<td>45</td>
<td>40</td>
<td>35</td>
</tr>
<tr>
<td>Maximum volume/Capacity ratio</td>
<td>0.85</td>
<td>0.85</td>
<td>0.85</td>
<td>0.85</td>
<td>0.85</td>
<td>0.85</td>
<td>0.85</td>
<td>0.85</td>
<td></td>
</tr>
<tr>
<td>Vehicle capacity (standing allowed)</td>
<td>16</td>
<td>35</td>
<td>85</td>
<td>120</td>
<td>85</td>
<td>120</td>
<td>85</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>Vehicle capacity (standing not allowed)</td>
<td>16</td>
<td>25</td>
<td>66</td>
<td>80</td>
<td>66</td>
<td>80</td>
<td>66</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>Cost per vehicle(USDm)</td>
<td>0.032</td>
<td>0.064</td>
<td>0.180</td>
<td>0.240</td>
<td>0.220</td>
<td>0.260</td>
<td>0.220</td>
<td>0.260</td>
<td></td>
</tr>
<tr>
<td>Capacity per lane(Veh/h)</td>
<td>400</td>
<td>300</td>
<td>250</td>
<td>200</td>
<td>300</td>
<td>250</td>
<td>300</td>
<td>250</td>
<td></td>
</tr>
<tr>
<td>Cost of way(USDm/lane-km)</td>
<td>0.500</td>
<td>0.500</td>
<td>0.500</td>
<td>0.500</td>
<td>0.500</td>
<td>0.500</td>
<td>0.500</td>
<td>0.500</td>
<td></td>
</tr>
<tr>
<td>Cost of Terminals (USDm/peak hour vehicle)</td>
<td>0.002</td>
<td>0.005</td>
<td>0.011</td>
<td>0.022</td>
<td>0.011</td>
<td>0.022</td>
<td>0.011</td>
<td>0.022</td>
<td></td>
</tr>
<tr>
<td>Cost of stops (USDm/stop)</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.03</td>
<td>0.01</td>
<td>0.03</td>
<td>0.01</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>Cost of depot (USDm/coach)</td>
<td>0.010</td>
<td>0.030</td>
<td>0.045</td>
<td>0.050</td>
<td>0.045</td>
<td>0.050</td>
<td>0.045</td>
<td>0.050</td>
<td></td>
</tr>
<tr>
<td>Energy consumption(Mjoules/coach-km)</td>
<td>11.97</td>
<td>12.1</td>
<td>19.36</td>
<td>32.43</td>
<td>19.36</td>
<td>32.43</td>
<td>19.36</td>
<td>32.43</td>
<td></td>
</tr>
<tr>
<td>Fuel Consumption(U/100veh-km)</td>
<td>19</td>
<td>25</td>
<td>40</td>
<td>67</td>
<td>40</td>
<td>67</td>
<td>40</td>
<td>67</td>
<td></td>
</tr>
<tr>
<td>Cost of fuel(USD/l)</td>
<td>1.30</td>
<td>1.30</td>
<td>1.20</td>
<td>1.20</td>
<td>1.20</td>
<td>1.20</td>
<td>1.20</td>
<td>1.20</td>
<td></td>
</tr>
<tr>
<td>Other Cost/veh-km(USD/coach-km)</td>
<td>0.86</td>
<td>0.265</td>
<td>0.398</td>
<td>0.465</td>
<td>0.465</td>
<td>0.442</td>
<td>0.465</td>
<td>0.442</td>
<td></td>
</tr>
<tr>
<td>Cost/coach/year(USDm)</td>
<td>0.04</td>
<td>0.028</td>
<td>0.042</td>
<td>0.049</td>
<td>0.047</td>
<td>0.052</td>
<td>0.047</td>
<td>0.052</td>
<td></td>
</tr>
<tr>
<td>Cost/lane-km/year(USDm)</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>Cost/terminal/year (%of capital cost)</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Cost/station or stop/year (USDm)</td>
<td>0</td>
<td>0</td>
<td>0.009</td>
<td>0.009</td>
<td>0.18</td>
<td>0.18</td>
<td>0.18</td>
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<tr>
<td>High Labour Costs</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other Cost/veh-km(USD/coach-km)</td>
<td>2.9</td>
<td>0.758</td>
<td>1.136</td>
<td>1.33</td>
<td>1.26</td>
<td>1.39</td>
<td>1.26</td>
<td>1.39</td>
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<tr>
<td>Cost/coach/year(USDm)</td>
<td>0.2</td>
<td>0.123</td>
<td>0.185</td>
<td>0.216</td>
<td>0.206</td>
<td>0.226</td>
<td>0.206</td>
<td>0.226</td>
<td></td>
</tr>
</tbody>
</table>
Outputs of analysis

The public transport model produced the following information for each case of trip making conditions:

a) The total and operating cost per passenger using the feeder, trunk, distributor or direct services. The cost includes capital and operating costs.

b) The travel time for the passenger. It was assumed that on average passengers will travel half of the route length within the feeder and distributor catchment areas; and the full distance between the route catchment and the terminal the catchment is feeding to or distributing from. It was also assumed that the average waiting time is equal to half the service frequency unless the peak hour vehicle frequency was more than 20 minutes. In which case an average wait time of 10 minutes was assumed.

c) The average energy consumed by the vehicles transporting each passenger using each service is derived from the fuel consumption.

Analysis of the outputs

The output data was used to determine the minimum total and operating costs, minimum travel time and minimum energy consumption for each component of the FTD trip; which were added to calculate the minimum value for a FTD service and for the Direct Service. The values for the FTD were divided by the values for the DS (FTD/DS cost, FTD/DS time and FTD/DS energy) as an easy way to compare the performance of the two alternatives.

1296 Cases were developed and analyzed by determining trip making conditions which are advantageous to either FTD or DS.

DISCUSSION OF FINDINGS

Initial outputs

Table 3 provides a summary of the basic outputs of the study indicating the average, lowest and highest values of the minimum FTD and DS trips for high labor rate, low labor.
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b) The travel time for the passenger. It was assumed that on average passengers will travel half of the route length within the feeder and distributor catchment areas; and the full distance between the route catchment and the terminal the catchment is feeding to or distributing from. It was also assumed that the average waiting time is equal to half the service frequency unless the peak hour vehicle frequency was more than 20 minutes. In which case an average wait time of 10 minutes was assumed.

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DISCUSSION OF FINDINGS

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<table>
<thead>
<tr>
<th></th>
<th>Feeder- Trunk Distributer service</th>
<th>Direct Service</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Labour cost</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total Cost/pass trip MIN(USD)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Operating Cost/pass trip MIN(USD)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ave Time/trip MIN(m)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Energy/trip MIN (mj)</td>
<td></td>
</tr>
<tr>
<td>Min</td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.12</td>
<td>25.14</td>
</tr>
<tr>
<td></td>
<td>0.91</td>
<td>3.62</td>
</tr>
<tr>
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<td>1.14</td>
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</tr>
<tr>
<td></td>
<td>13.10</td>
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<tr>
<td></td>
<td>2.54</td>
<td>73.37</td>
</tr>
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<td>Ave</td>
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<td></td>
<td>2.38</td>
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<td>18.66</td>
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<td></td>
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</tr>
<tr>
<td></td>
<td>5.65</td>
<td>4.785</td>
</tr>
<tr>
<td></td>
<td>4.838</td>
<td>4.25</td>
</tr>
</tbody>
</table>

Frequency with which Feeder Trunk Distributer Services are better than the Direct Services.

Table 4 shows the distribution of the FTD/DS ratios wrt Total Cost, Operating Cost, Travel time and Energy Consumption for the 1296 cases derived by the combinations of the parameters shown in table1.

<table>
<thead>
<tr>
<th></th>
<th>Cost/pass trip MIN(R)</th>
<th>Op.Cost/pass trip MIN(R)</th>
<th>Ave Time/trip MIN(m)</th>
<th>Energy/trip MIN (mj)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low labour</td>
<td>High labour</td>
<td>Low labour</td>
<td>High labour</td>
</tr>
<tr>
<td>Min</td>
<td>0.89</td>
<td>0.85</td>
<td>0.80</td>
<td>0.83</td>
</tr>
<tr>
<td>Max</td>
<td>1.61</td>
<td>2.57</td>
<td>1.63</td>
<td>2.67</td>
</tr>
</tbody>
</table>

DISTRIBUTION OF CASES

<table>
<thead>
<tr>
<th></th>
<th>Cost/pass trip MIN(R)</th>
<th>Op.Cost/pass trip MIN(R)</th>
<th>Ave Time/trip MIN(m)</th>
<th>Energy/trip MIN (mj)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>&lt;0.5</td>
<td>0</td>
<td>0</td>
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</tr>
<tr>
<td></td>
<td>&lt;067</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td></td>
<td>&lt;1</td>
<td>109</td>
<td>211</td>
<td>420</td>
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<tr>
<td></td>
<td>&lt;1.25</td>
<td>985</td>
<td>823</td>
<td>847</td>
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<tr>
<td></td>
<td>&lt;1.5</td>
<td>192</td>
<td>155</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>&lt;2</td>
<td>10</td>
<td>96</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>&gt;2</td>
<td>0</td>
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</tr>
<tr>
<td>Total</td>
<td>1296</td>
<td>1296</td>
<td>1296</td>
<td>1296</td>
</tr>
</tbody>
</table>

Table 4 shows that:

a) The total cost was less for cases of FTD service that cases for Direct service in 8 and 12 per cent of cases for Low or High labour costs respectively.

b) The operating costs of FTD services were less than those for Direct Services in more than a third of the cases tested.
c) Passenger travel time when using FTD services was always longer than using Direct services.
d) FTD services were found to use less energy than Direct Services in over 97% of cases.

It must be noted that these proportions where FTD is more appropriate only reflect the cases selected in the study not the situation in practice. The next section identifies which conditions are more appropriate for FTD.

**Operating conditions where FTD services are more appropriate than Direct Services**

The output of the analysis was examined to find the operating condition where the FTD service is more appropriate was over represented as being more appropriate than the Direct service for total cost, operating costs, travel time and energy consumption (as surrogate for gas emissions), Table 5 summarises the findings this analysis.

**FTD service appropriate in terms of Total Cost**

Table 5 shows that 458 cases (of the 1296 cases) achieved a ratio of the total cost of FTD and Direct services is less than 1; i.e. the FTD is less costly than the Direct service. The table shows that this is most prevalent when:

a) The percentage trips going from the origin to the destination is high at over 15%  
b) The destination trip attraction density is higher than 100 trips/ha in the peak hour.  
c) The service serves a destination that can be serviced with one distributer route.  
d) The trip production density at the residential area is higher than 40 trips/ha in the peak hour.

**FTD service appropriate in terms of Operator Cost**

While the decision on selecting a transport solution should be based on the total cost (in the broadest sense), most transport authorities base their decision on the operating cost alone, omitting the capital costs and operating costs borne by the transport authority. Table 5 shows the parameters values that are prevalent where the operating costs of the FTD service has a lower operating than the Direct service. 458 Cases found the FTD to be less costly than the Direct service. Table 6 shows that FTD is preferable to a Direct service where:

a) The route length is shorter than 30 km.  
b) The destination catchment area can be serviced with one public transport route.  
c) Approximately 5 per cent of trips originating at the residential area are travelling to
TABLE 5: Operating conditions appropriate for FTD services

<table>
<thead>
<tr>
<th>Pk hr trunk pass in peak direction</th>
<th>O-D Distance (km)</th>
<th>% origin trips to destination</th>
<th>Origin trip density (Tr/ha/hr)</th>
<th>Destination trip density (Tr/ha/hr)</th>
<th># Catchments at destination</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>11</td>
<td>5</td>
<td>20</td>
<td>20</td>
<td>1</td>
</tr>
<tr>
<td>5000</td>
<td>20</td>
<td>10</td>
<td>40</td>
<td>100</td>
<td>5</td>
</tr>
<tr>
<td>10000</td>
<td>30</td>
<td>25</td>
<td>85</td>
<td>200</td>
<td>10</td>
</tr>
<tr>
<td>20000</td>
<td>40</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total cost (Low Labour Cost)</td>
<td></td>
<td></td>
<td>458</td>
<td>Cases &lt;1.0</td>
<td></td>
</tr>
<tr>
<td>168</td>
<td>163</td>
<td>144</td>
<td>100</td>
<td>112</td>
<td>192</td>
</tr>
<tr>
<td>133</td>
<td>120</td>
<td>56</td>
<td>186</td>
<td>142</td>
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<tr>
<td>88</td>
<td>83</td>
<td>258</td>
<td>172</td>
<td>204</td>
<td>114</td>
</tr>
<tr>
<td>69</td>
<td>92</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating cost (Low Labour Cost)</td>
<td></td>
<td></td>
<td>458</td>
<td>Cases &lt;1.0</td>
<td></td>
</tr>
<tr>
<td>165</td>
<td>134</td>
<td>185</td>
<td>177</td>
<td>142</td>
<td>202</td>
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<td>157</td>
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<tr>
<td>99</td>
<td>21</td>
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<td>161</td>
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<tr>
<td>37</td>
<td>43</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Travel time</td>
<td></td>
<td></td>
<td>327</td>
<td>Cases &lt;1.4</td>
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<tr>
<td>90</td>
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<td>109</td>
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<td>87</td>
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<td>81</td>
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<td>69</td>
<td>312</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Energy</td>
<td></td>
<td></td>
<td>314</td>
<td>Cases &lt;0.8</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>184</td>
<td>134</td>
<td>135</td>
<td>102</td>
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<td>42</td>
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<td>86</td>
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<tr>
<td>14</td>
<td>18</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

FTD service appropriate in terms of Travel Time

The study found that FTD service never produced a shorter travel time than the Direct Service. Table 5 shows that 327 cases produced travel times for FTD services that were less than 1.4 time longer than Direct services; all the other cases produced relatively longer travel times for FTD. To achieve the lowest ratio requires route distances longer than 30km.

FTD service appropriate in terms of Energy Consumption

Table 5 also shows the effect of Service on energy consumption. It found that except for 53 cases the FTD service was always more energy efficient.
Effect of high labour costs on the appropriateness of FTD service

Table 6 shows the results of the analysis which assumed labour costs were 5 times higher than currently apply in South Africa.

In terms of Total cost of service, FTD service was found to be more appropriate:

a) On routes short routes less than 20km.

b) On routes to destinations with trip density of 200 passenger/ha.

In terms of Operator cost of service, FTD service was found to be more appropriate:

a) On routes shorter than 30km.

While the operating conditions are obviously more appropriate FTD in terms of total cost are not the same for low and high labour costs, they are in agreement on short trip length and high trip density at the destination. In terms of operating cost, FTD services are more appropriate on routes shorter than 30 km for both low and high labour costs.

Table 6: Effect of high labour costs on FHT service being appropriate

<table>
<thead>
<tr>
<th>Pk hr trunk pass in pk dir (pphpd)</th>
<th>O-D Distance (km)</th>
<th>% origin trips to destination</th>
<th>O Trip density (Tr/hr/ha)</th>
<th>D Trip density (Tr/hr/ha)</th>
<th># catchments at destination</th>
<th>Total cost (High Labour Cost)</th>
<th>Operating costs (High Labour Cost)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>11</td>
<td>5</td>
<td>20</td>
<td>20</td>
<td>1</td>
<td>225</td>
<td>346</td>
</tr>
<tr>
<td>5000</td>
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<td>20000</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Total cost (High Labour Cost)</td>
<td>225</td>
<td>cases</td>
<td>&lt;1.0</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating costs (High Labour Cost)</td>
<td>346</td>
<td>cases</td>
<td>&lt;1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Further analysis
Further work on the study can include:

a) A study of the effect of reliability on the two PT alternatives.

b) A review the values of the parameters used in the study to identify whether more accurate values of boundary conditions could be determined.

c) The development of a multi-criteria evaluation method to combine the outcomes of the three criteria; namely cost, time and energy; which could be used to choose the “best” mode for each component of the route; as opposed to the current comparison of least cost, least time or least energy consumption.

CONCLUSIONS

This paper described an analysis of the effect of peak hour public transport volume, route length, percentage of trips generated from the origin distributed to the destination, peak hour public transport trip production density from the origin, peak hour public transport trip attraction density to the destination and the number of routes distributing public transport trips at the destination on the cost, average passenger travel time and energy consumed per passenger using a Feeder-Trunk-Distributor service compared to those incurred when using a Direct Service in over a thousand cases.

The study found that the following conditions can favor the implementation of Feeder Trunk Distributor when replacing Direct Services:

a) High trip density at origins and destinations.

b) Single destination catchments.

c) Services shorter than 30 km in terms of total and operator costs and energy consumption and services of 40 km in terms of travel time.

d) Peak hour passenger volumes in the peak direction of less than 10 000. This might seem to be counter intuitive.

Further research work is required to include the effect of the improved reliability provided by dedicated facilities, route length, on the definition of boundary conditions of percentage of trips from origin to the destination and public transport trip densities, and the application of multi-criteria assessment.

REFERENCES


CNG CONVERSION OF VEHICLES IN DHAKA: AN ANALYSIS OF AIR QUALITY, GHG AND CONGESTION IMPACTS

Zia Wadud 1

1 University of Leeds Centre for Integrated Energy Research Leeds-United Kingdom

Abstract

Motor vehicles are one of the major sources of air pollution in Dhaka, the capital of Bangladesh. The government took various policies to convert the petroleum vehicles on road to run on compressed natural gas (CNG), which allows both air quality improvements and energy security benefits. The first objective of this paper is to quantify ex-post the air quality and climate benefits of the CNG conversion policy, including monetary valuations, through an impact pathway approach. Around 2,045 (1,665) avoided premature deaths in greater Dhaka (City Corporation) can be attributed to air quality improvements from the CNG conversion policy in 2010, resulting in a saving of around USD 400 Million. CNG conversion was clearly detrimental from climate change perspective using the changes in CO2 and CH4 only (CH4 emissions increased), however, after considering other global pollutants (especially black carbon) the climate impact was ambiguous. several years into the policy, there is now a widespread belief among the policymakers that the CNG conversion may have increased car ownership and car travel due to their lower running costs, resulting in more congestion and a reversal of the strategy is on the cards. Our second objective is to test the hypothesis whether CNG conversion had genuinely increased car ownership and car travel, and thus congestion in Dhaka city. Results show that ownership did not increase, but travel of on-road vehicles increased due to the CNG policy. However, additional congestion costs are still only one-half of the health benefits brought about by the policy.
DEVELOPMENT OF ON ROAD EMISSION AND FUEL CONSUMPTION MODELS FOR ESTIMATING EMISSIONS AND FUEL CONSUMPTION OF MOTORCYCLES IN ASIAN DEVELOPING COUNTRIES

Thaned Satiennam¹, Thana Radpukdee², Wichuda Satiennam³, Atthapol Seedam⁴, Warasak Pasangtiyo⁵ and Yoshihiko Hashino⁶

Abstract

This study aims to develop the on road emission and fuel consumption models that can be applied with a traffic simulation to estimate emissions and fuel consumption of motorcycles in Asian developing countries. The motorcycle onboard measurement system was developed to measure instantaneously and continuously record the on road driving data, including speed-time profile, emissions and fuel consumption, by every second. The testing motorcycle was driven on road network of Khon Kaen City to collect the on road driving data during the morning peak hour for 2 months. The collected on road driving data was applied to develop on road emission and fuel consumption models by using regression analysis. The on road exhaust emission and fuel consumption models were developed with high relations between amount of exhaust emissions and fuel consumption with instant speed and acceleration rate. The two strategies of traffic management for motorcycle at signalized intersection, including exclusive zone for motorcycle stopping for signal and exclusive left-lane and Hook Turn for motorcycle, were evaluated by applying a traffic simulation with developed models. The study road section was a section of Sreechan Rd. with 3 signalized intersections in Khon Kaen City. The evaluation results reveal that both strategies could improve level of service of intersections by decreasing travel time, delay and queue length at intersections and reduce fuel consumption and emissions of vehicles travelling through intersections once comparing with existing condition.

1. Introduction

Motorcycle has become a popular mode in many Asian cities with its high accessibility. It is a private vehicle for almost low-income households due to cheap and advantage for a short distance travel in the congested cities. However, motorcycle was recorded as highest mode violated traffic rules and involved in traffic accidents. To alleviate this problem, appropriate traffic management and
control concerning with motorcycle is necessary rather than traffic rule education and traffic law enforcement. To evaluate traffic control strategy in term of emission and fuel consumption reduction, an estimation of on road emissions and fuel consumption by traffic simulation is necessary. It requires emission and fuel consumption models sensitive to instantaneous speed profile of motorcycle. The existing driving cycle of motorcycle may not be a good representative for driving cycle of other cities. Therefore, the objectives of this study are to develop emission and fuel consumption rate models and to present an application of developed models through evaluating the traffic control strategies for motorcycle.

2. Research methodology

This section explains the procedure of research method as displayed in Figure 1. The scope of this research is classified into two parts. The development part is the approaches which are developing the models of on road emissions and fuel consumption. The application part is the approaches which are applying the developed models to evaluate the traffic control strategy for motorcycle. Each method for each part of the research will be expressed as the following.

2.1 Onboard measurement system development

To instantaneously measure and continuously record the speed-time profile and the exhaust emissions of the motorcycle driving on the road network, the onboard measurement system was further developed from the previous study (Seedam et al.,
2014) by installing onboard the motorcycle. The developed onboard measurement system consists of several units, including the data logger for processing and recording the collected data, the rear wheel speed sensor for measuring the speed, the exhaust gas analyzer for measuring an amount of exhaust emissions. The installing positions of system units onboard motorcycle are displayed in Figure 2. The component and function of system units are described in detail below.

![Figure 2 Component Units of Developed Onboard Measurement System](image)

The data logger was designed and developed to process the collected data from several measurement units and to record it into the data storage. It consists of the microcontroller and the memory storage. Since the microcontroller has to process and record the data within a short period because the signal data from many installing measurement units is converted to the record format and is recorded into the memory storage every second. The microcontroller for this system was therefore designed for real-time visibility of the recording data and easy accessibility by dividing the microcontroller into two parts. The first part processes the data from the rear wheel speed sensor. The second part processes the data from the exhaust gas detector and records all data into a memory card. The transferred data in the microcontroller and the installing measurement units is displayed in Figure 3.

![Figure 3 Detail Diagram of Onboard Measurement System](image)
To measure the speed of the driving motorcycle, a magnetic sensor was installed on the rear wheel of the motorcycle to detect the wheel rotation every second. The magnetic poles were installed on the rear wheel. While the wheel is rotating, the magnetic poles will produce the pulse. The pulse is then converted to a voltage signal by using a voltage converter circuit. Finally, the microcontroller will convert this voltage signal to speed-time data.

To measure the amount of emissions, including CO, CO2, HC, and NOx, the mobile exhaust gas analyser, was installed on the rear side of motorcycle as displayed in Figure 2 because the suction tube of the equipment can be connected to the motorcycle’s exhaust pipe. The suction tube sucks the exhaust gas into the equipment to analyse the amount of emissions. The analysed data is displayed on the monitor of equipment and recorded in the memory storage by second.

To measure the existing position of the motorcycle driving along a road network, the GPS module is installed on the high position of the motorcycle. The microcontroller transfers the data of position and speed of driving motorcycle to the memory storage every second.

To test the accuracy of the developed motorcycle onboard measurement system, the testing motorcycle was driven on a specific route to measure and record its speed-time profile and the exhaust emissions. The collected speed-time profile compared with the exhaust emissions is plotted as a graph displayed in Figure 4. While the speed of driving motorcycle was increasing with constant acceleration, the amount of emitted CO2 was increasing as displayed by Figure 4(b) because the engine was combusting more gasoline and air, and hence produces more amount of CO2. However, once the driving speed of the motorcycle was increasing with increasing acceleration, the amount of emitted CO and NOx was increasing as shown in Figure 4 (a) and (d). Increasing acceleration caused imperfect combustion which emits more
amount of CO and NOx. Vice versa, while speed-time of motorcycle driving was decelerating, the amount of emitted HC was increasing, as shown in Figure 4(c). Since the deceleration is reducing the engine combustion, the remaining combusted gasoline and air therefore is increasing. All tested results imply that the developed onboard measurement system could accurately measure and record the on road driving data of the motorcycle.

2.2 Collection of on road driving data

This study selected the Khon Kaen City, i.e. Khon Kaen Municipality, as a study area since this city represents the characteristics of Asian developing cities, e.g., high congested traffic condition, especially during peak hours, and a high number of motorcycles, approximately 30% of mode share (SIRDC, 2008). Khon Kaen province is located in the Northeast of Thailand. The Khon Kaen City covers an area of 228 km². Recently, there is about 250,000 population living in this city.

To measure the on road driving pattern and exhaust emissions, the onboard measurement system was installed on the selected motorcycle. The selected size of motorcycle was a 4-stroke 113 CC motorcycle which is a small-size motorcycle normally used in Asian developing cities. The motorcycle was driven on the selected routes of Khon Kaen City network, as displayed in Figure 5, to collect the on road driving data during the morning peak hour between 7:00 a.m. to 9:00 a.m. for 112 hours.

2.3 Development of on road exhaust emission and fuel consumption models

The on road emission rate model presents the instant amount of emission (gram/sec) corresponding to instantaneous speed-time profile (km/hr, s). The on road exhaust emissions (CO, CO2, HC, and NOx) and speed profile of motorcycle driving on road network simultaneously collected by every second were applied to develop the on road exhaust emission rate model by using the linear regression analysis.

As similar to a development of on road exhaust emission rate model, the on road fuel consumption rate model presents the instant amount of fuel consumption (gram/sec) corresponding to instantaneous speed-time profile (km/hr, s). The on road fuel consumption and speed profile of motorcycle driving on road network simultaneously collected by every second were applied to develop on road fuel consumption rate model by using the linear regression analysis.
Figure 4 Motorcycle speed-time profile with exhaust emissions
2.4 Survey of road geometric and traffic data

To present an application of developed models of on road emission and fuel consumption, this study would apply the models to evaluate the traffic management strategy for motorcycle in term of emissions and fuel consumption reduction. A section of Sreechan Rd. with three signalized intersections, as displayed in Figure 6, was selected to implement the traffic management strategy for motorcycle since the Sreechan Rd. is the main arterial through CBD of Khon Kaen city with a high number of traveling motorcycle. A cross section of study road section is two-way two-lane with left roadside parking lane presented. The data of road geometric and traffic was collected for traffic simulation model development.
2.5 Traffic simulation model development

The framework of this study for traffic simulation model development is displayed in Figure 7. To evaluate the traffic management strategy for motorcycle at signalized intersection in terms of emissions and fuel consumption, the traffic simulation software that enables to simulate the behavior of individual vehicle traveling pass through signalized intersection, especially motorcycle, was required. This study selected the VISSIM software because the VISSIM currently is only one of traffic simulation software that has a function enabling to model lateral behavior of motorcycle when the motorcycle taking over the slower or stopping other vehicles at signalized intersection. Moreover, the VISSIM can measure the speed-time profile of individual vehicle while it travel passing the signalized intersection. The speed-time profile of individual vehicle, i.e. instant speed and acceleration rate by every second, was necessary information as an input data for emissions and fuel consumption rate models. The turning count data in intersections during morning peak hour (7:30 – 8:30 AM) was applied to develop the morning peak hour OD matrix for a process of model calibration. The turning count data in intersections during evening peak hour (4:30 – 5:30 PM) was applied to develop the evening peak hour OD matrix for a process of model validation. The OD matrixes were also classified into four vehicle types, including motorcycle (MC), passenger car (PC), pickup truck and van (LT) and 6-wheel truck and bus (HT). These OD matrixes were inputted in VISSIM through a function of turning movements.
To calibrate the developing traffic simulation model, this study simulated the morning peak hour OD matrix on the developing network. The results from modeling, including traffic flow and maximum queue length, were compared with same traffic measures simultaneously surveyed during the same period of morning peak hour OD matrix. The differences and GEH value are checked with criteria and they must pass the acceptance target as presented in Table 1. The GEH value is calculated by Equation 1. The traffic simulation model was developed similar to real condition as much as possible by adjusting the driving behavior parameters until the target traffic measures were accepted.

To validate the calibrated traffic simulation model, the evening peak hour OD matrix was simulated on the calibrated developing network. The traffic measures resulted from modeling were compared with same traffic measures collected during the same period of evening peak hour OD matrix. The differences and GEH value were checked with criteria and they must pass the acceptance target as presented in Table 1. The driving behavior parameters were adjusted in the repeating calibration process until the target traffic measures were accepted.
Table 1 Criteria and measures for model calibration and validation

<table>
<thead>
<tr>
<th>Criteria and Measures</th>
<th>Calibration Acceptance Targets</th>
</tr>
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<tbody>
<tr>
<td><strong>Hourly Flows, Model Versus Observed</strong></td>
<td></td>
</tr>
<tr>
<td>Individual Links Flows</td>
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<tr>
<td>Within 15%, for 700 veh/h &lt; Flow &lt; 2,700 veh/h</td>
<td>&gt; 85% of cases</td>
</tr>
<tr>
<td>Within 100 veh/h, for Flow &lt; 700 veh/h</td>
<td>&gt; 85% of cases</td>
</tr>
<tr>
<td>Within 400 veh/h, for Flow &gt; 700 veh/h</td>
<td>&gt; 85% of cases</td>
</tr>
<tr>
<td>GEH Statistics &lt; 5</td>
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</tr>
<tr>
<td>Total Link Flows</td>
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<tr>
<td>Within 5%</td>
<td>All Accepting Links</td>
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<tr>
<td>GEH Statistics &lt; 4</td>
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<tr>
<td><strong>Maximum Queue Length, Model Versus Observed</strong></td>
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<tr>
<td>Queue Length by Individual Approach</td>
<td></td>
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<tr>
<td>Within 20%</td>
<td></td>
</tr>
</tbody>
</table>

\[
\text{GEH} = \sqrt{\frac{(V-C)^2}{(V+C)/2}}
\]

Where as

\( V \) = Modeled traffic flow
\( C \) = Surveyed traffic flow

2.6 Calculation of Emissions and Fuel Consumption

This study calculated the emissions and fuel consumption by individual vehicle. The individual vehicle’s instant emissions and fuel consumption of each time step are calculated by applying the developed emission and fuel consumption rate models with a velocity and an acceleration rate of each time step of that individual vehicle, resulted from the traffic simulation model. Total emission and fuel consumption of the individual vehicle are the summary of instant emission and fuel consumption at each time step of that vehicle. Total emission and fuel consumption of all vehicles are calculated by Equation 2.

\[
\text{Total Emission/Fuel Consumption} = \sum_{i=1}^{n} \sum_{j=1}^{m} \sum_{k=1}^{3} \text{Instant Emission/Fuel Consumption of a Vehicle}
\]

Where as

\( i = 1, 2, 3, ..., n \) (Number of time step)
\( j = 1, 2, 3, ..., m \) (Number of vehicle)
\( k = 1 = \text{Motorcycle}, 2 = \text{Passenger Car}, 3 = \text{Pickup truck} \)
2.7 Evaluation of Traffic Management Strategy for Motorcycle

This study applied the developed on road emission and fuel consumption models to evaluate the strategy of traffic management for motorcycle at signalized intersection in term of reduction of emissions and fuel consumption. Two strategies, 1) Exclusive zone for motorcycle stopping for signal and 2) Exclusive left-lane and Hook Turn for motorcycle, were evaluated. The developed traffic simulation model was applied to simulate the traffic management strategy for motorcycle implementing on the study road section. To evaluate the strategy, condition with implementing by each strategy would be compared with the existing condition. Thus, the three scenarios are determined as follows.

1) Scenario1: Existing condition
2) Scenario2: Condition with implementing Exclusive zone for motorcycle stopping for signal
3) Scenario3: Condition with implementing Exclusive left-lane and Hook Turn for motorcycle

The evaluation parameters, including, traffic Measure Of Effectiveness (MOEs), emissions and fuel consumption, are considered to determine the most appropriate the traffic management strategy for a motorcycle at signalized intersection. The traffic MOEs consists of average travel time, average delay and average queue length by motorcycles, other vehicles, and all vehicles. The emissions include CO2, CO, HC, and NOx of motorcycles, other vehicles, and all vehicles. The fuel consumption was also considered by motorcycles, other vehicles, and all vehicles.

3. Results and discussions

3.1 Results of on road emission model development

The on road emissions and speed profile of motorcycle driving on road network simultaneously collected by every second were applied to develop on road emission models by using the regression analysis. The results of model development were displayed in Table 2. As the results, the relations between emissions of CO2, HC and NOx and instant speed as well as acceleration rate are very high as their values of R2 are very close to 1, except that the relation of CO emission and instant speed as well as acceleration is not high. These developed on road emission rates were further applied to evaluate the traffic management strategy for motorcycle in term of emissions. As development of emission rate models of other vehicle types, the emission data measured in Automotive Emissions Laboratory of Pollutant Control Department (OTP, 2013) was applied to develop the emission rate models. The models were classified into two types of fuel usage, Gasoline and Diesel engine.
models were classified into two types of fuel usage, Gasoline and Diesel engine. The emissions include CO2, CO, HC, and NOx of motorcycles, other vehicles, and all vehicles. The evaluation parameters, including Traffic Measure Of Effectiveness (MOEs), which consists of average travel time, average delay and average queue length, are considered to determine the most appropriate traffic management strategy for a motorcycle at signalized intersection. The fuel consumption and instantaneous speed as well as acceleration rate is high, a coefficient of determination (R²) closing to 1. This developed on-road fuel consumption rate model was further applied to evaluate the traffic management strategy for motorcycle in term of fuel consumption reduction in the next chapter.

### 3.2 Results of fuel consumption model development

The on road fuel consumption and speed profile of motorcycle driving on road network simultaneously collected by every second were applied to develop on road fuel consumption rate model by using the regression analysis. The result of model development was presented in Table 3. As the result, the relation between fuel consumption and instant speed as well as acceleration rate is high, a coefficient of determination (R²) closing to 1. This developed on-road fuel consumption rate model was further applied to evaluate the traffic management strategy for motorcycle in term of fuel consumption reduction in the next chapter.

**Table 2 On road emission rate models of motorcycle**

<table>
<thead>
<tr>
<th>On road emission rate models of motorcycle</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>LN(EMR\textsubscript{CO}) = 0.101 - 0.002u + 0.449a</td>
<td>0.571</td>
</tr>
<tr>
<td>LN(EMR\textsubscript{CO2}) = 0.269 + 0.005u - 0.548a</td>
<td>0.961</td>
</tr>
<tr>
<td>LN(EMR\textsubscript{HC}) = 0.005 - 0.000099u + 0.014a</td>
<td>0.811</td>
</tr>
<tr>
<td>LN(EMR\textsubscript{Nox}) = -0.001 + 0.000089u - 0.015a</td>
<td>0.931</td>
</tr>
</tbody>
</table>

where as EMR = Emission Rate (g/s), u =Instant Speed (km/hr), a = Acceleration Rate (m/s\textsuperscript{2})

### 3.3 Results of traffic management strategy evaluation

The evaluation results of traffic flow measures of effectiveness are displayed in Table 4. As results of motorcycle’s traffic flow measures of effectiveness, both strategies could improve the motorcycle’s traffic flow measures from the existing condition. The strategy of exclusive zone for motorcycle stopping for signal (decreasing 13.7% of average travel time, 4.8% of average delay of motorcycles from the existing condition) could improve traffic flow measures of motorcycle less than the strategy of exclusive left-lane and hook turn for motorcycle (decreasing 23.9% of average travel time, 30.4% of average delay of motorcycles from the existing condition).

**Table 3 Fuel consumption rate model of motorcycle developed by collected data**

<table>
<thead>
<tr>
<th>On road fuel consumption rate model of motorcycle</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>FR = 0.0041 + 0.004u - 0.277a</td>
<td>0.838</td>
</tr>
</tbody>
</table>

where as FR = Fuel Consumption Rate (ml/s), u = Instant Speed (km/hr), a = Acceleration Rate (m/s\textsuperscript{2})
As results of traffic flow measures of effectiveness of other vehicles, both strategies also could improve traffic flow measures of other vehicles from the existing condition. The strategy of exclusive zone for motorcycle stopping for signal (decreasing 18.9% of average travel time, 21.3% of average delay of other vehicles from the existing condition) could improve traffic flow measures of other vehicles more than the strategy of exclusive left-lane and hook turn for motorcycle (decreasing 4.4% of average travel time, 5.1% of average delay of other vehicles from the existing condition).

As results of traffic flow measures of effectiveness of all vehicles in the system, both strategies could consequently improve traffic flow measures of all vehicles from the existing condition. The strategy of exclusive zone for motorcycle stopping for signal (decreasing 15.2% of average travel time, 17.2% of average delay, 22.6% of average queue length of all vehicles from the existing condition) could improve traffic flow measures of all vehicles more than the strategy of exclusive left-lane and hook turn for motorcycle (decreasing 3.3% of average travel time, 3.4% of average delay, 12.9% of average queue length of all vehicles from the existing condition).

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>1. Existing</th>
<th>2. MC Stopping Zone</th>
<th>3. MC lane &amp; Hook turn</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average Travel Time (sec)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motorcycle</td>
<td>63.5</td>
<td>54.8 (-13.7%)</td>
<td>48.3 (-23.9%)</td>
</tr>
<tr>
<td>Other Vehicles</td>
<td>143.1</td>
<td>116.1 (-18.9%)</td>
<td>136.8 (-4.4%)</td>
</tr>
<tr>
<td>All Vehicles</td>
<td>125.9</td>
<td>106.7 (-15.2%)</td>
<td>121.8 (-3.3%)</td>
</tr>
<tr>
<td><strong>Average Delay (sec)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motorcycle</td>
<td>50.4</td>
<td>48.0 (-4.8%)</td>
<td>35.1 (-30.4%)</td>
</tr>
<tr>
<td>Other Vehicles</td>
<td>127.2</td>
<td>100.1 (-21.3%)</td>
<td>120.8 (-5.1%)</td>
</tr>
<tr>
<td>All Vehicles</td>
<td>111.7</td>
<td>92.5 (-17.2%)</td>
<td>107.9 (-3.4%)</td>
</tr>
<tr>
<td><strong>Average Queue Length (veh)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All Vehicles</td>
<td>31</td>
<td>24 (-22.6%)</td>
<td>27 (-12.9%)</td>
</tr>
</tbody>
</table>

The evaluation results of emissions are displayed in Table 5. As results of motorcycle’s emissions reduction, both strategies could reduce emissions of motorcycles from the existing condition. The strategy of exclusive zone for motorcycle stopping for signal (decreasing 5.0% of CO2 emission, 3.3% of CO emission, 1.9% of HC emission, 2.0% of NOx emission of other vehicles from the existing condition) could reduce emissions of motorcycles less than the strategy of exclusive left-lane and hook turn for motorcycle (decreasing 8.9% of CO2 emission, 15.4% of CO emission, 23.0% of HC emission, 23.0% of NOx emission of motorcycles from the existing condition).
As results of emissions of other vehicles, both strategies also could reduce emissions of other vehicles from the existing condition. The strategy of exclusive zone for motorcycle stopping for signal (decreasing 9.1% of CO2 emission, 8.7% of CO emission, 8.6% of HC emission, 8.9% of NOx emission of other vehicles from the existing condition) could reduce emissions of other vehicles more than the strategy of exclusive left-lane and hook turn for motorcycle (decreasing 3.8% of CO2 emission, 5.7% of CO emission, 7.0% of HC emission, 3.5% of NOx emission of other vehicles from the existing condition).

As results of emissions of all vehicles in the system, both strategies could consequently reduce emissions of all vehicles from the existing condition. The strategy of exclusive zone for motorcycle stopping for signal (decreasing 7.4% of CO2 emission, 8.2% of CO emission, 8.4% of HC emission, 8.7% of NOx emission of other vehicles from the existing condition) could reduce emissions of all vehicles more than the strategy of exclusive left-lane and hook turn for motorcycle signal (decreasing 6.0% of CO2 emission, 6.8% of CO emission, 7.6% of HC emission, 4.2% of NOx emission of other vehicles from the existing condition).

Table 5 Results of Emissions Evaluation

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>1. Existing</th>
<th>2. MC Stopping Zone</th>
<th>3. MC lane &amp; Hook turn</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CO2 Emission (kg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motorcycle</td>
<td>690.1</td>
<td>655.7 (-5.0%)</td>
<td>628.4 (-8.9%)</td>
</tr>
<tr>
<td>Other Vehicles</td>
<td>932.5</td>
<td>847.2 (-9.1%)</td>
<td>896.8 (-3.8%)</td>
</tr>
<tr>
<td>All Vehicles</td>
<td>1,622.6</td>
<td>1,502.9 (-7.4%)</td>
<td>1,525.3 (-6.0%)</td>
</tr>
<tr>
<td></td>
<td>CO Emission (kg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motorcycle</td>
<td>338.7</td>
<td>327.5 (-3.3%)</td>
<td>286.6 (-15.4%)</td>
</tr>
<tr>
<td>Other Vehicles</td>
<td>2,823.3</td>
<td>2,576.6 (-8.7%)</td>
<td>2,661.2 (-5.7%)</td>
</tr>
<tr>
<td>All Vehicles</td>
<td>3,162.0</td>
<td>2,904.0 (-8.2%)</td>
<td>2,947.8 (-6.8%)</td>
</tr>
<tr>
<td></td>
<td>HC Emission (kg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motorcycle</td>
<td>134.0</td>
<td>131.4 (-1.9%)</td>
<td>103.2 (-23.0%)</td>
</tr>
<tr>
<td>Other Vehicles</td>
<td>3,484.7</td>
<td>3,184.9 (-8.6%)</td>
<td>3,240.0 (-7.0%)</td>
</tr>
<tr>
<td>All Vehicles</td>
<td>3,618.8</td>
<td>3,316.2 (-8.4%)</td>
<td>3,343.2 (-7.6%)</td>
</tr>
<tr>
<td></td>
<td>NOx Emission (kg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motorcycle</td>
<td>134.2</td>
<td>131.5 (-2.0%)</td>
<td>103.3 (-23.0%)</td>
</tr>
<tr>
<td>Other Vehicles</td>
<td>3,806.7</td>
<td>3,467.1 (-8.9%)</td>
<td>3,673.2 (-3.5%)</td>
</tr>
<tr>
<td>All Vehicles</td>
<td>3,940.9</td>
<td>3,598.6 (-8.7%)</td>
<td>3,776.5 (-4.2%)</td>
</tr>
</tbody>
</table>
The evaluation results of fuel consumption are displayed in Table 6. As results of motorcycle’s fuel consumption, both strategies could reduce fuel consumption of motorcycles from the existing condition. The strategy of exclusive zone for motorcycle stopping for signal (decreasing 2.8% of fuel consumption of motorcycle from the existing condition) could reduce fuel consumption of motorcycles less than the strategy of exclusive left-lane and hook turn for motorcycle (decreasing 18.5% of fuel consumption of motorcycles from the existing condition).

As results of fuel consumption of other vehicles, both strategies also could reduce emissions of other vehicles from the existing condition. The strategy of exclusive zone for motorcycle stopping for signal (decreasing 16.8% of fuel consumption of other vehicles from the existing condition) could reduce fuel consumption of other vehicles more than the strategy of exclusive left-lane and hook turn for motorcycle (decreasing 3.9% of fuel consumption of other vehicles from the existing condition).

As results of fuel consumption of all vehicles in the system, both strategies could consequently reduce fuel consumption of all vehicles from the existing condition. The strategy of exclusive zone for motorcycle stopping for signal (decreasing 14.0% of fuel consumption of other vehicles from the existing condition) could reduce fuel consumption of all vehicles more than the strategy of exclusive left-lane and hook turn for motorcycle signal (decreasing 6.9% of fuel consumption of other vehicles from the existing condition).

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>1. Existing</th>
<th>2. MC Stopping Zone</th>
<th>3. MC lane &amp; Hook turn</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fuel Consumption (kg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motorcycle</td>
<td>44.60</td>
<td>43.34 (-2.8%)</td>
<td>36.36 (-18.5%)</td>
</tr>
<tr>
<td>Other Vehicles</td>
<td>177.44</td>
<td>147.56 (-16.8%)</td>
<td>170.45 (-3.9%)</td>
</tr>
<tr>
<td>All Vehicles</td>
<td>222.04</td>
<td>190.90 (-14.0%)</td>
<td>206.81 (-6.9%)</td>
</tr>
</tbody>
</table>

4. Conclusions and Recommendations

The onboard measurement system was developed and installed on the motorcycle to drive on the selected routes of Khon Kaen City road network to measure the driving pattern, exhaust emissions and fuel consumption. The on road emissions, fuel consumption and speed profile of motorcycle driving on road network simultaneously collected by every second were applied to develop on road emission and fuel consumption models by using the regression analysis. As the results of regression analysis, the on road emission and fuel consumption rate models were developed with high relations between emissions and fuel consumption, and instant speed and acceleration rate. The evaluation results reveal that both strategies could improve the level of service of the study intersections by decreasing travel time, delay and queue length at intersections. Also, the fuel consumption and emissions of vehicles travelling through intersections decreased. The strategy of exclusive zone
for motorcycle stopping for signal could more improve intersection’s level of service and less fuel consumption and emissions of vehicles than the strategy of exclusive left-lane and Hook Turn for motorcycle at these study intersections. As recommendations for further studies, the developing onboard measurement system can be further used to collect the on road data that can be used to develop the eco-driving cycle for a motorcycle that can be applied for a development of an eco-driving assistance system for a motorcyclist for reducing fuel consumption and emissions. The developed on road and fuel consumption rate models will be further applied to evaluate other traffic planning, such as a design of traffic signalized control at intersection or a design of coordination control of signalized intersections for minimizing emissions and fuel consumption.

5. Acknowledgement

The authors would like to express their appreciation to the Asian Transportation Research Society (ATRANS) for financial support on this research work.

6. References


CLIMATLANTIC : MOBILITY STRATEGIES TO REDUCE CARBON FOOTPRINT IN ATLANTIC AREA

Véronique Seel\(^1\), Dominique Breuil\(^2\),

Abstract
During CLIMATLANTIC project, partners have developed an approach to reduce the carbon footprint for Atlantic Area territories. The project was conducted in a coordinated manner based on four topics in which reductions should be found: land planning, energy, mobility of people and goods, and change in behavior. This approach has resulted in a set of policy recommendations in each of the topics, addressing territorial authorities. EIGSI was responsible for the Mobility topic. The objective of the communication is to analyze the transferability of these recommendations on Mobility in the context of developing and emerging economies. After recalling the main results of CLIMATLANTIC project, the presentation will be devoted first to the study the specificities of the AA territories regarding Mobility and other topics and to the priorities and recommendations which have been identified, ranging from research and training to improve mobility conditions, each inducing a set of actions to be implemented by strategic choice of leaders of such communities. Then the presentation will focus on the definition and organisation of actions related to the transport of people and goods in an urban and peri urban territories and the issues under the various externalities that influence the mobility in these specific contexts. Finally it will be concluded with the analysis of the transferability

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1  Context of CLIMATLANTIC

Climate change has become a major concern for the future of Europe. This applies both to efforts to mitigate climate change by tackling the growth in greenhouse gas emissions and the need for measures to adapt to the impacts of climate change.

Together these challenges will impact on the development of Europe's economies and societies over the coming years. However the different regions of the Atlantic Area will not respond homogeneously to these challenges due to the wide diversity of productive structures across the Atlantic Area, more sectorial specialisations in the southern countries and more diversification in the northern part of the Atlantic Area.

The Atlantic Area is likely to be more vulnerable to climate change than other European regions. Apart from the consequences of climate change, the transfer of population towards coastal zones, unemployment rates and economic issues will have a direct relationship with transport organisation and mobility demand. The range of the impacts on transport is quite large, directly or indirectly, from the eventual reductions of land and increase of flood risks to population moves and agricultural production changes. To face these challenges a two-fold strategy should be implemented: firstly a strategy that includes measures to reduce the emission of greenhouse gas emission from the transport system and from the productive sector, secondly a strategy for the adaptation of Atlantic regions to the short-term impacts of the climate change.

The overall aim of the CLIMATLANTIC project is to foster the development of strategies at regional and local level aimed at reducing the carbon footprint in the European Atlantic Area. This was to be achieved by setting up think-tanks drawn from participating regions to develop a list of proposals for strategic actions and policy changes and to draw up a list of pilot projects to be planned, executed and evaluated in one or more regions. The strategic analyses delivered by the Climatlantic Think Tanks are mainly conceived as helpful instruments for key decision makers at the local, regional and European levels.

Four thematic think-tanks were set up addressing key topics in which substantial reductions of the carbon footprint of the European Atlantic Area are envisaged: Energy and Mobility, both of them focussed directly on ways of reducing their associated GHC emissions and Spatial Planning and Social Behaviour, where it is examined how urban development plans, transport systems and public attitudes might be modified in ways that would lead to GHG reductions.

Additionally, a fifth think-tank aims at developing a strategy for the reduction of the carbon footprint of the European Atlantic Area from the diagnosis and recommendations defined in the four thematic think tanks.

Each of the five think-tanks was coordinated by experts in the field and fed by the corresponding pillar working groups formed by experts nominated by the different organizations acting as partners in this Project.
This communication focuses on the mobility issues and recommendations which have been
developed during the project.

For a large and diverse territory like AA, mobility for passengers and goods is a multilevel
problem which requires coordinated and coherent solutions from the bottom level (ex
cities) to the top level which is a global entity, not really defined although several
institutions propose orientations or directives.

Several tools and methodologies exist in order to help local authorities improve mobility
with regards to Climate criteria (cf for instance Sustainable Urban Mobility Plans\(^3\),
SUMPs). These local optimisations suffer sometimes some lack of coordination and some
incoherencies between neighbouring or similar cities.

To help filling the gaps or clarifying overlaps, CLIMATLANTIC approach was developed
at 2 levels

- A global strategic framework focusing on the major orientations regarding AA
  mobility challenges and providing recommendations for actions and projects. These
  have been consolidated by interviews with several politicians.
- A methodology to help organising territories according their own specificities and
  objectives. This methodology has been tested on the territories of some
  CLIMATLANTIC partners

Although dedicated to the AA territories, this approach remains generic and could be
deployed on other large territories.

2 Mobility Strategy Framework

This first approach was split in 3 parts

- A generic state of the art among all the propositions which have been recently
  expressed regarding AA mobility
- The characterisation of AA specificities and trends dealing with transport demand
  of passengers and goods
- The elaboration set of recommendations and priorities

2.1 AA mobility context

Considering the importance of transport in the general economy and its high impact on
carbon footprint, all the political decision-making European institutions have taken
positions and developed actions to reduce these impacts as much as possible. European
Commission as well as local authorities associations (like the Conference of AA cities)
have expressed their positions and given some orientations for the future of transport in the
AA.

The global situation of European transport is described in the several projects and studies
which have been mentioned already. Few of them are detailed at the regional level

\(^3\) Cf [www.mobilityplans.eu/docs/SUMP_guidelines_web.pdf](http://www.mobilityplans.eu/docs/SUMP_guidelines_web.pdf)
(NUTS3). In the same way, the level of GHG transport emissions at regional AA level is not clearly determined.

In general in Europe, the highest motorway density is found around European capitals and other big cities. However there are big differences within the AA since two of the regions where this density is highest are Greater Manchester (138km/1000km²) and Merseyside (100 km/1000 km²). Coastal regions with a thriving tourism industry have noticeably denser motorway networks than other peripheral regions. Except for the UK, the railway density in km² is low in all AA.

However, when the density is calculated versus the number of inhabitants, the position of the AA regions tends to increase due to the demography.

Apart from Northern Ireland and UK, the tonnage ratio of road freight between international and national is around 1/5 (Eurostat). Even on the north/south corridor, less than 25% of the transiting freight is international. For the remaining goods transported by road, the majority of them (around 60%) do not travel more than 500 km, which means they rarely cross over a region, they have a tendency to remain in the same region (departure and arrival).

Regions with better accessibility to raw materials, suppliers and markets enjoy generally more competitive market positions. The majority of the AA regions are under the average level of accessibility in Europe (ESPON Polyc).

Considering Maritime transport, the number of passengers in AA ports is very low. For the freight, slightly more than 90 M tons went through Le Havre harbour in 2009 which is double the amount of freight going through Portugal, Nord west Spain or NW UK or Ireland. And the total of those five regions matches the South Nederland tonnage (Rotterdam).

Although the number of small airports has increased in the recent years mainly in the south of AA, the number of travellers remains quite low compared to other European regions and did not really increase in the past years. Apart from Manchester and Eastern Ireland, AA regions stand in the lower half of the hierarchy in number of air travellers (Eurostat 2009). It is the same for freight transport. However the fast development of low-cost flights in the southern regions

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4 Eurostat regional yearbook 2010  
5 Eurostat tran_r_magom nm  
6 Eurostat: tran_r_avpa nm
of AA could change this position although this increase concerns all the south of Europe (ex Porto, growing something like 15-20% per year in the last 2-3 years, more than 5 million passengers per annum by now). They could for instance follow the growth of Liverpool John Lennon Airport: since 2001, passenger numbers have increased eight-fold, with 5.5 million passengers using Liverpool in 2007.

The FOCI project used the "contactability" indicator to measure the links between cities in Europe. Considering the possibilities to make a return travel in one day (14hrs) plus 6 hours work in between, the FOCI project constructed a map for travels by plane and rail. For AA regions, around 20 larger cities were included in this study which shows that apart for UK and Ireland, connections between AA cities are quite scarce and connections with outside parts of Europe are quite centralised towards capital cities.

Travel surveys show that the overwhelming majority of trips (97.5%) are ‘short’ distance (not longer than 100 km). The remaining 2.5% of trips account however for more than half (53%) of all passenger km. In general 40% of all trips are work-related. The remaining 60% falls into the categories of leisure activities and informal work (such as household work and child care). Leisure time (and travel) could become more prominent in the future, as time use surveys show a tendency in more prosperous societies for leisure time to approach time devoted to obligatory activities, those being equally divided into formal and informal work.

2.2 Evolution of mobility demand

2.2.1 Mobility drivers in AA

These drivers are strongly related to urban sprawl which influences both transportation of passengers and goods will essentially. 4 drivers are the basis of all movements in a territory:

- Demography
- Age of the population
- Urbanisation
- Economy

Demography

The different scenarii proposed in DEMIFER concerning the changes in population for 2050 with regard to different policies, show that there is a strong difference between AA regions. France, UK and Ireland population should increase in some scenario by 75% (min 50%) meanwhile in Spain and Portugal it will decrease between 25% to 50%. Overall the population in AA regions is expected to grow.

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7 Source Transtool, cf also Transvision final report, march 2009, Report on Transport Scenarios with a 20 and 40 year Horizon
8 DEMIFER Demographic and Migratory Flows affecting European Regions and Cities, Final Report Sept 2010
This is confirmed by the prospective on the coastal European regions\textsuperscript{9}; currently in 97\% of these regions more than 50\% of the inhabitants live less than 50 km from the sea. The population concentration in this coastal strip exceeds 75\% of the region’s population in the case of 88\% of these regions. Some 194 cities with more than 100,000 inhabitants are also located less than 50 km from the sea. These major conurbations are home to 38\% of these regions’ inhabitants.

\textbf{Ageing population}

Europe is experiencing an ageing population\textsuperscript{10}. However, the proportion of elderly persons (over the age of 65) compared to the national average differs appreciably from region to region. According to several scenario (ex ESPON) it is likely that the population in AA regions will not reach a critical ageing dependence ratio in 2050 with the exception of North Portugal. Immigration concerns mainly young people, the ageing process is slower in the areas experiencing population growth.

Although there are pockets where retirement migration has created unbalanced age structures in AA regions, the population of many accessible, intermediate or rural areas is relatively young, due to in-migration of young families in pursuit of a “rural lifestyle”. Age clearly influences travel patterns. Above a certain age, people travel less than when they were younger. The general increase in life expectancy and improved health provision however mean that older people can nowadays enjoy the pleasures of independent mobility for longer than previous generations. Moreover, old people today generally travel more than the same age group did in previous decades thanks to the greater availability and financial accessibility of mobility and to the acquired habit of travelling more.

\textbf{Urbanisation}

Urbanisation has increased over the past decades (51.2\% in 1950, 72.2\% in 2005 in Europe\textsuperscript{22}) and has modified transport needs. Local and short distance trips, collective transport and commuting are issues specific to urban transport. The proportion of the population residing in urban areas is expected to increase from 72\% in 2007 to 84\% in 2050.

\textsuperscript{9} Eurostat regional yearbook 2010
The negative externalities of transport – congestion, air pollution, noise – are far higher in urban areas. An urban environment shortens distances and allows for economies of agglomeration which, from a certain size and under certain conditions, may however become diseconomies (congestion, high land prices and rents, insecurity)\textsuperscript{11}.

Urban areas and their hinterland are no more two separate entities; they overlap and interlink in a complex system of economic and social interactions. Examples are commuting, service provision, leisure and recreation activities. These linkages result in development patterns which underlie trends and changes over time. Urbanisation, counter-urbanisation and commuting are key drivers in rural-urban development. As a result of these flows, many accessible rural areas are well integrated into a wider functional urban area, with the advantages this brings in terms of access to jobs and higher order services.

The case of gateway cities, bridging worldwide networks with the European territory deserves special attention. They are mainly large port and airport cities and are particularly subject to the dynamics of worldwide integration, in terms of trade and migration flows, but also exchange of knowledge. Their worldwide interface functions favour their intra-European networking at macro-scale as well as at intra-regional level

\textit{Economy}

Economy is the result of human life in a territory, which generates products or services to attract investors or to generate exports. It is an essential component which is directly connected to urban sprawl and population evolution; it generates flows of people and goods.

Current urban development – at least in Western Europe and during the last 50 years - has been characterised by a shift of business activities to suburbs. Indeed, tendency for jobs to increase faster in the suburbs and on the urban fringes than in the centres and inner districts of metropolitan areas is characteristic of all developed countries. This trend is slowing down especially with the rebirth of city centres in major cities (for instance in AA in Liverpool, Bordeaux, Bilbao…), creating offices, retail centres, shops… in populated areas of cities; this is also one of the reasons for the quite recent concern about city logistics.

The structure of industrial business is changing in AA\textsuperscript{12}. There are structural processes that respond to the new organisation of productive activity and changes in the competitive strategies of numerous enterprises, as they become part of the so-called knowledge society and flexible system of production in a global world. This readjusts urban and metropolitan economic trends and leads to the development of new industrial areas, while others are affected by a sharp decline in their traditional activities.

This situation is particularly evident in many AA cities as a result of the industrial structure they have inherited, characterised by the predominance of low-technology sectors, dependent on natural resources and labour and traditionally affected by cost competition and significant negative environmental externalities. The strategies applied by local and regional public authorities to adjust and redevelop concerned areas have varied greatly and

\textsuperscript{11} The Future of Transport, Focus Groups’ Report 20.02.2009
\textsuperscript{12} Strategies for Revitalising Industrial Sites in AA, REVITA, INTERREG IIIB project, Espace Atlantique
resulted in differing industrial sector developments. These strategies are strongly linked to the transport networks' improvements both for passengers and freight (cf for instance TGVs influence on regional developments of companies and plants).

Among the large variety of industrial and services activity sectors in the AA some have already been identified as the key factors of growth like:

- Food industry as well as earth grown material were conditionally a major sector
- The development of tourism is anticipated to increase in the coming years
- The improvement of the gateways is a strong economic driver.
- The new technologies “NBIC” (nanotechnology, biotechnology, information technology and cognitive science, referred to as “converging technologies”) should be a source of economic development\(^{13}\). these sectors should drive the next innovation wave which is expected to emerge by 2020.
- The development of marine energies should also contribute to the economic development. The deployment of renewable energies production systems will offer a direct alternative to fossil fuels and the possibility to use it locally

2.2.2 Demand prospective

The trends on mobility demand will differ according to the situation of the cities.

The most significant demand's evolutions in AA will concern:

- A general increase of the mobility expectations for passengers and freight both locally (for instance increased urban sprawl) and on long distance (ex leisure and global economy)
- The diversity and personalisation (requiring spatial and time flexibility) of the needs adapted to the different categories of citizens from residents (work, shopping,....) and travellers (tourism, business)
- The growing concern on environmental, security, safety and health criteria in the modal choices
- The development of e commerce
- Rapid transit for passengers and freight as well as hubs facilities and regrouping platforms

2.3 Strategic framework

The objective of this global level approach is to focus on recommendations which should be significant for AA territories. The first step was to determine what are the types of territories in AA; then, this framework is divided in 3 parts which will be general guidelines for territory:

- Policies directly linked to the context and specificities of AA
- Policies likely to be influenced by them
- Generic policies which are relevant although not specific. These will not be mentioned in this communication

\(^{13}\) Polycentric Europe, smart connected places, ESPON report 2010
### 2.3.1 Types of territories

Considering the previous AA specificities, 3 main types of regions represent the various structural situations that can be found in AA regions regarding both territorial organisation and mobility considered as the accessibility to the main centres of the area:

- predominantly urban, dominated by a metropolitan area (accessibility <60mn)
- group of equivalent medium sized cities grouped in a polycentric network, (accessibility <40mn)
- medium sized city with smaller satellites (accessibility <40mn)

This analysis must be completed by the population density. The difference between dense of diffuse area is expressed through the density of population per Km², according Eurostat and Epson studies, the threshold is around 80 inhab/Km²

From these assessments, the second and third above categories may be split in 2. This leads to 5 types of territories' situations which can be characterized more precisely. This approach takes into account the structural organisation and internal flows in an area.

Size and boundaries of specific territories are always difficult to determine precisely. Several factors need to be taken into account to assess the contactibility between the living spots, especially small or remote areas like:

- the distance of the nearest city which gives access to services and hub functions (attractivity aspect),
- their integration in global flows due to specific situation or activity; for example, this is the case for touristic areas (lot of them in AA) or a worldwide branded local product (Cognac or Porto for instance !) or high tech/ knowledge center
- the proximity with neighbouring regions. Co-operation between adjacent rural regions can enhance their position, for example in marketing their assets or accessing urban services (for instance Pau and Tarbes in south west of France)

### 2.3.2 Policies linked to the context

These recommendations are based on the foreseen evolutions of the transport activities context. These evolutions will have impacts at local level on carbon footprint and their consequences on policy making must be considered when developing new transport strategies. Obviously they were mainly related to the geopolitical situation of AA and proposed actions like:

- the increase of the number of european gates and their efficiency (harbours, airports, stations). Many of the exiting gates depend on local authorities. Several types of measures can be undertaken both to promote their advantages, to develop new maritime routes (ie encouraging new small companies with clean vessels), to optimise the various technical components (from Information to loading, handling, storing,…), to use renewable (marine) energies, to integrate the connections to these gates in the local transport strategies.
- the conditions to enter and the provided quality services should meet minimum quality standards (preferably homogeneous in all AA gates) for all types of actors.
in an each type of gates whichever the size of the gate is and for all type of services (information of travellers, freight handling,...).

- the improvement of the connections between long distance and local/ regional ones for both passengers and freight. This concerns the localisation of hubs, logistics platforms, and the optimisation of their role as decoupling external and internal flows links with territorial management).

- The development of transport networks to facilitate the transit to/from the gates and the related hubs and platforms ; especially In many areas, like in the costal corridor in the north of Porto the gateway character poses important transport and logistical problems, due to the concentration of significant traffic generators like port area, airport, logistic companies, most of them associated with external trade logistics

- The upgrading of existing infrastructure and the development of multimodal terminals at sea and river ports and on city logistic consolidation centres

Building or renovation activities should aim at minimising environmental impacts of transport infrastructures. This means that Local Authorities should encourage :

- the utilisation of renewable energies ; marine energies should be used in all the sea terminals.

- the development of energy positive buildings and equipments using appropriate material and supervision systems to monitor the life of the infrastructure

In the intermediate distances, new technologies are less mature and modal choices are fewer than in cities or urban communities. Cars and trucks will remain the most utilised transport modes among the connecting transport modes, except :

- The connections between AA major cities (and with the gates) are improved using rail or coaches networks which require a complete renovation of the related infrastructure and operating methodology

- Sea routes are developed (cf Interreg and Marco Polo programmes for instance)

- Capillarity links between territories, infrastructures as well as transport modes, are adapted to the various demands for passengers and freight transport.

2.3.3 AA influenced policies

This concern all types of activities such as :

- Information systems and especially journey planners, which information must be available for all European customers or service providers which can transfer/ transform these data to their own customers in order to facilitate the movement of people and goods. All development should be realised within European Integrated Multimodal Information and management Plan

- The respect of CO₂ and pollutant emissions standards for vehicles or transport activities on their territories. The encouragement of business-based GHG certification schemes and the utilisation of common EU standards in order to estimate the carbon footprint of each passenger and freight journey to allow better choices of cleaner transport solutions.
Obviously the support of Local Authorities must support these innovative developments and mainly on the following points:

- Effective coordination of all research works which intend to improve AA transportation situation. This begins with the definition of coordinated and clear orientations for research organisms, includes support and/or incentive to develop and promote local competences dealing with these specific problems and requires a real management of the cooperation between all stakeholders. An effective network regrouping all transport research team in AA should be set up.

- Education institutions dealing with the specificities of the transport maritime aspects should be developed in order to provide skilled, experienced and competitive labour forces

- This coordination must be linked with implementation of efficient decision aid tools to monitor the evolution of mobility in each territory of the AA, to develop perspectives related to AA situations according to recent and specific changes and to consolidate the global requirements. Mobility observatories are too few in AA and current forecast surveys and models are too generic

- Development of supports the SMEs which propose innovative approaches in mobility concepts and technologies, not only on fundings but also in several promotional and marketing activities.

3 Methodology for territories

The aim of this second part of the CLIMATLANTIC approach is to give territories' organisations guidelines to develop their own measures to reduce carbon footprint with respect to the strategic framework and ensure coherence with other AA territories. The first question is to determine the "territory" ; regarding mobility (as well as other social activities) territories are not defined by administrative boundaries but by more subtle criteria.

To build an appropriate context-specific methodology several topics must be taken into consideration

- The nature of the territory
- The instantiation of the mobility domains in the territory
- The type of measures/instruments which can be utilised

Mobility improvements of projects can be identified with this 3 dimensions approach as well as the appropriate indicators which can evaluate their benefits and costs.

3.1 Nature of territories

ESPON projects (DEMIFER, FOCI and EDOMA) clearly show the differences between AA regions regarding several criteria. The report on metropolitan areas in Europe\(^ {14} \) proposes a complementary approach on the functions performed by cities and agglomerations at the regional or local level in order to organise and control the various social systems which are represented in their territory. 6 types of functions are identified:

\(^{14}\) Metropolitan areas in Europe, FRUS, BBSR-Online-Publikation Nr. 01/2011
• Living facilities: housing, shops, crafts,…
• Social facilities: transport, health,…
• Administration: politics, law & courts, police,….
• Innovation & prospective: research, education, innovation,…
• Culture: arts, sports, tourism
• Economy: industries, services,…

Looking at these functions with a mobility view precise the context and the specificities of each territory; this will lead to appropriate proposition for mobility improvements.

3.2 Mobility domains

Mobility presents several faces, according to the points of views of its various stakeholders. CIVITAS programme proposed eight domains as the basic building blocks of an integrated strategy for clean urban transport. Cities strategies are designed in combining actions or measures belonging to several of those blocks.

The TIPTAP project\(^{15}\) approach is more territorial development oriented and is based on territorial identity or efficiency.

Combining these two approaches and considering the objective of CLIMATLANTIC, the following domains have been identified as the most susceptible to be the theatre of local authorities’ decisions applicable in each of the 5 types of territories. These domains of actions are for passengers and freight:

• Clean fuels and vehicles grouping all actions in favour of the development of more environmental friendly transport resources
• Mobility management encompassing decisions which tend to organise mobility of citizens and goods, from personalised travel plans to integrated pricing. These decisions are also linked to development strategies of the Territory and of its main components (ex cities)
• Alternative mobility usages or modes which can be described as less car intensive life style or "soft measures". This domain encompasses activities dedicated to the behaviour changes from stakeholders
• Demand management: this covers all actions which aim to optimise the demand response
• Collective passengers transport on several aspects like quality of services, travel information, network development, intermodality, ticketing. Although this is clearly people oriented, similar actions could be developed for goods in the future, especially with the development of Internet of Things or freight mixity
• Logistics: this deals with the actions aiming to improve the distribution of goods over an area, urban, peri urban or regional. They can be related to fleet management, route planning, storage facilities,…
• Mobility information systems which covers all actions related to information technologies, from mobile exchange to operation exploitation software

\(^{15}\)TIPTAP: Territorial Impact Package for Transport and Agricultural Policies, ESPON project
• Infrastructures: covers all actions related to the design and implementation of any kind of infrastructure not taken into account in previous topics. This domain is strongly linked to Land Planning actions.

3.3 Types of instruments and impacts on carbon footprint
In each of the above domains, local authorities may set up different instruments or measures to improve mobility. They can be grouped 5 different types in which only actions dealing with carbon footprint reduction have been kept in CLIMATLANTIC

3.3.1 Managerial position (governance)
These instruments concern the positioning of local authorities regarding the stakeholders involved in the transport system and the structure of their relationships. They generally will not have a direct impact on carbon footprint but they will be multipliers (or dividers) of the efficiency of the operational instruments. This positioning must be defined between 2 extremes which can qualified as
- Virtual when there is a lack of central management authority; the equilibrium of the whole systems relies upon relatively invisible mechanisms. So the organisation lies upon more or less explicit behaviour of actors (for instance the congestion in certain streets at specific hours,...)
- Directed when system is centrally managed during long term operation to continue to fulfil those purposes.

Of course mobility system over a large city is rarely in these extreme situations; a collaborative organisation between stakeholders has to be set up by local authorities to determine the roles and duties of every one.

3.3.2 Monitoring instruments
Monitoring instruments refer to all the measures which aim to predict and control mobility activities; these include planning, traffic control, regulations, evaluation of implementations, etc. ... up to legal or social initiatives regarding specific target groups. Among these instruments are for instance limitation of emissions or optimising fuel efficiency

Planning instruments comprise all measures that concentrate on planning the utilisation of the various resources to meet the transport demand passengers and freight as already mentioned). Impacts of these measures may be short term (real time adaptation of a network capacity) or very long term like the planning of infrastructures.

3.3.3 Economic instruments
This type of measures concerns the financial actions intending to encourage more energy efficient vehicles, to reduce demand for transport and encourage modal shift, etc.

The range of these instruments is quite broad. It goes from the pricing strategy of fully integrated networks to incentive for companies to use more environmentally efficient vehicles.

3.3.4 Information instruments
The aims of this type of instruments are to inform each target groups or mobility users on
the actions and improvements envisaged or realised. They deal with the development of communications and information media as well as raising public awareness or to stimulate the use of alternative travel modes. They cover different kinds of actions such as:
- promotion of services, mobility modes through various media from paper newsletter to most advanced web2.0 sites
- organisation of workshops, conferences, manifestations
- training & education of existing drivers as well as future ones

3.3.5 Technological instruments
The implementation of technologies represent the most visible part of the actions realised in each domain. Regarding these instruments, local authorities have 3 types of actions:
- either they are in the position to implement innovative equipment or systems in a proactive way to push all actors in mobility to reduce their GHG emissions; Guidance systems, real time information on traffic on bus shelters as well as charging/fuelling facilities or optimising delivery bays localisation and usage are examples of such actions
- or they can only facilitate and encourage these actors to use such equipment
- or they can help enterprises which develop such equipment on their territory

3.4 Relations between instruments and mobility domains
The final step of the methodology is to determine what actions or measures was appropriate in a specific territory for each mobility domain. The matrix in the next page contains the main topics which must be studied and detailed in "polycentric" territories and adapted according the context of each of them.

A similar approach has been developed inside the Partnership on Sustainable, Low Carbon Transport (SLoCat); 3 types of territories have been identified in developing countries in order to propose targets (vs the 5 Climatlantic territory type): rural, urban, national and regional connectivity.
Among the 6 main targets, 3 are about the accessibility of the 3 type of territory and the 3 others are about road safety, Quality of air and GHG reduction. Furthermore, SLoCat points out all the questions about the crosscutting contribution of transport to sustainable development and connects transport’s key dimensions under other possible sustainable development goal.

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16 http://www.slocat.net/
<table>
<thead>
<tr>
<th>Managerial position</th>
<th>Coordination of different types of vehicles/services</th>
<th>Mobility Management</th>
<th>Alternative mobility modes</th>
<th>Demand Management</th>
<th>Collective PT</th>
<th>Logistics</th>
<th>Infrastructures &amp; land Planning</th>
<th>Mobility SI &amp; NTIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clean fuels and vehicles</td>
<td>Choice of motorisation, common procurement procedures for the different types of vehicles/services</td>
<td>Inter cities strategies for Intermodality, integrated mobility planning &amp; Involvement of stakeholders PPP framework</td>
<td>Strategies for cooperation with companies, institutions associations for mobility plans for Soft modes</td>
<td>Identification of representative targets Organization of demand and flow analysis for targets (rural/urban...)</td>
<td>Organisation of links between cities, homogeneousness between cities Linking the business community and public transport</td>
<td>Cooperation with regional freight operators &amp; stakeholders, Extended Freight partnerships</td>
<td>Coordination of the evolution of techniques and technologies of Info Systems (ex mobile info, web2.0, RFID, accessibility of public transport data...)</td>
<td></td>
</tr>
<tr>
<td>Logistics</td>
<td>Homogenisation of Plan for the development of clean fleets in Local Authorities Follow up of emissions, Air quality...</td>
<td>Coordination of the tariffs evolution, including links between cities Continuous evaluation of modal share in/between cities Mobility observatories</td>
<td>Coordination of sharing vehicles systems with cities PT systems Development of inter cities connections Periodical evaluation of the number of users</td>
<td>Requirement evolution analysis Orientation of the demands, Access follow up, respect of regulations</td>
<td>Hierarchical network optimisation according local and inter cities demand Connectivity with outside world (ex P+R, links to main stations...) Periodical surveys for PT and non PT users</td>
<td>Analysis of the evolution of goods flows in/between each city Definition of city logistics areas Hierarchical logistics master plan, coordination of good flows between cities, homogenisation inside cities</td>
<td>Coherence in the design and set up of infrastructure Evaluation of impacts on urban &amp; territory evolution</td>
<td></td>
</tr>
<tr>
<td>Infrastructures &amp; land Planning</td>
<td>Coordination of exploitation &amp; maintenance resources Local incentives for clean vehicles Joint procurement Funding from various organisms</td>
<td>Facilitation of commercial, industrial activities Integration of environmental externalities Mutualisation of services</td>
<td>Fiscal incentives to companies that support ecological mobility plans Coordinated tariffs for vehicles sharing (integrated pricing)</td>
<td>Adaptation of transport resources to demand Coherent &amp; homogeneous deployment of clear zones and accessibility scheme for all cities, Definition of</td>
<td>Define a clear and sustainable and common scheme for financing for PT</td>
<td>Grouping/dispatching flows for cities Diversification of activities in UCCs, optimisation of deliveries Access restrictions</td>
<td>Coherence in the design and set up of infrastructure Evaluation of impacts on urban &amp; territory evolution</td>
<td></td>
</tr>
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<td>Mobility SI &amp; NTIC</td>
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</tbody>
</table>

| Information systems : intermodal | Promotion of Clean fleets for enterprises Awareness campaigns Eco driving learning | Clear Tarification propositions, Coordinated Info offices and campaigns dedicated to each specific mode Maps of the zone | Maps, routes and regulations about access restriction, Public Transport Integrated on-line, on ground information | Traffic information for drivers (remote & real time) info and stakeholders | Insert Intelligence and communication capabilities in construction Signing, coherence in design... | Ergonom / accessibility of Information systems |
|---------------------------------|-----------------------------------------------|--------------------------|------------------|--------------|----------|----------|------------------|------------------|
| Technology | Development of local services providers and manufacturers | Mobility agencies, specific planning and strategic software | Clean shared vehicles Car sharing websites, All access and supervision TIC equipment and soft | Clean adapted fleet(ex on demand), Accessibility and conviviality for passengers | Advanced delivery bays, Consolidation centers & logistics platforms, urban freight organisation & operators, Environmental friendly buildings Integration of new services (ex Battery loading facilities, accessible fuelling stations...) | Journey planners Smart card, contact less, internet loading |

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The aim of this matrix is to point out all the actions and projects (grouping actions) which can be launched in a territory; since they have been defined at the global level, they stand as a coherent framework in which coordinated local actions (for instance city level) can be initiated. This approach reveals the synergies and synchronisations between them as well as avoids perverse or contradictory impacts.

4 Transferring to other territories
As far as Mobility and CO2 reduction are concerned, transferability is often limited to good practices examples or theoretical models. Methodology frameworks are proposed to implement SUMP which are mainly oriented towards cities, not really to larger territories. The aim of CLIMATLANTIC was to design a first attempt to fill in the gaps in existing approaches, providing a structured multilevel methodology for territories encompassing several types of living urban, peri-urban and rural.

So far, many projects and experiences have provided a wide range of concepts and instruments for transferability in mobility domains, depending on different goals, contexts of application, measures, policies to transfer, actors involved…

The EU project Sharing Opportunities for Low carbon Urban transport (SOLUTIONS)\(^\text{17}\) stresses the importance of practical collaboration by accommodating exchange of innovative transport solutions between cities from Europe, Asia, Latin America and the Mediterranean. The main aim is to address global challenges and EU objectives for sustainable urban mobility, energy efficiency and fight against climate change. The reinforcement of a global dialogue between Europe and other industrialised and emerging countries and the implementation of specific solutions in China, India, Brazil and Mexico are both key outcomes of the project.

Another project, SaferBrain\(^\text{18}\), aims to improve safety levels of the road transport system and its components in Emerging Economies, focusing the attention on vulnerable road users (VRU’s), and contributing to the overall scope of reducing the number of fatalities and severity of injuries caused by road accidents in countries such as India and Brazil. The main outcome of the project is the development of a generalized transferability audit checking the applicability and acceptability of Measures, Guidelines and Tools.

For CLIMATLANTIC, transferability is based on the ability to adapt the multilevel methodology according to the various contextual characteristics of a more or less urbanised area defined with respect to extended contactability criteria. Such an approach gives the opportunity to mix efficiently several solutions, to set up the framework for different projects which can be managed rigorously and to optimise synergies of actions in an integrated strategy for territorial development.

\(^\text{17}\) http://www.urban-mobility-solutions.eu/
\(^\text{18}\) http://www.saferbrain.eu/
THE IMPORTANCE OF MARKETING PROCESSES ON THE PERCEPTION AND IMAGE OF PUBLIC TRANSPORT IMPLEMENTATION STAGE FOR AN INTEGRATED MARKETING POLICY IN THE BUCHAREST AGGLOMERATIONS

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Abstract

Objectives:
• Needed as cities move their attention on citizens’ needs and on better communication
• Need focused on educational and informational policies for changing behavior

Methodology:
• Stakeholder Consultation and Public Information into a SUMP.
• Exploring ‘best practices’ in public transport marketing and branding world.
• Analyzing background of marketing for mobility in Romanian agglomeration; Particularity of Bucharest agglomeration.
• Passenger rights and obligations (EU and national regulations).
• Steps needed in the marketing field for short, medium and long terms, to improve mobility in Romanian Municipalities.

Data:
• Case study: Public Transport Marketing in Bucharest agglomeration
• Presentation of Bucharest area, social-economic, mobility and organizational aspects;
• Analysis of PT network in Bucharest area; key figures and issues.
• Marketing and Information System: responsibilities, current status and SWOT analyses
• Brand and identity
• Internal communication
• User education/ information systems
• Marketing campaigns
• Public relations and external communications
• User feedback systems
• Online engagement
• Necessary measures and actions for optimization and integration, part of SUMP;
• Actors’ responsibilities

Conclusions and results:
• Sustainable approach;
• Short and long term results.
URBAN MOBILITY AND AIR QUALITY IN CLUJ-NAPOCA, ROMANIA

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Abstract
The aim of this paper is to analyze the implications of the reduced development of the public transport in Cluj-Napoca, Romania, during the last decades against the changes in other aspects such as urban form, land-use, population, economic development, motorization indexes, etc. A series of elements should be analyzed in this respect: urban mobility aspects, quality of public transport services, and air quality aspects.

Methodology: After the presentation of the travel-related zones, the outcome will be considered under specific urban mobility aspects such as modal share, public transport availability and possible improvements. In terms of air quality related to public transport, the gap of missing data is willing to be overcome by several studies.

Data: The general data in the urban area will be collected from the institutions in the field and specific data will be gathered from the local public transport company.

Expected conclusions: As a result of the multi-layered analysis several suggestions will be provided for further improvements to the local policy.
INFORMAL TRANSPORT SERVICES IN BOGOTÁ AND N’DJAMENA: ACTORS, INTERACTIONS AND CHARACTERISTICS

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Abstract
Most informal transport services in developing countries display a high number of different actors directly or indirectly involved. They often tend to develop networks in order to help negotiate with other institutions, maintain services and solve problems. These networks can become very powerful and understanding them is essential for further improvement of informal public transport and its integration into formalized structures.

We analyse the interrelationships of the actors involved in informal transport services in Bogota (Colombia) and N’Djamena (Chad). We do so by using information collected in onsite research, mainly comprising interviews with syndicates, drivers and vehicle owners, but also observations. Both cities’ services are organised and formalised to differing degrees, with Bogota offering formalised trunk services via its BRT System and some integrated feeder lines, whereas N’Djamena has no formal service. The informal services assessed in Bogota are the “Bici-taxi” services, who mainly offer feeder services for the BRT. In N’Djamena we analyse the case of “moto-taxis”, who play a major role in suburban areas especially.

In conclusion, we describe each city’s network of actors (by identifying the actors, their function and role for public transport, and their internal hierarchies and interdependencies) and discuss their different characteristics. We also aim to gain deeper understanding of how the network of actors is influenced by the cities’ transport services’ level of formalisation, and to consider aspects of governance to interpret our findings.
IMAGINING COMPLETE STREETS FOR DEVELOPING AFRICA

David O. Nelson¹, Nels O. Nelson², Eline Bakker³,
with assistance from Helawie Sewnet⁴ and Kai Hoffman⁵

Submitted for Presentation at
CODATU XVI, February 2015 at Istanbul Technical University, Turkey

Abstract
The North American Complete Streets movement is a reaction to that culture’s excessive concern for automotive mobility to the virtual exclusion of all other modes. Other cultures have not made that mistake to the same degree but the authors imagine that the lessons and methods integral to Complete Streets may be useful for the developing world. In this paper, the authors review key elements of the Complete Streets approach and review possible adaptations and applications that respond to the unique needs of rapidly urbanizing areas in developing nations.

Over the last decade, a “Complete Streets” have movement has taken the world’s most heavily motorized nations⁶ by storm... The movement seeks to rectify deficiencies in traditional street design processes and standards through policies broadening the level of service on urban streets to more diverse constituencies.

Complete Streets is a design and management approach that plans, designs and maintains streets for safe, convenient, inclusive and comfortable travel and access by users of all ages and abilities regardless of their mode of transportation while also

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⁶ United States, Canada and Australia
reimagining streets as not just a way to get from here to there safely; but also as places, in and of themselves, serving diverse social, economic, and environmental needs.

Design elements of a North American Complete Street vary based on context and project goals, but they generally include: pedestrian infrastructure such as sidewalks, crosswalks, shade trees, and accommodations for wheelchairs, strollers, and travel by the disabled; traffic calming measures; bicycle accommodation; mass transit accommodations, such as bus pullouts and shelters, transit signal priority, and dedicated bus lanes; and streets as places.

The authors imagine that urbanizing Africa (and other rapidly urbanizing regions) might adapt and employ principles from the Complete Streets movement. Perhaps the developing world can sidestep the errors made when many western streets were built in the second half of the 20th century. But Complete Streets for African cities need to respond to different needs from their North American counterparts. Unique considerations for the African context and elsewhere in the developing world include:

- A large informal sector that places unique demands on the pedestrian areas of city streets and can impinge on the space available for pedestrians.
- Many unsanctioned and informal settlements with improvised public services.
- Very low levels of motorization and a wide range of non-motorized conveyances create more opportunities for conflict between motorized and non-motorized travelers.
- Minibuses, integral to African urban transport, place unique demands on streets as stops and terminal areas consume more curb space than typical for larger and less frequent conventional bus service.
- Concerns about safety at crossings are exacerbated when the numbers of vulnerable non-motorized travelers increase.
- With rapid rural-to-urban migration, large fractions of the populace have little experience with fast moving motor vehicles.
- The choice of facility construction and maintenance techniques and materials affects how easily streets can be maintained. Non-African materials are expensive. Labor is relatively cheap, but financial resources are dear.
- Cultural norms relating to gender roles add additional complexity to mobility management.

The paper imagines how African transport planners might expropriate the Complete Street concept for application to challenges faced in rapidly urbanizing areas of the developing world.

**Introduction**

African cities and the rest of the developing world are constructing or redeveloping streets, roadways and other transport facilities. Many developments reflect traditional North American standards that favor automobiles over other modes for mobility. Those standards are changing in North America in recognition that they do not promote the interests of all travelers and are not
well adapted to the multi-modal urban milieu. North American cities are coming to recognize
deficiencies in their design paradigms and embracing a more holistic view of streets.

Background
For more than 50 years, North American transportation planning and design primarily focused on
the movement of automobiles. This created a transport network that was well adapted for a
society with high rates of motorization, available land and inexpensive fuel. Streets and roads
were convenient for drivers but the needs of other travelers, including younger or older people,
those with disabilities, and those who traveled by transit, bicycle, other non-motorized
conveyances or foot were generally under serviced. In the last decade, increasing numbers of
North Americans have to come to recognize that cities and neighborhoods lack safe places to
walk or cycle to key community resources such as shops, schools and parks.

The Complete Streets movement started gaining momentum ten years ago focusing on the design
and construction of multi-modal streets that safely serve all modes and travelers, including
pedestrians, cyclists, and transit riders as well as motorists. In recent years, 27 US states, 42
regional planning organizations, 38 counties and 379 municipalities in 48 states have adopted
formal policies that require roadway officials to plan, design, construct, operate and maintain
appropriate facilities for pedestrians, bicyclists, transit vehicles and riders, children, the elderly
and people with disabilities in all new roadway construction, retrofit or reconstruction projects.
(Seskin and Gordon-Koven, 2013)
What is a Complete Street?

Complete Street programs are a mix of governance, policy and technical elements. The policy and governance start with a regulatory framework that defines the vision and intent, scope, review process, performance measures, exceptions and variances and implementation. At a technical level, the policies focus on network connectivity, street design and context sensitivity.

- **Context Sensitive** - A “Complete Street” responds to adjacent land uses and local needs. Each street should reflect its setting, traffic mix, traffic volumes, motor vehicle speeds. Each project must be considered both separately and as part of a connected network. Each connection needs to facilitate changes in mode and reduce the potential for conflicts between different uses of the same streets and connections.

- **Network Connectivity** - A “Complete Street” is part of a connected, integrated multi-modal network that provides transportation options for all travelers regardless of their mode, status, wealth, age or gender.

- **Street Design** - A “Complete Street” is a living, flexible, holistic entity. Its morphology reflects multi-modal, pluralistic details relating to cross-section, connections, throughput, level of service and materials.

**Context Sensitive**

Context sensitive street designs reflect a mélange of values. The design solutions do not rigidly adhere to automobile-centric standards, instead the design results from a collaborative, interdisciplinary approach involving all stakeholders. The Complete Street process marries engineers and planners with the community and other stakeholders to integrate and balance community, aesthetic, historic and environmental values with transportation safety, maintenance and performance goals.

Every street is a place as well as a thoroughfare. Urban planning skills in place making and community involvement are applied. As a result, there is no “one size fits all.” Every context is unique. Consequently every street can be different as it responds to the particular needs of travelers and neighbors that use that street. The successful complete street designer displays flexibility and sensitivity over and above technical competence. Complete street design entails extensive collaboration among diverse interests to achieve a whole that is greater than the sum of its parts.

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7 This paper focuses on the technical considerations. For more about policy and governance, the interested reader can start their online search at www.smartgrowthamerica.org.
Network Connectivity
Networks of complete streets have four characteristics. (Congress for the New Urbanism, 2012)

1. **Key Nodes** - The network focuses on key locations where multiple mode-specific networks overlap and connect. This maximizes connectivity and improves mobility for all travelers regardless of mode.

2. **Inherently diverse and complex** - The network of Complete Streets encompasses a broad hierarchy of streets that accommodate many different mixes of traveler types. Most streets are designed to serve traffic in all forms. The fastest roadways may be restricted to motor vehicles while others are designed to be quiet with only the occasional motor vehicle. Sustainable street networks feature a rich array of street and route types, rather than contextless, blanket design.

3. **Safe and walkable** - Pedestrians and non-motorized vehicles need to be able safely move along (and across) the broadest arterials. All but the highest speed roadways must be safe for all users, especially accommodating non-motorized modes.

4. **Proper spacing and design of major streets** - Major streets have the greatest potential for large-scale placemaking providing for social, civic, and commercial activity. Major streets should accommodate travelers with different modes and different speeds within a single cross section. A major boulevard should support faster speeds in the center, and slower speeds and non-motorized modes in the outside lanes.

Well-connected street networks improve mobility by allowing people to travel more directly. With connected streets, more destinations are accessible by non-motorized modes.

City streets fall into two broad categories: arterials and non-arterials.

- **Arterials** are the city’s trunk lines that connect neighborhoods to major destinations
- **Non-arterials** connect arterials with neighborhoods.

An operating speed limit of 40 kph is a typical for arterials located in areas with high pedestrian volume. A universal targeted operating speed of 25 kph is a good target for turning movements at intersections. (Los Angeles City Planning Department, No Date) Within the two broad categories, the hierarchy ranges from wide to narrow with the greatest width assigned to the highly motorized thoroughfares. But all streets have the same cross sectional elements in various
degrees and details with the fastest motorized modes at the center of the street and the slowest pedestrian travel on the outer fringe. The elements to be considered in the design of complete streets are arrayed in Figure 3 and discussed below.

**Street Design**

The design of complete streets encompasses a hierarchy of streets along a continuum from major arterials including expressways, boulevards and avenues through local roads and streets to minor alleyways and pedestrian walkways. Major arterials accommodate higher motorized speeds and volumes with positive safeguards to reduce intermodal conflicts and protect non-motorized travelers. Safeguards can be relaxed as motorized traffic speeds and volumes are reduced. At the lowest end of the continuum non-motorized modes dominate as motorists crawl down the street through the neighborhood.

![Figure 4: Elements of the Prototypical Complete Street Design](source: City of Chicago, 2013)

The **Pedestrian Realm** is commonly referred to as the sidewalk. It is divided it into three zones,

- **Frontage Zone** - is the area between the walkway and building, fence or yard. Typically this is the edge of the right of way. It may be nothing more than the place where people stand to window shop or where there’s a front stoop or a door mat. Or it may contain an outdoor café, benches, or bike parking.

- **Walking Zone** - is the area dedicated to walking. It should provide a logical unobstructed path of travel. Attempts to create meandering sidewalks usually fail because pedestrians want to the walk in the most direct route. It should be sized to provide sufficient space for the expected pedestrian volumes, but not overly wide as to appear barren.

- **Sidewalk Furniture Zone** - lies between the curb and walking zones. It features street trees, planters, bus shelters, parking meters, utility poles, lamp posts, signs, bike racks, news racks, benches, waste receptacles, and water fountains. Placing these items in this zone keeps the walking zone free of obstructions. This zone can be landscaped in residential neighborhoods and provides some level of separation between children playing on the sidewalk and moving traffic.
The Interstitial Area lies between the pedestrian realm and the motorized lanes. This highly flexible area contains elements used by all modes. On larger roads in North America it is the primary place for cycling. It is generally built ~20 cm below the pedestrian realm with a well-defined curb separating the two areas. The curb prevents water and cars from encroaching on the sidewalk.

- **Transit Stops** - Buses, taxis and vans pickup, discharge and wait for passengers in the interstitial area along the curb. The waiting passengers stand in the pedestrian realm but the vehicles remain below the curb on the verge of the motorized lanes.

- **Bicycle facilities** present difficult challenges because cyclists can operate like both pedestrians and automobiles. A high quality facility will separate cyclists from both automobiles and pedestrians. Such a protected “cycle track” segregated from motor traffic with a second curb is recommended on streets where motorized speeds exceed 50 kph and cycling volumes are high or growing. Unprotected bike lanes are common in most North American cities but present more and more safety problems as cycle volumes increase. In cities where cycling is more common, such as Amsterdam and Copenhagen, bicycle lanes are less common with a greater proliferation of cycle tracks.

- **On-street parking** supports retail stores, slows moving traffic, and protects pedestrians from errant drivers and fast moving traffic. However, each parking space is also valuable land that can be used to extend the Pedestrian Realm or provide more exclusive facilities for bicycles and other slower non-motorized modes. Parking cars often conflict with cyclists. Motorized travel is often affected by cars and trucks idling in the travel lane waiting for a parking space to become available. It is very important to keep parked automobiles out of the pedestrian realm.

The Vehicle Realm is primarily reserved for motor vehicles. On smaller roads this realm would be shared with bicycles and other non-motorized conveyances.

- **Bus lanes** are travel lanes designated for exclusive use by buses. They may be rush-hour only or reversible lanes or they may be physically separated transitways. Under many circumstances bus lanes can be shared with cyclists, especially if there are low bus or bike volumes. On streets without dedicated bicycle facilities and where the bus lane is the right-most lane, cyclists should be allowed to share the bus lane, as there is no other practical place for cyclists to ride.

- **Travel Lanes** are typically used by automobiles, trucks, bikes and transit. The number of lanes should be kept to a minimum.

- The optional **median** is the center portion of a roadway, but not a motorized travel lane. It may be striped, protected with bollards, raised, or simply elevated above the drivable surface. Only larger streets have medians. They can serve many functions including maintaining separation between opposing directions of motorists and providing refuge for pedestrians crossing the street. Landscaped medians replace a non-functional paved area with green
infrastructure that can help with storm water retention and CO2 absorption while mitigating traffic noise. Landscaping makes streets more attractive.

Success Stories

**Madison, Wisconsin**, is the state capital and the home of the state’s largest university with 42,000 students and 18,000 employees. With so many students and a substantial population of low income families more than 9% percent of Madison walks to work; 5% take bikes, and 9% ride buses. (Slotterback and Zerger, 2013) This combined 23% is well above the combined North American average of 8%. To promote and facilitate non-motorized transport Madison has a long established and growing network of separate paths and lanes for non-motorized transport radiating from its core. It has also banned private automobiles from one its principal commercial streets making that street the exclusive preserve of buses, bikes and pedestrians.

**New Haven, Connecticut**, is the home of Yale University, but also a city with 25% poverty rate. As such, the community has large population of non-motorists and limited resources for street improvements. After several high profile pedestrian fatalities, local officials responded to a grassroots campaign with a community based program to identify and implement street improvements tipping the balance from motorists back toward pedestrians and cyclists. (Slotterback and Zerger, 2013) Much of the program is organized around feedback received via social media. Street improvements have focused on expanding and redefining the interstitial space between the motorized lanes and the pedestrian realm claiming space for cyclists and creating areas of pedestrian refuge that reduce opportunities for conflict where pedestrians cross streets.

**Sacramento California** is a state capital with a recent history of double-digit population growth that led to low-density, automobile-oriented residential and commercial development. In recent years, Sacramento residents started to complain that they did not feel safe biking or walking on most newer streets. Leadership recognized the need to create a more multimodal street network. With a new Complete Streets mandate, road maintenance work has been aggressively adding missing crosswalks and bike lanes and reducing motorway lane widths. On several streets...
receiving new treatments, total collisions dropped by 32 percent, with even more dramatic declines in bicycle and pedestrian crashes. (McCann, 2012) In one case, the city converted two one-way streets in downtown from three automobile lanes to two, creating room for new dedicated bike lanes in the interstitial area. The number of bicyclists on these streets more than doubled in one year and there has been a general downward trend in overall collisions.

Overseas, Bogota, Colombia, suffers from too many cars, too much pollution, and too many people; its nine million inhabitants are plagued by automobile horns, squealing buses, and thick smoke. Mayor Enrique Peñalosa took steps to balance the transport network against this by dramatically altering the network morphology creating bus-only lanes, pedestrian avenues, and exclusive bicycle lanes. He once said, “I was almost impeached for getting cars off sidewalks which car owning upper classes had illegally appropriated for parking.” (Martin, 2011) Bogota transformed one of the main deteriorating downtown avenues into a dynamic pedestrian public space in an effort to democratize the street system.

Curitiba, Brazil, has implemented systems to create jobs, improve public transportation accessibility, promote housing development, and improve waste management. City planners employed an integrated a "radial linear-branching pattern" to protect density by diverting traffic from the city center and protect green areas by encouraging industrial development along radial axes. Under the leadership of Mayor Jaime Lerner Curitiba created the first large scale “Bus Rapid Transit System.” (UN, 2011)

Complete Streets for Africa and the Developing World
Across the globe, traditional villages and ancient cities reflect an organic and holistic approach to building and maintaining streets and places. But the rise of the automobile is affecting streetscapes and urban form in every nation. Traffic jams and roadway fatalities are something that nearly every nation has in common. However, cities in Africa and elsewhere in the developing world face a complex of challenges distinct from their more developed cousins.

The African context for street design is very different from North American cities. The image of Complete Streets for Africa must respond to different conditions but the concepts relating to network connectivity, multimodal street design and context sensitivity still apply. Unique considerations in the African context include, but are not limited to the factors listed below.

Figure 6: Commercial activity in Frontage Zone spills all the way to the curb. Pedestrians forced into the Interstitial Area
Every vibrant city around the world has a strong informal sector where immigrants get their starts, deficiencies in established systems are addressed and critical demands are satisfied. The informal sector is very much alive on African streets. This places demands on the pedestrian realm that are tolerated and expected by the neighborhood but not always consistent with the street design. With generally mild or warm temperatures, storefronts in busy squares and along major arterials tend to spill out onto the sidewalk. Street vendors, hawkers, and beggars also work the sidewalk with no storefront whatsoever. These vital activities impinge on the space available for pedestrians sometimes “forcing” them into the interstitial zone to get where they are going.

Planful transport system development is hampered when large fractions of the populous reside in unsanctioned and informal settlements. Public services, including transport, for these marginal residents are generally improvised. Most travel by foot, minibuses and non-motorized conveyances. Some streets and networks are overwhelmed by this haphazard influx of population. It unrealistic to think that the informal sector can be removed or replaced. Instead, planners and engineers need to acknowledge and plan for its near term inevitability.

African cities have very low levels of motorization; perhaps the lowest on earth. Low use of private automobiles for personal travel has encouraged the development of vibrant minibus networks and the use of wide array of non-motorized conveyances. With relatively low levels of automobile use and high levels of non-motorized travel there is a clear tendency for the pedestrian realm and interstitial area to encroach on the realm nominally reserved for motorized vehicles. This entirely natural and understandable tendency creates more opportunities for conflict between motorized and non-motorized travelers and reduces the travel quality for both constituencies. It’s easy to
Imagine that the level of service offered to all travelers might be better if the formal boundary between the motorized and pedestrian realms were shifted closer to the middle of road with fewer or narrower motorized lanes and stronger sanctions against pedestrians in the motorized lanes and against automobiles on the sidewalk.

Denizens of African cities use a wider range of non-motorized conveyances than in many other parts of the world. Burros, horse carts, mules, push carts, and wheel barrows are fairly common. By contrast, due to the pavement conditions in parts of many cities, bicycles can be fairly rare. It’s not obvious to western transport planners what adaptations in the designs of major thoroughfares are appropriate for dray animals and human carried loads.

Minibuses are the integral to urban transport in Africa. With their high service frequencies, relatively small capacity and heterogeneity of routes the minibuses place unique demands on the interstitial zone and sidewalk furniture area where buses and passengers wait for one another. Minibus stops and terminal areas consume more curb space than typical for larger and less frequent conventional bus service due to the queues of the buses and passengers and the circulation space necessary for buses and passengers to find and make the appropriate connections.

Crossings and conflicts always pose significant safety concerns when non-motorized travelers need to interact with motor vehicles. These concerns are exacerbated when the numbers of vulnerable non-motorized travelers increase. Pedestrians spilling into the motorized lanes due to inadequate sidewalk and interstitial space add to conflicts that slow throughput for both motorists and pedestrians.
Law enforcement and traffic control is problematic in many developing nations. Enforcement and control becomes easier when there is good correspondence between the way the traffic facility was designed and how its users want to use it. Deficiencies in enforcement and control are compounded when drivers are inexperienced or poorly trained.

With rapid population growth resulting from both migration and fertility, African transport networks are increasingly stretched and challenged. Many streets in the oldest and most densely developed portions of the city offer a limited cross section for automotive travel without severely hampering pedestrian movement hence pedestrians tend to spill into the motorized realm creating safety hazards and hampering motorized movements. Perhaps some streets in these networks should be set aside as walking streets popular in older European cities.

With rapid rural to urban migration, large fractions of the populace have little experience with fast moving motor vehicles. Inexperienced pedestrians create new opportunities for conflicts with motorized traffic, especially where pedestrians intermingle with automotive traffic.

The choice of street construction and maintenance techniques and materials used to build streets affects how easily they can be maintained. Non-African materials are expensive. Labor is relatively cheap, but financial resources are dear. Perhaps a focus on locally sourced paving materials and simple lighting systems could allow African
cities to raise the standard of service offered by their street networks. Without proper maintenance, the utility of the street for all classes of travelers deteriorates. Maintenance of street lights is a particular challenge for African cities.

- Cultural norms relating to gender roles add additional complexity to mobility management. Women in skirts can’t or won’t ride bikes. Some traditions keep women from travelling in the company of unrelated men. These norms are not reflected in western designs for Complete Streets but will need to be addressed in many societies if streets are to serve the mobility needs of all travelers.

Applying Complete Streets Concepts to Rapidly Developing African Cities

Complete streets are local affairs. Each street is collaboratively designed in concert with local residents and travelers. Complete Streets are designed to provide a multiple overlapping networks across the city.

- Network - The Complete Street is a link in several overlapping networks that provide connectivity for safe travel by foot, non-motorized conveyance and motorized mode. Crossings and connections in the overlapping networks are must be thoughtfully designed to minimize interference and conflicts between non-motorized travel and automobiles. The Complete Street does not over-consider the needs of current and future automobile travelers to the exclusion of pedestrians.

- Street Design - As new streets are built or existing streets rehabilitated, engineers and planners must consider what roles this street must play in the overall network and then consciously consider how those network obligations can be met.
  - Careful design and management to provide adequate space and clear boundaries for the pedestrian realm will keep it from spilling into the interstitial area.
  - Thoughtful design to manage the flexible interstitial space will provide transit stops, paths for non-motorized conveyances and parking. Planners must consider where private automobiles will be stored when they are not in use. In African cities, there is tendency for automobiles to invade the pedestrian realm. This behavior is antithetical to Complete Street design. The interstitial space should be designed and managed to keep stopped transit vehicles, parked cars and non-motorized vehicles out of the motorized lanes on arterial and larger non-arterial streets.
Carefully mark and limit the motorized lanes where they are not to be shared with non-motorized transport. Keep travel lanes narrow in densely settled areas to limit maximum speeds and reduce the distances that pedestrians need to cross. Where the right of way is wide, motorized speeds are high and volumes of non-motorized conveyances are substantial, consider a second curb to protect the inner edge of the interstitial area.

Carefully consider how pedestrians and non-motorized conveyances will cross major streets.
Design connections and intersections in a planful manner with safety and efficiency for all modes in mind.

**Context** - On each street, actively work with the community and travelers to assign space to all users of the street. Complete streets are “living entities” that can change as their context changes. Actively manage the street to maintain or planfully adjust how street space is used. Design the street to be flexible and capable of adaptation over time as the needs of travelers and the community change.

Many African city dwellers walk to work, and African’s don’t yet consider this a luxury, but increasing numbers of North Americans are vying for circumstances where they’d able to walk 20 minutes to work. Planners of African cities have an opportunity to offer commuters-en-pied
safe travel by constructing sidewalks and protected footpaths and walkways designed with pedestrians (and other non-motorized travelers) at the forefront of the design.

Avoid an autocratic approach to roadway development. “All of us are smarter, than some of us,” so wise leaders listen to everyone and weigh their concerns before making decisions. The Complete Street is for everyone, not just the motorists.

Carefully consider materials, facilities and construction techniques to yield a street that can be economically maintained and operated. Some labor intensive paving techniques that exclusively rely on local materials might be prohibitively expensive in North America but yield the lower initial and life cycle costs when considered in the African economic context. Perhaps cobblestones should be more widely used. Poorly maintained streets are never complete.

Avoid expensive traffic control systems. Use roundabouts when possible where two street cross. Western traffic planners are rediscovering roundabouts and finding they offer a superior level of service to traffic lights under many conditions. For the time being, African cities can afford traffic control officers at many intersections. The officers reduce conflicts and improve safety at locations where flows of non-motorized and motorized travelers must cross one another at grade. Human traffic controllers offer a level of reassurance, control, time efficiency and discretion that is not available from a traffic light.

Finally invest in building and maintaining lighting systems that create safe conditions for all users of the street. Dark streets are not safe to travel during the night.
Imagining Complete Streets for Developing African Cities

After more than 50 years of catering to the motorized traveler, North American transport planners are pursuing a more modally balanced approach to street design. Their new approach is supported by focusing on multilayered network design, richly textured street designs and a context sensitive approach to planning. As rapidly growing cities in Africa and elsewhere in the developing world develop and tune their transport infrastructure it’s possible to imagine how the new North American Complete Streets approach might be applied to build more useful streets for the world’s fastest growing cities.

References

Chicago Department of Transportation, 2013. Complete Streets Chicago: Department of Transportation; Design Guidelines


ITE (Institute of Transportation Engineers), 2006. Context Sensitive Solutions in Designing Major Urban Thoroughfares for Walkable Communities Washington, DC

Los Angeles Department of City Planning, No Date. Complete Streets Manual: Chapter Nine of the City of Los Angeles Mobility Plan Los Angeles California
Imagining Complete Streets for Developing African Cities

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References

Chicago Department of Transportation, 2013. Complete Streets Chicago: Department of Transportation; Design Guidelines


ITE (Institute of Transportation Engineers), 2006. Context Sensitive Solutions in Designing Major Urban Thoroughfares for Walkable Communities Washington, DC

Los Angeles Department of City Planning, No Date. Complete Streets Manual: Chapter Nine of the City of Los Angeles Mobility Plan Los Angeles California


McCann, Barbara et al, 2012. It’s a Safe Decision: Complete Streets in California, National Complete Streets Coalition www.completestreets.org


AN ANALYSIS ON RAPID URBANIZATION ISSUES IN MONGOLIA AND ITS EXTERNALITIES. A CASE STUDY ON APARTMENT AND GER RESIDENTIAL AREAS IN ULAANBAATAR CITY

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Abstract

The rapid migration from rural to urban area and sharp increase in number of vehicles have been becoming major factors of environmental and transportation issues in Ulaanbaatar City and its total population is estimated to number 1.3 million, where 60% are residing in `ger` area. `Ger` is the traditional dwelling house of Mongolians with no accesses to essential social infrastructure, such as sanitation and heating systems. Majority of the migrants are settling in fringe areas (`ger` area) due to not enough income sources for purchasing new houses. Therefore, the ordinary movement of residents for commuting trip to work or attending trip to school and other trips, has been facing difficulties due to insufficient road condition, not enough public transit alternatives, and public facilities. In the result, it creates tremendous traffic congestion and increase in number of accidents in town areas, both in peak and off-peak hours.

The research aims to analyze current socio-economic differences between two residential areas and to disclose whether trip characteristics have differences depending on the residential areas.

For this objective, household interview survey (HIS) data including person-trip survey will be used in order to grasp socio-economic differences and analyze actual travel behaviors and assessments of the current level of service of public transit and infrastructure facilities.

Finally, the result can be expected that rapid in-migration and sharp increase in number of vehicles with lack of proper countermeasures had brought negative consequences in ordinary movement of residents in apartment and ger residential areas.
SUFFICIENT ACCESSIBILITY AS A POLICY TO INFORM URBAN PATTERNS APPROPRIATE TO MITIGATE CLIMATE CHANGE, AIR QUALITY AND ENERGY CHALLENGES IN DEVELOPING COUNTRIES.

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Abstract

Objective: The goal of transport has always been to increase accessibility; because this translates into more choice, benefit and ultimately wellbeing. However, increasing accessibility also has costs such as capital and operating cost, environmental consequences and increasing inequality in access between the haves and have-nots of society.

The objective of the paper is to begin a discussion on “How much accessibility is sufficient?”; or “Is there a point beyond which additional accessibility produces only marginal, if not negative, benefits?” Answers to these questions will provide much needed guidance to town planning authorities with respect to the patterns that cities of developing countries should take when faced with rapid urban growth and to transport authorities with respect to investments/interventions in transport infrastructure and services.

Methodology: The study assumes that decision making is based on maximising utility and that this can be modelled through respondents stating their preference.

Data: Data was obtained by interviewing 47 employers and 400 employees who were asked to trade-off between the consequences of different catchment areas of employees and jobs respectively. Employees were selected from two categories namely private and public transport users. The attributes presented to employers included Percentage of current labour pool in the catchment area, transport subsidy, CO2 emissions and CO2 taxation and those presented to employees were number of jobs advertised, change in salary, travel time and travel cost.

Expected conclusions: The paper presents the sizes of catchments at which either the increase in benefits to employers or employees decreased or actually became negative.
IMPACT DES NOUVEAUX TCSP SUR LA MOBILITÉ DES USAGERS À ALGER


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Résumé

Nous proposons dans notre communication de présenter les résultats d’une enquête portant sur les TCSP réalisée en 2013 sur le terrain par l’équipe de recherche transport et mobilité urbaine de notre laboratoire et complétée par quelques données relatives à la fréquentation du métro et du tramway recueillies auprès de leurs usagers respectifs par des sondages d’opinion. Ces derniers ont été effectués par les exploitants du métro et tramway en l’occurrence RATP El Djazair et SETRAM.

Depuis l’année 2011, la ville d’Alger a connu la mise en service simultanée des TSCP, en l’occurrence le tramway et le métro. L’exploitation de l’ensemble des données révèle, que le métro a permis en dépit de la distance relativement réduite de son linéaire de transporter quotidiennement 43 806 voyageurs. Par ailleurs, les motifs des déplacements effectués par métro sont pour la majorité d’ordre professionnel, puis pour les services, achats et loisirs, les motifs pour études étant relativement faibles du fait du nombre réduit d’infrastructures universitaires desservies par le métro. Quant à la fréquentation du tramway, l’examen des résultats de nos enquêtes sur le terrain ainsi que la lecture des chiffres de 2013, fournis par les services d’exploitation de l’entreprise traduisent que la fréquentation du tramway semble encore méconnue par les usagers et reste en dessous des prévisions de l’étude. L’on rappelle que l’étude prévoyait 150 000 voyageurs/jour dès la mise en service du tram, alors que les chiffres obtenus avoisinent les 74 000 voyageurs/jour.

Mots clés : TCSP, mobilité, usager, urbain, Alger
1- Introduction:
La ville d’Alger fonctionne toujours avec un modèle monocentrique, où se concentre la grande part des emplois des secteurs tertiaire et secondaire. Il y a génération de mouvements pendulaires (habitat à la périphérie /travail au centre) dans lesquels la distance, le coût et le temps deviennent un handicap majeur dans le fonctionnement du système urbain.

Ainsi, sous le double effet de sa densification et de son extension, Alger connaît une demande en déplacement en nette augmentation, au moins 10% de déplacements supplémentaires viennent s’ajouter chaque année.

Face à cette situation, les autorités responsables de l’aménagement urbain et des transports ont déployé des efforts financiers considérables pour améliorer l’offre de transports collectifs ces dernières années et tenter de réduire l’usage de l’automobile.

Des actions entreprises par les pouvoirs publics en matière d’infrastructures routières (trémies, ponts, dédoublement de voies, deuxième rocade sud, radiales etc.) et de transport urbains (tramway, métro, téléphérique, électrification du rail etc.) tendent à faciliter la mobilité à l’intérieur de son périmètre mais peinent à résorber de manière durable les difficultés liées au besoin de déplacement.

Le métro et le tramway ont une forte charge symbolique : ils représentent l’entrée dans la modernité du pays et l’espoir d’une refonte de l’ensemble du système de transport. Il sont donc perçus comme le point de départ d’une nouvelle politique de transport planifiée qui résoudrait les problèmes de congestion et qui rééquilibrerait l’espace algérois.

En somme, le contenu de la présente communication met en exergue l’examen des impacts sur la mobilité des usagers d’une part en exploitant les premières données de mise en service du métro et du tramway et d’autre la discussion des résultats de l’enquête fréquentation effectuée par nous même en 2013

II. Les transports urbains algériens orientés vers les TCSP : Une nouvelle stratégie.
De prime abord, l’on souligne que l’organisation des transports urbains dans la ville d’Alger est particulièrement complexe. Cette complexité tient d’abord au fait que le périmètre de transport urbain d’Alger tel qu’il découle de l’analyse des déplacements de nature « urbaine » ne coïncide pas avec les limites administratives de la ville d’Alger. Ce périmètre de transport urbain, qui reste à définir, déborde largement sur l’aire métropolitaine qui s’étend sur les wilayas limitrophes de Blida, Tipasa et de Boumerdès.

La nouvelle stratégie des transports urbains à Alger met en avant le développement des transports collectifs en site propre en tant que mode peu polluant, de répondre efficacement aux besoins d’accessibilité et de mobilité des habitants, en mettant en place un réseau de transport basé sur un schéma de macro-maillage qui intègre une hiérarchisation claire des axes.
et la définition de pôles d’échange ; enfin, il se place dans une perspective de développement économique et social de la capitale par l’aménagement de couloirs de transports en site propre.

La stratégie proposée se base donc sur un réseau de transports collectifs ce qui permet une restructuration du territoire de l’agglomération. De plus, une intermodalité de ce réseau permet de répondre aux différentes possibilités de déplacements en intégrant dans le réseau les différents modes de transport : le transport collectif en site propre, tramway, métro, chemin de fer, pour le transport de masse d’une part, et l’autobus, téléphérique pour le transport complémentaire, d’autre part.

Enfin, la création de nœuds de connexion des transports lourds sous forme de pôles d’échanges garantissent la liaison entre les différents modes et sont renforcés par la localisation de grands équipements générateurs de flux de déplacements importants. La figure 1 illustre les actions de la stratégie des transports urbains mise en place par les pouvoirs publics.

**Figure 1. Actions de la stratégie des transports urbains à Alger.**

Les modes et entreprises de transport urbain existants et en cours de réalisation comprennent :

**Le chemin de fer de banlieue,** a connu un programme de modernisation (électrification des lignes) et de développement (construction d’une nouvelle ligne reliant Baba Ali à la ville nouvelle de Sidi Abdellah). Le réseau de la banlieue dessert les relations Alger-Centre/Blida/El Affroun et Alger-Centre/Thenia (avec prolongation prochaine sur Tizi-Ouzou). Sa gestion est assurée par une société des transports ferroviaires voyageurs de la banlieue algéroise, filiale de la Société nationale des transports ferroviaires (SNTF), titulaire d’une licence de transport ferroviaire délivrée par le Ministère des transports et utilisant les infrastructures ferroviaires dont la SNTF est concessionnaire. La zone d’influence du chemin de fer de banlieue dépasse le périmètre de transport urbain susceptible d’être envisagé pour la zone d’Alger, mais son rôle dans les limites du périmètre est toutefois relativement important.

**Le métro d’Alger,** dont une première ligne Grande Poste/Haï el Badr de 9km et dix stations est mise en service depuis novembre 2011 sera prolongée dans des délais rapides (mise en

Le tramway d’Alger, dont la première ligne Est Fusilliés/Dergana via Bordj-el-Kiffan sera prolongée ultérieurement vers Birmandrais du côté Sud-ouest à partir de la station les Fusillés. L’on souligne que la mise en exploitation de la première ligne Bordj El Kiffan-Les Fusillés a été effectuée en 2011 et Bordj El Kiffan – Dergana est opérationnelle depuis 2014. La gestion du tramway était assurée initialement par l’entreprise des transports urbains algérois (ETUSA), puis la gestion est cédée à une entreprise mixte en l’occurrence la SETRAM (Société Algérienne des Tramways) et regroupant les trois entreprises ; Entreprise du Métro d’Alger, RATP Développement et l’ETUSA.

Les services d’autobus dans l’hyper-centre de la ville, en cours de développement, de modernisation et de réorganisation. Ces services sont gérés par une entreprise publique, l’ETUSA, à laquelle seront délivrées par les services du Ministère des transports les autorisations requises par la réglementation. L’ETUSA assure aussi la gestion des transports par câble (téléphériques existants et en cours de construction) dans la zone centrale de la ville.

Les services d’autobus et minibus en dehors de l’hypercentre. Ces services, qui seront réorganisés, sont gérés par des entreprises privées, aux quelles seront délivrées par les services du Ministère des transports les autorisations requises par la réglementation.

Tout compte fait, la coordination des offres de transports ne pourra être possible que s’il est question d’abord d’intégration physique minimisant les ruptures de charges, mais aussi et surtout d’intégration tarifaire et d’information multimodale. Or, ces deux dimensions ne pourront être à l’ordre du jour en l’absence d’un cadre réglementaire et institutionnel qui en propulse le moteur. Il s’agit, on l’a bien deviné de l’autorité organisatrice des transports urbains, dont il a été question depuis la promulgation de la loi N° 01-13 du 7 août 2001 portant organisation des transports terrestres, mais qui peine jusqu’à nos jours à voir le jour.
Figure 1. Réseaux du métro et tramway d’Alger et leurs extensions

Source : TABTI-TALAMALI (2012)

3. Examen des premières données d’exploitation du métro et tramway sur la mobilité

3.1 Impacts du métro

Le tracé de la première ligne du métro dans la partie Nord de la ville correspond à l’axe le long de la côte, où se trouve concentrée la population et les emplois. La mise en exploitation de la ligne a permis à une partie de la population, dont la mobilité était en grande partie opprimée faute de moyens disponibles et adéquats du fait de l’insuffisance de l’offre, d’avoir accès au centre de la ville où se trouvent les emplois et les services.

Le Métro d’Alger qui dispose de 14 rames de 6 voitures chacune permet de relier Hai El Badr à Tafourah-Grande Poste de 5h à 23h, 7j/7, au rythme d’une rame toutes les 3 minutes en période de pointe et toutes les 5 minutes aux heures creuses.

Eu égard justement à sa grande capacité, à sa ponctualité, la régularité de son passage et sa grande amplitude, que le métro a permis, en dépit de la distance relativement réduite de son linéaire, à transporter un nombre de voyageurs en constante augmentation depuis sa mise en service et jusqu’à nos jours. En effet, comme le montre les données sur le tableau 1, la fréquentation n’a pas cessé d’évoluer entre le 01/11/2011, date de mise en circulation commerciale et le 31/03/2013 (date des derniers chiffres obtenus de l’exploitation du métro) pour atteindre le chiffre de 18 millions de passagers transportés, soit en moyenne 43 806 voyageurs qui utilisent le métro quotidiennement.
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Tableau 1: Fréquentation mensuelle des voyageurs

<table>
<thead>
<tr>
<th>Fréquentation mensuelle</th>
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<tbody>
<tr>
<td>4ème trimestre 2011</td>
</tr>
<tr>
<td>Nombre de voyageurs transportés</td>
</tr>
<tr>
<td>Pic du mois / mois</td>
</tr>
<tr>
<td>Fréquentation moyenne</td>
</tr>
</tbody>
</table>

Source : BERCHACHE, R, journée d’étude pratiques de la mobilité à Alger juin 2013

Graphique 1 : fréquentation du métro depuis la mise en service

3.2 – Impacts du tramway

Le tramway, ce moyen de transport en site propre qui vient compléter la panoplie des transports de masse a pu permettre, outre la satisfaction des attentes et les besoins de la population et termes de mobilité dans des conditions de confort, de sécurité et de rapidité assez appréciables, d’améliorer la qualité de vie des algériens et d’engendrer de nouveaux noyaux urbains sur le plan revitalisation et requalification urbaines.
Le 1er tronçon de la ligne du tramway, d’une longueur de 23,3 kms permet de relier les Anassers (Fusillés) à BordjEl Kiffan, avec une fréquence de 4 mn à l’heure de pointe et de 10 mn à l’heure creuse. Une nette progression en termes de fréquentation a été relevée entre le mois de Novembre et celui de Décembre 2012 pour régresser durant le 1er trimestre 2013. Toutefois, il est à préciser que les données indiquées ci-dessous (tableau 2) ne concernent que les chiffres communiquées par la SETRAM, l’entreprise en charge de l’exploitation du tramway depuis le mois de Novembre 2012.

Par ailleurs, les données extraites des ventes et venant du système ne sont toujours pas représentatives de la fréquentation. Les données sont traitées manuellement de façon traditionnelle. C’est pourquoi, les chiffres ci-dessous ne représentent que les voyageurs qui achètent et valident à la fois leurs titres de transport avec les gammes tarifaires confondues (20 DA, 40DA et 50 DA). Autrement dit, uniquement les voyageurs qui valident leur titre de transport sont pris en compte. Le nombre de voyageurs réellement transportés est plus important. A priori, les voyageurs qui ont pris le tramway sans valider leurs titres de transport avoisinent les 50% de l’ensemble des usagers transportés durant ce 1er trimestre 2013. Par conséquent, on peut raisonnablement conclure que les usagers transportés par tramway durant un semestre est 2 fois celui réellement relevé, soit près de 6 millions voyageurs.

Graphique N°3

Fréquentation 4ème trimestre 2012 (validation des tickets)
Le 1er tronçon de la ligne du tramway, d'une longueur de 23,3 km, permet de relier les Anassers (Fusillés) à BordjEl Kiffan, avec une fréquence de 4 mn à l'heure de pointe et de 10 mn à l'heure creuse. Une nette progression en termes de fréquentation a été relevée entre le mois de Novembre et celui de Décembre 2012 pour régresser durant le 1er trimestre 2013. Toutefois, il est à préciser que les données indiquées ci-dessous (tableau 2) ne concernent que les chiffres communiquées par la SETRAM, l'entreprise en charge de l'exploitation du tramway depuis le mois de Novembre 2012.

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Graphique N°3

Tableau 2 : Fréquentation du tramway

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<thead>
<tr>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Nombre de voyageurs transportés</td>
<td>178 910</td>
<td>242 720</td>
<td>833 810</td>
<td>551 278</td>
<td>542 244</td>
<td>526 469</td>
<td>2 845 431</td>
</tr>
<tr>
<td>Pic du mois / mois</td>
<td>17 106</td>
<td>26 756</td>
<td>35 124</td>
<td>30 000</td>
<td>26 491</td>
<td>26 202</td>
<td>-</td>
</tr>
<tr>
<td>Fréquentation moyenne</td>
<td>15 634 237</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source : SETRAM & Berchache Juin 2013

Graphique 4

4. Enquête fréquentation du métro et tram : Résultats et discussion

Dans le but de compléter l'analyse sur les impacts, nous présentons dans cette communication les résultats d'une enquête réalisée par l’équipe Transport et Mobilité Urbaine du laboratoire Ville, Urbanisme et Développement Durable de l'Ecole Polytechnique d’Architecture et d’Urbanisme (EPAU) d’Alger. L’enquête portant sur la fréquentation du métro et du tramway s'est déroulée durant le mois d’avril 2013 et a concerné un échantillon de 1000 usagers du métro et du tramway (500 personnes interrogées pour chaque mode).
 Nous avons dirigé nos enquêtes au niveau des principales stations du métro et du tramway par un questionnaire sous forme d’entretien. Les principaux thèmes du questionnaire s’articulent sur les points suivants :

- Les catégories socio professionnelles,
- Les motifs de déplacements
- L’inter modalité,
- Prix du voyage.

1. Catégories socio professionnelles et fréquentation du tram et tramway

L’examen des résultats obtenus montre que ce sont les employés des administrations, services et commerces qui utilisent le plus avec 67% suivi des étudiants (17%), alors que la catégorie des fonctions libérales représente 6%, les retraités et chômeurs avoisine les 9%. Quant à la catégorie des ouvriers, l’étude a donné un taux de 1%. Cette faible valeur est liée certainement au prix du ticket qui est assez élevé.

Aussi, l’analyse des résultats, force est de constater que la fréquentation du métro par les étudiants n’est pas assez significative. Ceci peut être expliqué d’une part par l’important maillage du réseau de transports de bus pour étudiants et d’autre part par le nombre réduit de facultés et écoles supérieures à proximité de la ligne du métro.

Concernant la fréquentation du tramway, les résultats de l’enquête révèlent que les catégories employés et étudiants occupent la première place avec un taux de 77%. A l’inverse du métro, les étudiants fréquentent quotidiennement ce mode de transport et leur part est très significative (32%) . Ceci s’explique par le fait que la ligne du tram longe les campus universitaires de Bab Ezouar, El Harrach et Caroubier. L’on souligne que le recours à ce moyen de transport par les étudiants trouve son explication à travers les éléments suivants : la durée du déplacement, la fréquence et qualité de service comparativement au transport de bus étudiants marqué par des difficultés de circulation à Alger (embouteillage tout heure sur les lignes du réseau)

Comme pour le métro les chômeurs et les retraités ont recours à ce moyen de transport et représentent 13%. Par ailleurs, les résultats de l’enquête nous renseigne que la fréquentation du tram par la classe des ouvriers est relativement faible avec un taux de 8% et reste en dessous du taux enregistré chez les chômeurs et retraités. L’on note que le tramway est peu fréquenté par la catégorie des professions libérales (2%). Cette catégorie sociale utilise majoritairement le véhicule particulier pour des raisons professionnelles ou autres.
En somme, les résultats de la fréquence d’utilisation du métro et du tram montrent que la tranche d’âge 36-59 ans (population active) est la plus représentée parmi les usagers quotidiens.

2. Motifs de déplacements

Les résultats des enquêtes traduisent clairement pour les deux moyens de transport, les motifs de déplacement sont pour la majorité d’ordre professionnels et études. Ainsi, pour le métro, ces résultats s’expliquent par la présence de nombreux emplois, commerces et services dans le centre-ville notamment au niveau des stations de 1er mai, Khelifa Boukhalfa et la Grande Poste. L’on retrouve également pour le tram dans la première position les déplacements liés au motif travail, suivi pour le motif études. Nous marquons que la fréquentation du tramway par les étudiants trouve son explication dans le gain du temps sur le déplacement (la durée du trajet est 10 à 20 mn pour rejoindre les campus sur le tram alors que sur le réseau autobus étudiants, la durée du trajet dépasse les 60 mn). Il y a lieu de souligner que la part représentant le motif visites est assez remarquable car ce motif tient une grande part dans les déplacements quotidiens de la population (visites à la famille et aux amis).

3. Choix modaux sur le nouveau système de transport urbain

Nous observons sur le tracé du réseau du métro et du tramway que l’inter modalité s’effectue au niveau de la station des Fusillés, ce qui nous a amené à enquêter les usagers seulement au niveau de cette station. L’on indique qu’au niveau de cette station se rejoignent le métro, le tram, le téléphérique et l’autobus.

Plus de 73% des personnes enquêtées empruntent dans leurs déplacements les deux modes les plus performants, en l’occurrence le métro et le tramway contre 15.% pour l’autobus - tramway et 11% bus -métro et 1% téléphériques –modes lourds(métro et tram).

Aussi, toutes les personnes interrogées sont unanimes et soulignent l’incohérence observée au niveau de la station qui est marquée par un dysfonctionnement en termes de fréquences entre les différents modes (métro et tram trop élevées alors que bus et téléphérique relativement faibles)

L’on not que ce manque d’organisation, de cohérence et de coordination entre les multiples acteurs des transports publics est le principal handicap pour la réussite de l’intermodalité et seul la mise en place de l’autorité organisatrice des transports urbains qui pourrait améliorer la situation.

4. Prix du voyage

Dans notre enquête nous avons jugé important de connaître les avis des usagers concernant les prix des tickets pratiqués pour le métro et le tram. Pour le métro, les résultats de l’enquête consignés dans le tableau ci-dessous montrent effectivement que 81% des usagers interviewés considèrent que le prix du ticket est relativement cher. L’on indique que le prix pour un déplacement sur toute la ligne est de 50,0 Dinars Algériens équivalent à 1,0 euro. Par ailleurs
14% des usagers sont satisfaits du prix du ticket pour leurs déplacements et 5% qui sont prêts à aller jusqu’au double du prix actuel.

Pour le tramway d’Alger, le prix du déplacement entre les stations oscillait entre 20 et 50 DA à la date de mise en service. Au moment où nous rédigeons ce papier, le prix du ticket a été uniformisé et ramené à 40 DA. Nos enquêtes sur le terrain révèlent que 92% des usagers sont unanimes que le prix du ticket est assez élevé contre 8% des usagers qui considèrent comme correct. Aussi, selon les responsables de l’entreprise du tramway, 20% des usagers du tram ne paient pas leur ticket. D’autres voyageurs utilisent un ticket plusieurs fois en essayant d’éviter les contrôleurs.

Face à cette situation nous considérons, que la mise en place d’une autorité organisatrice aura la charge de réguler le marché des transports et d’adapter l’offre à la demande, l’adoption d’une tarification intégrée, quel que soit l’opérateur et quel que soit le mode de transport emprunté, sera plus à même d’unifier le prix du transport. Le prix à payer sera d’autant plus réduit qu’il ne sera question que d’un seul ticket de transport que l’usager pourra utiliser invariablement sur tous les réseaux de transport offerts sur le marché.

**Conclusion**

En dépit de la mise en service récente du métro et du tramway, on peut d’ores et déjà affirmer que le rôle qu’ils jouent dans la prise en charge de la demande de déplacement des usagers est déterminant. La mobilité est d’autant plus aisée grâce à leur grande capacité d’absorption de la demande et de leur amplitude, et le sera encore davantage quand les linéaires du métro et du tramway seront complétés par leurs extensions respectives.

Il est vrai que la mise en service des TCSP constituera une occasion pour les décideurs de mettre fin à l’anarchie qui gangrène actuellement le service des TC, et pour les usagers la possibilité d’en finir avec les désagréments dont ils souffrent au quotidien. D’où les changements pressentis quant à la stratégie des déplacements qui sera désormais adoptée aussi bien par les autorités et les transporteurs que par l’ensemble des usagers.

Références Bibliographiques.

AIT AOUADIA, O. 2012 « Maitriser et revivre la ville :Le métro d’Alger » mémoire de master, Université Paris1,

BAOUNI, T. 2009 « Les transports dans les stratégies de la planification urbaine à Alger », revue Insaniyat N° 43-44, pp 75-95


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MÉTRO LÉGER DE SFAX : UN PROJET DE MOBILITÉ DURABLE ÉCONOME EN ÉNERGIE

Riadh Haj Taieb

Résumé: Le réchauffement climatique, résultant des émissions de gaz à effet de serre (dégagements industriels toxiques, bâtiments, transport…etc.), contribue à la moitié des phénomènes extrêmes que connaît la planète (inondations, sécheresse, ouragans…). La ville de Sfax est également touchée par ces phénomènes. Les dernières inondations à Sfax caractérisées par une forte intensité des pluies en 2009 et 2013 et l’augmentation de la température 2°C durant les cinquante dernières années, selon les études et recherches de l’université de Sfax, n’en sont qu’un exemple.

Face aux changements climatiques, les villes, partout dans le monde, se mobilisent. Sfax est parmi ces villes engagées dans la lutte contre le réchauffement climatique.

Ces dernières années, Sfax a également engagé une politique novatrice avec pour objectif de devenir une ville « verte » et sobre en carbone. La ville a ainsi élaboré en 2006 une stratégie de développement du Grand-Sfax 2016 intégrant des objectifs environnementaux ambitieux. Le volet développement durable a été réalisé avec le soutien de la Coopération allemande au développement (GIZ), de la Banque mondiale et de l’Union Européenne.

Partant du principe que la mobilisation locale peut faire bouger les choses, la ville de Sfax a élaboré en 2013 un diagnostic approfondi de ses émissions de gaz à effet de serre et de leurs sources afin d’identifier les actions à engager pour les réduire.

Le bilan carbone, outil choisi pour réaliser ce diagnostic a débouché sur un résultat clair. 54% des émissions des GES sont attribués aux transports de marchandises et aux déplacements. Plusieurs projets sont proposés pour réduire de 20% les émissions de Gaz à effets de Serre en 2020 dans la ville de Sfax.

Parmi ces projets phares l’élaboration d’un PDU/NAMA Transport, la mise à niveau des TC par autobus et l’étude de faisabilité pour la mise en place d’un métro léger à Sfax.

Cette communication présentera le pourquoi du projet de Métro Leger de Sfax, les étapes de réalisation de l’étude de faisabilité, les résultats en terme d’estimation du cout et l’échéancier de réalisation ainsi que son impact sur la réduction de CO2, d’économie d’énergie et sur l’attractivité des transports dans la ville de Sfax avant de conclure par la présentation des facteurs de réussite de ce projet.
1. Introduction

La réduction des émissions de gaz à effet de serre (GES) n’est plus seulement un enjeu climatique, c’est aussi un enjeu de développement socioéconomique. La hausse tendancielle des prix de l’énergie, la compétitivité des entreprises, le développement de l’industrialisation et la nécessité de création d’emplois; sont autant de facteurs qui devraient conduire les pays en développement à orienter leur stratégie de développement vers un modèle sobre en carbone intégrant la lutte contre les changements climatiques. Réussir cette mission nécessite l’implication de tous les acteurs, de la plus petite collectivité aux diverses instances de l’État, de chaque entreprise à chaque citoyen. La lutte contre le changement climatique doit émerger d’un processus collectif orchestré au niveau local et impliquant forcément la société civile.

Dans ce contexte, la ville de Sfax prépare l’élaboration d’un Plan Climat-Energie Territorial (PCET) qui est un projet territorial de développement durable, axé sur la réduction des émissions de GES, la dépendance énergétique et l’adaptation climatique; et visant à atteindre deux principaux objectifs, face au défi du changement climatique :

- L’atténuation, essentiellement à travers le développement des énergies renouvelables, une meilleure efficacité énergétique, une transformation profonde des politiques de transport…

- L’adaptation, en réduisant la vulnérabilité du territoire dans un contexte où les impacts du changement climatique ne pourront plus être intégralement évités, même avec d’importants efforts d’atténuation.

Pour atteindre cet objectif, les acteurs de la ville de Sfax en parfaite coordination avec l’Agence Nationale de Maitrise de l’Energie, envisagent d’inscrire la préoccupation du changement climatique dans les décisions de long terme (Plan de Déplacement Urbain, Plan d’Aménagement Urbain, urbanisme opérationnel, constructions, infrastructures, reconversion d’activités étroitement liées aux conditions climatiques,…).

A l’échelle nationale, la Tunisie a adhéré aux efforts de lutte contre le changement climatique en ratifiant les conventions internationales (CCNUCC et le PK). En adoptant, une politique volontariste de maîtrise de l’énergie, elle a manifesté sa volonté à améliorer sa situation énergétique face à l’augmentation des prix de l’énergie et à mener, conjointement, une politique d’atténuation des émissions de GES et de lutte contre les changements climatiques.

Désormais, à l’instar des initiatives internationales impliquant les villes dans la contribution au paquet Climat Energie, notamment en Europe, la Tunisie manifeste aujourd’hui son intérêt à enclencher un tel processus considérant que les villes, de par leurs potentialités et responsabilités, y sont les principaux leviers.
La ville de Sfax, en est un cas concret, avec une population estimée à 540 000 personnes (2012), elle est un des plus grands pôles industriels du pays, comportant une usine de production d’engrais, une fonderie de plomb, des usines de tissage, savonneries et des industries agro-alimentaires. Elle est considérée, en 2002, l’une des villes les plus polluées du pays.

Dès lors, la conception d’un plan Climat Energie ville, pourrait être appropriée à cette ville, qui regroupe toutes les activités économiques et sociales consommatrices d’énergie (déchets solides, éclairage public, transport, matériel roulant, bâtiments, environnement urbain, urbanisme…) et pourrait par conséquent avoir un potentiel important en termes d’économie d’énergie et d’atténuation des émissions de GES.

De plus, cette ville a capitalisé une expérience et des acquis importants dans le domaine de la maîtrise de l’énergie en réalisant des études et lançant des actions en la matière en collaboration avec l’Agence Nationale de Maitrise de l’Énergie et la Coopération Allemande (GIZ) . Selon l’inventaire Carbone de la ville, les émissions totales sur l’ensemble du territoire du Grand Sfax ont atteint 5,2 Millions TéCO2 en 2010. Le secteur du transport émet 54% des émissions de GES.

Le profil climat énergie de la ville de Sfax, ses potentialités et ses acquis, sont autant de facteurs motivants pour engager le projet de « Métro Leger de Sfax », visant à impliquer cette ville à l’effort national de maîtrise de l’énergie et de la lutte contre les changements climatiques, et faisant de Sfax une ville respectueuse de l’environnement et du climat à l’horizon 2020 par l’installation d’un nouveau mode de transport propre.

2. Méthodologie

La ville de Sfax est parmi les rares villes tunisiennes qui ont engagé une stratégie de développement local en 2006. La Stratégie de Développement du Grand Sfax (SDGS) est un processus par lequel les responsables municipaux, en partenariat avec le secteur privé, la société civile, l’université et les organismes nationaux concernés, ont pu identifier les principales problématiques urbaines, arrêter les options stratégiques du développement durable de la ville de Sfax, sur le moyen & long termes (2016).

Le thème de « transport urbain » dans la ville de Sfax reste au cœur des débats dans la mesure où il touche la vie des hommes et des activités dans leur quotidienneté. Ce thème a constitué une composante intrinsèque de la stratégie de développement considérée comme étant un cadre de référence essentiel pour l’orientation des décisions et pour la détermination des actions à entreprendre.
Le "bilan transport et circulation" dressé dans le cadre de la SDGS a permis de saisir les raisons qui ont conduit à l'émergence de diverses sources de contrainte et de blocage ayant conduit dans la pratique à une mobilité non durable se traduisant par des implications lourdes de connotations négatives sur le fonctionnement de la ville. Le système de circulation et de transport reste à améliorer au niveau de l’offre d’une part et de la gestion d’autre part.

Parmi les indicateurs d’alerte montrant l’incapacité du système de circulation et de transport de subvenir aux besoins de la ville de Sfax est le développement de plusieurs grands projets urbains qui sont plus juxtaposés qu’intégrés et ne tenant pas compte convenablement des besoins en transport et stationnement.

La proximité transport – aménagement est contrariée par des enjeux stratégique, méthodologique, institutionnel,…L’approche dualiste qui en découle, a entraîné des effets pervers tant au niveau de l’aménagement qu’à celui des transports en élevant, par là, les coûts et les externalités négatives.

L’organisation mono-centrique de l’espace urbain est manifeste à Sfax. L’essentiel des problèmes de transport et de stationnement et des problèmes urbains en général provient de la dissymétrie fonctionnelle qui est apparente entre un hyper-centre aspirateur de flux se "tertialisant" de plus en plus et une périphérie résidentielle, sous équipée s’étalant et s’urbanisant de plus en plus.

Etant donné la faible part des emplois entraînants/structurants crées aux communes périphériques, l’on s’oriente vers une congestion véhiculaire croissante de Sfax. L’insuffisance, à l’échelle urbaine, de l’infrastructure des transports quant à la qualité du réseau et l’état de la chaussée, est bien ressentie par les usagers habituels et occasionnels.

L’analyse des déplacements motorisés urbains fait apparaître une dissymétrie évolutive et croissante au niveau de la structure du partage modal à Sfax dévoilant, durant ces dernières années, une régression sensible des transports en commun (passant de 28% en 1996 à 20% en 2009), une poussée surprennante de la voiture particulière (passant de 42% à 60%) et une régression des deux roues (passant de 30% à peine 12%) pour les mêmes dates.

La mobilité qui est définie comme étant le nombre de déplacements motorisés par jour et par personne, aurait connu une évolution importante au cours des vingt dernières années, passant de 1,47 (en 1996) à 1,94 (2009), soit au rythme de 2,16% par an.
L’évolution de cette mobilité par mode\(^1\) est schématisée dans le graphique suivant :

Graphique n°1 : Evolution de la mobilité urbaine par mode entre 1996 et 2009

La modification importante dans la répartition modale intervenue dans le Grand Sfax au cours de la dernière décennie, est imputable à l’augmentation significative du taux de motorisation des Sfaxiens surtout après les encouragements de l’Etat pour l’octroi des crédits pour l’acquisition des voitures de petites cylindrées, à la dégradation continue des prestations de transport collectif et à la concurrence déloyale du secteur privé notamment les taxis pratiquant le transport à la place au lieu du service à la course. Le transport collectif a connu une régression continue de l’utilisation des bus dont la part a décroché à 19% en 2014.

Toutes les raisons évoquées précédemment imposent une nouvelle stratégie de transport fondée sur la réhabilitation et la promotion du transport collectif lequel est en mesure de faire valoir des arguments et des atouts d’ordre social, économique et écologique. L’option pour la mise en place d’un mode de transport en site propre est devenue une demande locale insistant et urgente.

Un site propre signifie une emprise ou une voie affectée essentiellement au transport, par exemple, une piste cyclable pour les deux roues ou toute autre voie réservée au métro, au tramway ou aux bus... généralement avec une démarcation matérialisée physiquement et qui la rend infranchissable pour les autres moyens de transport. Sur les plans écologique et de la sécurité les transports en site propre présentent l’intérêt et non des moindres de préserver à la fois la vie humaine et l’environnement.

Selon des statistiques émanant du Ministère de l’intérieur, le nombre des victimes à l’échelle nationale en 1999 se présente comme suit : voiture particulière (347), transport collectif public ou bus (29) et métro (04).

D'autre part, les émanations polluantes du mode ferroviaire par exemple sont 100 fois moindres que celles de la route. Ces transports sont im battables du point de vue consommation énergétique sachant que si la voiture particulière, boulimique, consomme 09,3 litres par passager aux 100 km, au centre-ville, le métro, plus sobre, ne consomme que 0,1 litre de gaz-oil par passager aux 100 km soit 90 fois moins d'énergie.

L'Association Tunisienne des Urbanistes a procédé en 2005, par un bureau d'études spécialisé en transport (ETIC), à une évaluation énergétique, environnementale & économique du projet TCSP.

Cette évaluation énergétique et environnementale a été suivie par une analyse économique sur la base des coûts d’investissements et des avantages procurés par le projet. Les impacts sur la pollution atmosphérique ont été évalués pour les polluants dont le trafic routier constitue la principale composante, en l’occurrence le monoxyde de carbone (CO), les oxydes d’azote (Nox) et le dioxyde de soufre (SO2), le gaz carbonique (CO2) et les hydrocarbures imbrûlés (HC).

La quantification des émissions de ces polluants (en tonnes), se fait, à l'instar des consommations énergétiques, sur la base: des uvp-km et des uvp-heures à l'HPM relatifs au projet proposé, des ratios d'émissions de ces polluants par type de véhicules et de carburant utilisé (essence ou gas oil) et de la composition du parc véhicules dans le Grand Sfax par type et selon le carburant consommé. Le solde calculé (en tonnes) entre les deux situations de référence et de projet TCSP.

Le bilan énergétique du projet préliminaire du TCSP montre bien un gain important en consommation de carburant et en émissions de polluants particulièrement le CO2.

Graphique n°3 : Gains en temps et en consommation de carburant sur la période 2011-2016 (en millions DT)

Graphique n°4 : Emissions de polluants :

Les résultats relatifs aux émissions de polluants pour les deux situations considérées (avant et après réalisation du projet TCSP proposé à moyen et long termes), montrent que les gains en matière d’émissions de polluants sont de :

- 500 tonnes pour le CO ;
- 62 tonnes pour les Nox ;
- 69 tonnes pour les HC ;
- 9108 tonnes pour le CO2 ;
- 8 tonnes pour le SO2.

D’après le calcul économique, le Taux de Rentabilité Interne (TRI) du projet TCSP, s’élève à 10,8%. Ce taux montre, qu’en plus des avantages liés à la réduction de la consommation énergétique et des charges sur l’environnement, le projet TCSP proposé à moyen et long termes, est rentable pour la collectivité.

Les résultats de cette étude ont été transmis aux ministères de l’Environnement et du Transport pour justifier la nécessité de mettre en place un métro léger dans la ville de Sfax.
En réponse à une demande locale et régionale de plus en plus insistantes le Ministère du Transport a finalement engagé en 2011 deux études l’une sur l’amélioration des performances des transports par autobus et l’autre sur la faisabilité de mise en place d’un Transport Collectif en Site Propre (TCSP).

L’objectif de la première étude est de mettre à niveau le système de transport collectif par bus par l’amélioration des performances de la Société Régionale de Transport de Sfax (SORETRAS) et de la qualité du service de TC offert.

L’objectif de la deuxième étude est de définir un réseau de TCSP performant et écologiquement viable. L’étude devra répondre aux questions suivantes :

- Pourquoi ? Quelle clientèle prévisible pour ce projet ?
- Où ? Quels tracés, quelles correspondances avec les autres modes ?
- Comment ? Quels modes (trolleybus, tramway, métro léger…) ?
- Combien ? Quels couts de réalisation et d’exploitation ?

L’étude s’est déroulée en cinq phases :

- Phase 1 : Diagnostic du système de transport
- Phase 2 : Définition de 3 à 4 scénarios de desserte de la ville de Sfax
- Phase 3 : Evaluation des scénarios et choix du scénario retenu
- Phase 4 : Etude du scénario retenu (définition du système SP et du matériel roulant, estimation des couts, évaluation du TRI)
- Phase 5 : Elaboration d’un plan d’actions (phasage, lignes à réaliser en premier, actions à court, moyen & long termes)

3. Résultats des études de Transport Collectif

Les résultats de la première étude, relative à l’amélioration des performances du système de transport collectif par bus, élaborée par la SORETRAS sont les suivants :

- L’augmentation de l’offre par l’acquisition de nouveaux bus de différents types (standards, articulés, minibus) adaptés aux types d’exploitation et l’augmentation du taux de disponibilité du matériel existant
- La restructuration partielle du réseau par le rebroussement de certaines lignes suburbaines longues avant les stations extérieures actuelles et par la création d’une ligne circulaire dans la partie centrale de la ville de Sfax
- L’intégration tarifaire par la révision de la tarification de manière à améliorer les conditions de la correspondance entre lignes favorisant l’attractivité des TC
- L’amélioration des conditions d’exploitation par la réorganisation de la direction d’exploitation (personnel adéquat, informatisation de la...
gestion et formation recyclage du personnel) et par l’optimisation des distances inter-arôts et la création de couloirs réservés aux bus.

- L’amélioration de l’attractivité des services de la SORETRAS par des abris-bus contenant un minimum d’informations (horaires, schémas des itinéraires, etc...) et surtout l’amélioration de la qualité du service (informations sur le réseau disponibles, ponctualité respectée, fréquences améliorées, correspondances facilitées).

La SORETRAS a commencé la concrétisation de ces recommandations par l’acquisition de 98 bus, l’amélioration des conditions d’exploitation et l’engagement d’un plan d’économie d’énergie dans la gestion de sa flotte de matériel roulant (bus standard, bus articulé, minibus).

La seconde étude, élaborée par le Ministère du Transport se propose de mettre en place un système de transport collectif en site propre (TCSP) écologiquement viable dans l’agglomération de Sfax. L’objectif est d’accroître la part du Transport Collectif en offrant à la population un service de Transport efficace et attractif.

A cet effet, l’étude de faisabilité de ce système a préconisé à l’horizon 2029 un réseau TCSP composé de deux lignes de tramway (T1 et T2) et 3 lignes de BHNS (BH3, BH4 et BH5) pour un coût total estimé à 2000 millions dinars tunisiens. Ce réseau comprend :

**Ligne T1 de tramway : El Ons-Aéroport (22,8 km) :**

Au nord, la ligne entre dans le quartier d’El Ons pour sa desserte fine. Elle rejoint ensuite la route de Taniour jusqu’au carrefour avec le boulevard de Bizerte pour venir emprunter l’avenue des Martyrs de façon directe. Le choix de l’avenue des Martyrs permet d’assurer une bonne desserte du centre-ville et de proposer une bonne connexion à la gare ferroviaire qui pourrait alors être déplacée vers le nord pour développer un pôle multimodal. A la sortie du centre-ville, la ligne rejoint la route de Soukra puis la route de l’Aéroport.

**Ligne T2 de tramway : Gremda-Centre ville (10,7 km) :**

Cette ligne emprunte la route de Gremda puis assure la desserte de la ville Européenne par l’avenue Habib Bourguiba. Ce tracé permet d’assurer une très bonne correspondance avec le futur pôle multimodal à créer autour de la gare ferroviaire. La ligne vient ensuite se boucler côté ouest avec les lignes T1 et BH3.

**Ligne BH3 de BHNS : Sidi Mansour-Thyna (22,9 km) :**

Cette ligne dessert la route de Sidi Mansour depuis la faculté de droit, puis site propre dans Taparura pour ensuite rejoindre le centre-ville par le boulevard Majida Boulila. Ensuite, la ligne rejoint la route de Gabes pour desservir les quartiers de Thyna.
**Ligne BH4 de BHNS : Route de Menzel Chaker (6 km) :**

Cette ligne dessert la route de Menzel Chaker. Son terminus est proposé à la gare routière avec une excellente connexion à l’ensemble des lignes T1, T2 et BH3.

**Ligne BH5 de BHNS : Route de Mahdia (7,5 km) :**

Cette ligne dessert la route de Mahdia avec un terminus au centre-ville au niveau du pôle multimodal de la gare.

Graphique n° 5 : Réseau 2029 de TCSP

La réalisation sera concrétisée en deux phases:

**1ère phase de réalisation du réseau TCSP**

En raison de l’importance des coûts d’investissement, autant que devant l’importance des travaux avec des chantiers qui sont toujours perturbants pour la vie urbaine en termes de nuisances et surtout en termes d’emprises qui gênent la circulation des véhicules, il ne peut être envisagé de réaliser le réseau TCSP préconisé à l’horizon 2029 en une seule phase.

C’est pourquoi, il est proposé de retenir à l’horizon 2019 une première phase comportant une seule ligne de tramway, T1, avec un terminus limité au Chihia (soit une longueur de 13,5 km), et 5 lignes de bus fortes préfigurant le réseau 2029 et permettant d’améliorer les transports sur l’ensemble de l’agglomération. Le coût total de cette 1ère phase est estimé à 540 MD tunisiens.
Le tracé de la 1ère ligne de tramway permettra la desserte des grands pôles attractifs de la ville et des grands équipements tel que la majorité des grands sites universitaires (aéroport, centre-ville), les équipements sanitaires, les pôles culturels et récréatifs et les équipements sportifs, l’hyper-centre de Sfax avec la médina et le nouveau quartier El Jadida, la future gare ferroviaire, etc.

Quant aux lignes de bus fortes, elles seront implantées sur:

- La route de Gremda (B2) qui sera réaménagée entre la rocade km4 et l’avenue des Martyrs (couloirs d’approches, priorité aux feux) .
- La route de Gabès (B3 ouest) pour desservir Thyna avec des aménagements surtout à partir de la rocade km4 et sur l’avenue Majida Boulila,
- La route de Sidi Mansour (B3 est) réaménagée pour son tronçon dans le prolongement de Majida Boulila et jusqu’à la rocade km4,
- La route de Menzel Chaker (B4), avec des aménagements entre la rocade km4 et Majida Boulila, ..
- La route de Mahdia (B5) aménagée sur tout son axe puis avec un site propre ou couloir réservé le long de la voie ferrée jusqu’à son terminus à la gare ferroviaire.

Schéma n° 6 : Réseau 2019 en mode Tramway
Photo n°1 : Insertion du tramway T1 dans la route de Taniour

![Image of tramway in Taniour road](image1.png)

Photo n°2 : Insertion du tramway dans le centre ville /Rue des Martyrs

![Image of tramway in centre city](image2.png)

Le Planning de réalisation de la première ligne de tramway de Sfax est le suivant:

- Exécution des travaux: 2016-2018
- Mise en service de la ligne T1 du tramway en 2019 avec reorganisation du réseau bus.
Les autres phases de réalisation du réseau TCSP

- La seconde phase, prévue en 2022, devrait concerner la réalisation de la ligne T2, dans le centre-ville et route de Gremda, au moins jusqu’à la limite de la zone dense au nord de la rocade km4 (270 MD).
- La troisième phase, prévue en 2024, peut traiter du prolongement de la ligne T1 au nord, en fonction du développement du quartier d’El Ons (200 MD).
- La quatrième phase, prévue en 2029, comprendra le prolongement de la ligne T2 et la réalisation des lignes de BHNS, dans un ordre à définir en fonction de l’évolution de l’agglomération (935 MD).

4. Conclusion: les facteurs de réussite du projet.

La révolution tunisienne du 14 janvier 2011 a permis de revoir la stratégie de développement des différentes régions du pays. La nouvelle constitution promulguée en janvier 2014 ouvre la porte pour une décentralisation accrue du gouvernement local. Ces orientations sont favorables à une bonne gouvernance locale dans le domaine des transports urbains.

L’élaboration par la ville de Sfax d’une stratégie de développement à l’horizon 2016 actuellement en cours d’actualisation pour l’horizon 2030 d’une part et d’autre part l’engagement des projets structurants dans le secteur des transports: port, aéroport, autoroutes et tramway à Sfax montre bien une volonté politique pour mettre à niveau ce secteur stratégique pour le développement durable de la ville de Sfax.

Concernant le transport urbain à Sfax en général et le projet TCSP en particulier plusieurs facteurs doivent être réunis pour garantir une mobilité durable à Sfax à savoir:

- La mise en place d’une Autorité Organisatrice Régionale des Transport
- L’engagement des études d’exécution du projet TCSP en 2014 comme programmées dans l’étude de faisabilité.
- Création de parking (souterrain et aérien) au centre ville pour libérer les rues du stationnement sur voirie et aménager des voies réservées pour les transports collectifs.
- Elaboration d’un Plan de Déplacement Urbain pour la ville de Sfax en 2014.

D’ailleurs, notre association « Association de Développement Solidaire de Sfax » a déjà amorcé une stratégie de communication pour une mobilité durable par l’édition d’un calendrier pour 2014 diffusé auprès de 3000 ménages à Sfax.

Cet effort de sensibilisation sera inlassablement poursuivi par l’ADSS au cours des mois à venir. L’organisation le lundi 8 septembre 2014 d’une journée « villes sans voitures » a pour objectif de promouvoir les transports collectifs par bus et sensibiliser et informer les citoyens sfaxiens du projet TCSP qui permettra dans les années à venir de réduire la facture énergétique et contribuer à lutter contre les changements climatiques au niveau de la ville de Sfax.

5. References

Hassen Abid. 2005. ETIC. SDOTGS. Bilan environnemental du TCSP.
EGIS. Etude de faisabilité TCSP. 2013.
Appui aux associations opérant dans le domaine des transports. Ces associations doivent jouer à la fois un rôle de sensibilisation et de pression sur des acteurs de la ville de Sfax pour promouvoir les modes de transport collectifs propres au cours de la prochaine étape.

D’ailleurs, notre association « Association de Développement Solidaire de Sfax » a déjà amorcé une stratégie de communication pour une mobilité durable par l’édition d’un calendrier pour 2014 diffusé auprès de 3000 ménages à Sfax.

Photo n°3 : Calendrier 2014 élaboré par l’ADSS pour la promotion de la mobilité durable dans la ville de Sfax.

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5. References

Hassen Abid. 2005. ETIC. SDOTGS. Bilan environnemental du TCSP.


EGIS. Etude de faisabilité TCSP. 2013.
EVALUATION OF THE PERFORMANCE OF URBAN PUBLIC
TRANSPORT CONNECTIVITY.
BACKGROUND OF THE CONNECTIVITY ISSUES IN BUCHAREST
PUBLIC TRANSPORT MAIN STOPS

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Abstract

Increasing demand for urban mobility leads to a situation that is not sustainable and creates a variety of externalities. In order to address the externality issues, the authorities must develop a public transport system in accordance to the mobility needs of the city, offering a rapid and safe service, thus encouraging the creation and maintenance of sustainable travel patterns.

The objective of this paper is to analyse in detail the passengers’ movements in the transfer station, in order to identify physical measures that will finally reduce the time spent walking and transferring and will improve the quality of transfers.

The assessment of the transit station capacity in accordance to the mobility demand takes into account the routing decision from different areas of the transit station, the features and facilities for each station.

Also, the paper presents a practical analysis on the transfer station Eroilor in the Bucharest public transport network, tackling the issue of interconnectivity between metro lines and the issue of intermodality between surface lines and metro lines. The practical analysis suggests a set of solutions for the improvement of the existing facilities, measures for fast and safe transfer and new service facilities.

1. Introduction

The Bucharest public transport network consists in the surface public transport network – 147 routes for bus, trolleybus and tramway and in the underground public transport network – 4 metro lines.

The growing congestion on the city streets and the need to encourage sustainable travel patterns, lead to the need in the extension of the underground network, that...
Based on citizen opinion is the infrastructure for the most reliable and safe public transport service. In this respect, the metro development strategy (The General Urban Transport Master Plan, 2008) included in 2008, for the medium term a number of new metro lines, from which one line from west to east, linking two of the most populated residential areas to the city centre. This line is planned to be realised in stages. The technical stages will impose supplementary stress on the connection stations that would experience different level in pedestrian density and movements.

The increase in density levels could lead to critical safety condition for pedestrians. Therefore, in the designing of the new stations and of the connection passages and areas, an important aspect is to create the facilities that will assure effective and rapid circulation of pedestrians, especially in the peak periods.

In order to create a proper design, it is important to study the pedestrian movement in the metro station. An increase attention must be directed to the studies of pedestrian movement in crowded places.

Over the time, a series of research studies was undertaken, meaning that theoretical approach and methodologies of the analysis of pedestrian in metro station can easily be benchmarked and chosen the ones that fit to the current needs.

In general the studies of pedestrian movements in public transport stations include the pedestrian characteristics, route choice models, fundamental diagrams and simulations of the paths chosen. There is a great amount of useful information of the speed-flow diagrams/relationships (Daly et al., 1991) and pedestrian behaviour in the route choice evaluation (Daamen et al., 2005) for European and American pedestrians. Also, in terms of pedestrian simulation, there was an important amount of software simulation development. Different model simulation were developed along the time, including the NOMAD model that simulated the impact of access gates on passengers flow (Dameen, 2004), Pedroute (Maw and Dix, 1990) or SimPed (Daamen, 2004), that simulated the pedestrian behaviour, including walking, route choice in the transfer stations and boarding and alighting in the stations.

On the other hand the design of the metro facilities must be realised in order to provide access to train services in an attractive, safe and efficient environment and also, in a cost effective and consistent manner.

An analysis of the station dimension in detail and of the capacities of each spaces planned for the passengers must be undertaken to improved all the features of the station before implementing the plans (at the designing stage).

The space planning must be based upon passenger density and upon the well-known concept of “level of service”.

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This paper aims to analyse one of the Bucharest metro station in the assumption of the extension of the metro network with a new line from west to centre. Currently, the chosen station, namely Eroilor is a transfer station between two metro lines. In the near future, the station will be the end terminal to the west metro line.

Firstly the chosen methodology will be presented and secondly the results will be highlighted showing the needs in improvement of the current design.

2. Methodology

The identification of the performance of the metro station was undertaken in two stages. First a simple assessment of the station main elements was undertaken. A simple logigram of the routes was then presented that illustrated both capacities of station facilities and estimated flows observed and estimated for the project.

Second, a simulation using specialised pedestrian software was undertaken. The simulation used the VISWALK software along to the social force modelling principles.

2.1. Capacity assessment

The capacity assessment was realised based on the Fruin density principles and on standards in terms of station planning and design.

Space needed for normal operations in stations is planned in order to:
- minimize congestion
- be resilient to sudden growths (peaks) in demand and/or train service disruption.

Space planning is based on the concept of “level of service” and pedestrian density (John J. Fruin, 1971). The calculation of the capacity for different constraining elements of the stations considered standard formulas based on the Fruin’s level of services and dimensions already designed.

The levels of service used to calculate the capacities allow free circulation and provide a good level of comfort for the passengers. The table 1 describes those levels of services and highlights the levels used in calculation.
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<table>
<thead>
<tr>
<th>Level of service</th>
<th>Description (for queuing areas, walkways and stairways)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Free circulation.</td>
</tr>
<tr>
<td>B</td>
<td>Uni-directional flows and free circulation. Reverse and cross-flows with only minor conflicts.</td>
</tr>
<tr>
<td>C</td>
<td>Slightly restricted circulation due to difficulty in passing others. Reverse and cross-flows with difficulty.</td>
</tr>
<tr>
<td>D</td>
<td>Restricted circulation for most pedestrians. Significant difficulty for reverse and cross-flows.</td>
</tr>
<tr>
<td>E</td>
<td>Restricted circulation for all pedestrians. Intermittent stoppages and serious difficulties for reverse and cross-flows.</td>
</tr>
<tr>
<td>F</td>
<td>Complete breakdown in traffic flow with many stoppages.</td>
</tr>
</tbody>
</table>

Table 1. Levels of service

The main design elements considered are the following:
- Platforms
- Escalators
- Stairs
- Passageways/corridors
- Gate lines.

Therefore, the capacity represents the maximum limit of the passengers’ volume that can be accommodated by a station element (mentioned above) without causing interruptions in the circulation.

The unit capacity for each design element considered is:
- 0.5 sq m/person for platform (LOS D)
- 100 passengers/min for escalators
- 28 passengers/min/meter width (LOS C) for the two-way stairways – taking into consideration the opposing flow
- 40 passengers/min/meter width (LOS C) for the two-way passageway – taking into consideration the opposing flow and also considering the “edge effect” when measuring the width
- 25 passengers/min/gate for the gate line

The dimensions for each considered designed elements were considered from the station design drawings.

A calculation was undertaken and schemes were produce in order to evaluate the capacity of each design element mentioned above. Also, the routes and the corresponding flows were also calculated in order to assess the calculated capacity.

This simple approach gave the first results in terms of evaluation of the performances of the designed station in accordance to the existing one.
2.2. Pedestrian movement evaluation

A more complex approach was next undertaken. The simulation of the pedestrian movement produced the necessary results to undertake an extensive analysis of the facility in order to identify improvements in the station design.

The fundamental characteristics of the traffic flow are flow, speed and density, that can be analysed both at macroscopic level and at microscopic level. In this case it is necessary to undertake a microscopic analysis.

The chosen approach in the study was the simulation using a social force model (Helbing, Molnar, 1995 and Helbing, Vicsek, 1999).

In the Social Force Model, a pedestrian is considered to be subject to social forces that are the motivational engine of its movements.

The motivation to reach the goal produces an intended velocity of movement. The main assumption is that each pedestrian intends to reach a certain destination at a certain time, and then every movement will be targeted to reach the destination point. The ideal speed of the pedestrian is, then equal to the remaining distance per remaining time.

Also, there are two types of interaction of the pedestrians modelled using the social force model, namely the interaction between pedestrians and the one between pedestrians and obstacles.

The simulation of pedestrian movement follows those principles, being done using the VISWALK software.

This model was chosen because so far it is among the best microscopic models and has variables with physical meaning that can easily be measured.

In order to undertake this assessment, a complete and robust analysis was undertaken separately to evaluate the current flows, to develop future flows and relations between the designed station and the existing one and also between the metro stops and the surface stops. Firstly, pedestrian traffic data for the current situation were collected. Those data along with assumption of the new line were used in the calculation of future flows used in the microscopic simulation.

The testing in the microscopic simulation of the new station presented the performance of the entire Eroilor stop and helped in the design improvement before implementation.
3. Results

This chapter shows the results of the both approaches in the station performance assessment.

3.1. Presentation of the studied metro station

The Bucharest metro network has 4 metro lines in operation at this moment, as shown in figure 1. The Eroilor station is part of the existing metro station. Currently in this station enter around 12000 passengers per day. The station is also a transfer station between 2 metro lines, 1 and 3. As observed in the below figure the Eroilor station will be the first point of insertion in the network of the new west-east metro line.

![Figure 1. Bucharest metro network](image-url)
The access in the existing metro station and the link between the surface bus stations and the access to the metro station are shown in the figure 2, presented below.

![Figure 2. Eroilor station – existing accesses and connection to the surface transport](image1)

The new west-east line will connect into the exiting metro network at Eroilor station by the creation of a new Eroilor station linked almost perpendicularly to the old one, as shown in the figure 3.

![Figure 3. Eroilor station – new configuration](image2)
In the figure 3 that presents the new configuration of the transfer node Eroilor, the green elements represent the existing station, while the blue ones are the new facilities connected. The station Eroilor 2 will be a terminus station for this section until the line is completed connecting the west side of the city to the east side and passing through the city center.

The estimated loading of the two stations Eroilor 1 and 2 for the new line is around 130,000 passengers/day. Therefore taking into account that the new line will be implemented in stages, first stage being implemented with Eroilor as terminal stop and the loading of Eroilor stations is more likely to increase over the stages and also considering that the new configuration will gather pedestrians from 3 metro lines, concerns were raised regarding the free circulation of the passengers between the two stations Eroilor 1 and Eroilor 2.

This was the main reason for choosing this station to undertake an extensive analysis of the pedestrian movements.

3.2. Calculation of the station capacity

The routes start from the platform of the Eroilor 2 station and follow the path of the metro line 5 passengers through the station. There were identified two main routes:

- The first route (1) starts from the platform and ends at the gate line of the access A, passing through a set of 3 escalators.
- The second route (2) starts at the platform of Eroilor 2 station, passing first through 2 sets of escalators and dividing into two secondary routes, one leading to the transfer corridor to Eroilor 1 areas and the other directly to the access D corresponding to the second direct access point to the Eroilor 2.

The routes that define the main movements of pedestrians from/into Eroilor 2 are presented in the figures 4, 5 and 6 showed below:
Figure 4. Pedestrian movement in Eroilor 2 station – route 1

Figure 5. Pedestrian movement in Eroilor 2 station – route 2
In order to show that the capacity of the constraining elements along the route satisfies the forecasted demand, it was considered necessary to calculate the corresponding flows in two scenarios:

- The proposed project with Eroilor as terminus station for metro line 5
- The complete metro line 5 (from west to east) with Eroilor as a transfer station along the metro line

The flows that are passing through the station designed elements considered are calculated based on the daily loadings for the Eroilor 1 and Eroilor 2 station.

Based on the current statistics on the metro daily variation, 10% of the daily station loading is considered to be the peak hour station loading and the peak minute loading is considered to be the 60th part of the peak hour.

The minute flows are based on counted volumes in the station Eroilor 1 and estimated volumes for Eroilor 2. The estimation of the future volumes was realized using a VISUM transport model for the forecast year 2046 in both scenarios, model developed especially for the assessment of the project.

Therefore, the table below shows the loading for each station in the scenarios mentioned above, consisting in passengers boarding and alighting at platform per minute.

Table 2. Passengers flows at platform for Eroilor1 and Eroilor2 (passengers/min)

<table>
<thead>
<tr>
<th>Scenario 1</th>
<th>Platform loadings</th>
<th>Boarding</th>
<th>Alighting</th>
<th>Total flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>passengers/min</td>
<td>Eroilor 1</td>
<td>74</td>
<td>68</td>
<td>143</td>
</tr>
<tr>
<td></td>
<td>Eroilor 2</td>
<td>38</td>
<td>44</td>
<td>81</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scenario 2</th>
<th>Platform loadings</th>
<th>Boarding</th>
<th>Alighting</th>
<th>Total flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>passengers/min</td>
<td>Eroilor 1</td>
<td>77</td>
<td>73</td>
<td>151</td>
</tr>
<tr>
<td></td>
<td>Eroilor 2</td>
<td>68</td>
<td>65</td>
<td>133</td>
</tr>
</tbody>
</table>

The flows of passengers at platform consists in the following categories:

- Passengers starting/ending their trip using metro (origin/destination passengers) – that are using the accesses into the metro system and passing through the gate lines
- Passengers transferring from surface public transport – that are using the accesses into the metro system and passing through the gate lines
- Passengers transferring inside the metro system.

The tables below present the passengers flows for each category measured in passengers/minute.

Table 3. Passengers flows using the gate lines for Eroilor 1 and Eroilor 2 (passengers/min)

<table>
<thead>
<tr>
<th>Scenario 1</th>
<th>Flows through accesses</th>
<th>Boarding origin</th>
<th>Alighting destination</th>
<th>Surface transfer</th>
<th>Total flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>passengers/min</td>
<td>Eroilor 1</td>
<td>27</td>
<td>24</td>
<td>28</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>Eroilor 2</td>
<td>3</td>
<td>7</td>
<td>15</td>
<td>25</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scenario 2</th>
<th>Flows through accesses</th>
<th>Boarding origin</th>
<th>Alighting destination</th>
<th>Surface transfer</th>
<th>Total flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>passengers/min</td>
<td>Eroilor 1</td>
<td>21</td>
<td>18</td>
<td>11</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Eroilor 2</td>
<td>12</td>
<td>13</td>
<td>10</td>
<td>35</td>
</tr>
</tbody>
</table>

Table 4. Passengers flows transferring between Eroilor 1 and Eroilor 2 (passengers/min)

<table>
<thead>
<tr>
<th>Scenario 1</th>
<th>Transfer flows in metro</th>
<th>Passengers/min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between stations (Eroilor 1 and Eroilor 2)</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>Inside Eroilor 1</td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scenario 2</th>
<th>Transfer flows in metro</th>
<th>Passengers/min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between stations (Eroilor 1 and Eroilor 2)</td>
<td>98</td>
<td></td>
</tr>
<tr>
<td>Inside Eroilor 1</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

Those table present the passengers flows that move along the identified routes. In order to evaluate the splits between the flows for the 4 accesses into the metro system at Eroilor, the current preferences of the passengers in terms of access points in the metro system were considered.

Therefore, currently 75% of the passenger volume of Eroilor 1 uses the access B and the corresponding areas and 25% of the passenger volume of Eroilor 1 uses the
access C to leave/enter the metro system. So, based on this assumption the table below presents the flows using the gate lines of each access.

Table 5. Passengers flows using each access designed for the two stations (passengers/min)

<table>
<thead>
<tr>
<th>Scenario 1</th>
<th>Passenger flow (passengers/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station</td>
<td>Access</td>
</tr>
<tr>
<td></td>
<td>Eroilor 2</td>
</tr>
<tr>
<td></td>
<td>Access A</td>
</tr>
<tr>
<td></td>
<td>Access B</td>
</tr>
<tr>
<td></td>
<td>Access D</td>
</tr>
<tr>
<td></td>
<td>Eroilor 1</td>
</tr>
<tr>
<td></td>
<td>Access B</td>
</tr>
<tr>
<td></td>
<td>Access C</td>
</tr>
<tr>
<td></td>
<td>Access D</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scenario 2</th>
<th>Passenger flow (passengers/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station</td>
<td>Access</td>
</tr>
<tr>
<td></td>
<td>Eroilor 2</td>
</tr>
<tr>
<td></td>
<td>Access A</td>
</tr>
<tr>
<td></td>
<td>Access B</td>
</tr>
<tr>
<td></td>
<td>Access D</td>
</tr>
<tr>
<td></td>
<td>Eroilor 1</td>
</tr>
<tr>
<td></td>
<td>Access B</td>
</tr>
<tr>
<td></td>
<td>Access C</td>
</tr>
<tr>
<td></td>
<td>Access D</td>
</tr>
</tbody>
</table>

Based on the route description and the passenger volumes mentioned above, a movement scheme presenting the constraining elements was created for each scenario. The two schemes are shown in the figure 7 and 8.
Figure 7. Pedestrians movement scheme inside Eroilor metro station (forecasted for proposed project – Eroilor 2 station as terminus station)
Figure 8. Pedestrians movement scheme inside Eroilor metro station (forecasted for entire metro line 5 project – Eroilor 2 station as transfer station along the line)
3.3. Microscopic simulation results

The Eroilor station was 3-D modeled and each element as such stairs, waiting areas, passageway, platforms etc were taken into consideration. The figure 9 presents the configuration of the analysed stop.

Figure 9. Pedestrian areas in the Eroilor stop

Then routes were defined for each relation inside and outside the station. The matrix of the origin-destination pairs is presented in the table 6.

Table 6. Passengers flows between station elements
On the other hand the public transport service was also defined, by defining the line routes, headways and loadings for each train. The figure 10 presents the operating scheme:

![Figure 10. Metro lines operating scheme in Eroilor station](image)

The table 7 presents the headway and dwell time for each vehicle journey that stops at Eroilor station, including the new metro service.

Table 7. Train headway and loadings

<table>
<thead>
<tr>
<th>Line</th>
<th>Headway</th>
<th>Loadings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>60</td>
<td>105</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>95</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>40</td>
</tr>
</tbody>
</table>

For each vehicle journey an estimated number of passengers alighting was calculated. The results are presented in the table 8.

Table 8. Passengers alighting for each journey vehicle

<table>
<thead>
<tr>
<th>Journey</th>
<th>Alighting</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>120</td>
</tr>
<tr>
<td>2</td>
<td>110</td>
</tr>
<tr>
<td>3</td>
<td>100</td>
</tr>
<tr>
<td>4</td>
<td>90</td>
</tr>
<tr>
<td>5</td>
<td>80</td>
</tr>
<tr>
<td>6</td>
<td>70</td>
</tr>
<tr>
<td>7</td>
<td>60</td>
</tr>
<tr>
<td>8</td>
<td>50</td>
</tr>
<tr>
<td>9</td>
<td>40</td>
</tr>
<tr>
<td>10</td>
<td>30</td>
</tr>
<tr>
<td>11</td>
<td>20</td>
</tr>
<tr>
<td>12</td>
<td>10</td>
</tr>
</tbody>
</table>
After 2 simulation runs, the density of pedestrians was calculated. The figure 11 presents the pedestrian density for all the station elements. In the upper left it is represented the new platform, while in the right part of the figure, the two existing platforms are presented. The lower left shows the passageway level between the new and existing platform.

The figure 11 shows that in terms of densities there are a number of identified issues for each element. First the new platform is linked with the rest of the station facilities with escalators. Because of those escalators it is observed a crowding trend in front of those escalators mainly because of the elevated number of pedestrians that transfer to the other 2 platforms. On the passageway level, it is also observed a tendency of crowding in the passage area. High density are observed also on one of the existing platforms (the narrow one) especially after a train from Eroilor 2 arrived.

In order to illustrate the issue on the passageway level, the figure 12 shows a detail of that area. It is observed that a series of obstacles are interrupting the free movement of pedestrians and determine some inconvenience while walking. Those obstacles are structural vital for the station, but an alternative solution is to have a round corner to smooth the route.
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Figure 11. Eroilor station density

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Figure 12. Passageway detail

In terms of the densities on the existing platform, it is shown that the lateral platform of the existing station has high densities of around 4 passengers/m2. The proposal in this case was to extend the platform. The extension was possible because of the space behind the rear wall that is currently occupied by an unused parking track.

Also, the simulation runs estimated the duration of each route used in the station, routes that are either between platforms or between platform and exits.

The average exit time using the access area B, C and D is between 145s and 223s, while the A area is less than 60s, but it has no points of interest to be used. In terms of the movements between platforms the average travel time between the new platform and the existing lateral platform is 126s, while the travel time between the new platform to the central existing platform is 160s. This last travel time is influenced by the length of the route that uses the long corridor parallel to the existing station and the escalators to get to the central platform. The graphical representation is presented in the figure 13 and 14.

Figure 13. Average travel time from platforms to exit in relation to vehicle arrivals
4. Conclusions

Based on the capacities and flows schemes presented above, the Eroilor 2 station was design to provide a safe and free circulation along the transfer corridors and the routes entering/exiting the stations.

It is also noticed that all the design elements of the station have been dimensioned taking into account the potential growth in demand caused by disruptions in the normal operation of the trains or emergency situations and future growths of demand given by the network effect of future lines.

Some small issues where identified in terms of densities in the waiting area and on the passageway, but they were corrected along the design process with no major interventions.

Even if the testing showed small issues that have already been corrected, but no major problems in the design considerations, it is important that all the transfer nodes (station) to be analysed in terms of pedestrian movements, using specialised skills and software to ensure that free and safe circulation is provided through the design decisions.

5. References


Fruin, J.J. (1971a) Designing for Pedestrians: A Level of Service Concept. Highway research Record 355, 1-15


The General Urban Transport Master Plan, 2008, Bucharest City Hall,

Station planning standards and guidelines, 2012 edition, Mayor of London
INTERMODALITY – A SOLUTION TO THE PROBLEMS OF LARGE URBAN AGGLOMERATIONS

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Abstract

The large urban agglomerations are facing the negative effects of traffic congestion, the most unpleasant phenomenon of the contemporary society. The classical solutions of reducing traffic congestion by developing the infrastructure transit capacities have led to an increase in land occupation, to a degradation of the natural landscape and have attracted additional traffic. The accepted solutions are interdisciplinary and must ensure easy access to intermodal passenger transport and reduce the user’s need to travel without suppressing his access to activities and services.

Intermodality is an integral part of the sustainable mobility and its enhancement is of vital importance particularly, in high congested urban areas. This represents a solution to the current mobility problems in the cities and it involves the planning of the urban scheme so as to encourage short-distance trips. The case study is used to demonstrate the utility of such urban amenities concerns the regional bus stations in Bucharest and their paths in city. The locations of exchange poles is considered in order to reduce the pathways on Bucharest street network and the traffic congestion and, consequently, to increase the city dwellers’ quality of life.

Keywords: intermodality, urban transport, sustainable mobility

1. Introduction

Urban expansion and high dependence on the car and truck have led to congestion in cities and towns across Europe. Economic growth in many emerging metropolises generates a strong augmentation in mobility demands. Increases in car ownership are a risky consequence of this process. If motorization fulfills the mobility needs of people who have access to car, it has an impact on the structure of the city. At local level, the distances increase, thus disadvantaging those who do not have access to private vehicles. In addition, congestion, air pollution and dangerous driving degrade city life quality. At global level, oil depletion and global warming are physical limitations preventing the reproduction of models of urban development favored during the 20th century.

While transport enables the economy to grow, if not well-managed, it can also retard growth and the efficient delivery of essential social services. The lack of
comprehensive planning of transport systems, without due consideration to social, economic, environmental and cultural elements of the city, can result in physical breaks in the fabric of communities and reinforce social exclusion. The impact on quality of life and the environment cannot be underestimated. (Shanghai Manual, 2011)

Congestion and the accompanying issues of road safety and environmental pollution present major challenges in planning for improved accessibility and reducing the environmental impact of transport. The priority is to create urban transport systems that meet individual needs for mobility and the economic and social demand for rapid and efficient movement of goods and people, safely and cost-effectively. An integrated component of efficient urban mobility is minimising environmental and health impacts, particularly in densely populated areas (European Commission, 2013)

2. Sustainable urban mobility

The competition between transport modes led to a segmented transport system instead of an integrated one, especially in urban areas. In fact, every transport mode tried to use its own advantages regarding the growth of attractiveness on a highly competitive market. The transporters tend to maintain the intensity of the activity by using the routes that they operate to their maximum capacity. The lack of modal integration was made much worse, on international level, by the government policies that prohibit the companies to operate in other ways that their own and by placing a transport mode under state authorities control, maintaining the monopoly. (Stefanica, 2013)

Also, the competition between transport modes led to decreasing of public transport attractiveness and to increasing number of private vehicles which dominates the roads. As a result, the transportation sector is heavily responsible for public health issues in cities such as air pollution (acidification, smog), noise, greenhouse gas emissions, and road accidents. (Shanghai Manual, 2011)

With growing car dependency, an ageing population, and demands for new and flexible lifestyles, cities are faced with finding new transport solutions for rapid and easy movement of people. Furthermore, new technologies create high expectations for smart mobility options, such as real-time traffic information for travellers, drivers, fleet operators and network managers. New technologies also bring opportunities for integrating data for journey planning and electronic ticketing, and smart cards to facilitate interoperability between public transport modes.

The challenges of global warming, scarce energy sources and increasing energy prices are on the top of European, national and local policy agendas. In this context, green solutions are needed to reduce the environmental impact of transport in urban
areas. A major concern is to find ways and means to sustainably reduce transport emissions because urban traffic is responsible for 40% of CO2 emissions and 70% of other emissions from road transport in the EU. (European Commission, 2013)

In order to return urban places to people and to create more livable cities, decision makers in these cities urgently need to change the direction of urban transport development toward a more sustainable future. Establishing a sustainable urban transport system requires a comprehensive and integrated approach to policymaking and decision making, with the aim of developing affordable, economically viable, people-oriented and environment-friendly transport systems. (Shanghai Manual, 2011)

Breaking the cycle of increasing urban congestion and accompanying impacts on economy, society and the environment requires a change in mindset by both decision makers and transport users. A new culture in urban mobility is needed in order to deliver integrated and sustainable transport planning, and users need to adapt their attitudes and behaviour with regard to mobility. (European Commission, 2013)

Political will has become a key ingredient to improving urban transport policies in cities. The knowledge of what is happening and how to improve a situation is already there, and tools to address problems are well known by many practitioners. When a city mayor or another decision maker takes these tools and applies them in their city knowingly and appropriately, positive outcomes and benefits for city inhabitants can result. (Shanghai Manual, 2011)

3. Transport and Land Use Interaction

Unfortunately, city managers in developing countries are following the same car-oriented transport development patterns made by many cities in developed countries in the past. In the developing world, however, the trend is still largely in favor of the expansion of infrastructure for private motor vehicles. Policies for more and more road construction have clearly failed to cope with ever increasing demand from rapid motorization, resulting in a vicious circle as depicted in Figure 1. This cycle shows how the increase of infrastructure to alleviate travel demand will have apparently positive consequences in the short term, but some months later there will be a much greater congestion than before, thus increasing the problem rather than solving it. (Shanghai Manual, 2011)
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4. Reducing need to travel

Developing new infrastructure for reducing congestion is not anymore a solution to uncontrolled traffic growth. We have to look for solutions to actual problems of the cities in transportation and land use interaction. Transportation and land use are inexorably connected. Everything that happens to land use has transportation implications and every transportation action affects land use. We can’t anymore use exclusive transport solution for traffic congestion, we must search for interdisciplinary solution coming from transportation an land use relation. We must choose new urban development location that short distance trips can be encourage, and non-motorized transport modes can be used. We have to look for solution for reducing the need to travel. (Roman, 2014)

The reduction of the urban mobility will be reached when a series of new policies will be simultaneously implemented. This goal can be achieved through a restrictive policy for travelling with private cars, a development of a proper public transport, a properly land usage, technological solutions and certificates for the...
majority of the countries, where these measures are already implemented.

However, it should be retained three major difficulties that hinder the successfully application of the stipulated measures:

I) It is difficult to quantify as well as to measure directly the mobility phenomenon;

II) It is hard to obtain a global reduction of mobility due the fact that different situation will provide different number of trips;

III) The effect of the measure concerning the limitation and the reduction of mobility has a little impact on the total volume of transport.

Anyway continuous efforts are needed to be made by governmental and non-governmental organizations, on order to assume the success of strategies concerning the reduction of mobility and to combat the undesired effect of an intense traffic. Some communities have found a promising new course for handling growth and their transportation problems. Planners refer to these ideas as "livable" or "sustainable" communities. By whatever name, these plans focus on people, rather than on cars. (Dragu, 2005)

5. Intermodality

The concept of intermodality, as part of sustainable mobility, refers to the door-to-door transfer of people or goods by using several means of transport, including walking or cycling (Jones et. al., 2000). In general, the idea of intermodality aims to optimize travel conditions reclaiming the advantages of each mode being used while minimizing the negative impact that each one of them causes. (Pitsiava-Latinopouloua, 2012)

Intermodality is an integral part of the sustainable mobility and its enhancement is of vital importance particularly, in high congested urban areas. One of major reason why inducing mode shift from private cars to public services is difficult it is the lower accessibility of public transport modes. One possible strategy to improve accessibility by public transport is to extend the possibility to use public modes in various combinations (or even in combination with car). The basic idea is that even if one public transport network (e.g. rail) alone cannot provide high accessibility, an integrated use of different networks (e.g. rail plus bus) can. When a combination of transport modes is involved, interconnection represents a key part of the trip and the quality of interconnectivity is then a major requirement. A smooth transfer from one network to another is a matter of physical connections but also of functional and organisational aspects like e.g. integrated services and ticketing. (Stasio, 2011)

Effective interconnection requires the provision of both integrated networks and services. The achievement of this integration usually requires a strong co-operation between a range of authorities and providers in the public and private sectors. The
creation of effective interconnection may sometimes conflict with the priorities of authorities and providers who have hitherto been concerned solely with serving a local constituency.

Particularly in passenger transport none of the various actors is responsible for the whole intermodal route from house to house or for intermodal network connection. No transport company is generally responsible for building and operating interchange points either. (Stasio, 2011)

The points where the transfer from one mode to another takes place represent sensitive points that can encourage or discourage intermodality. The existing amenities in these places, regarding the reduction of transfer time and especially the commodity and comfort of the transfer (escalators and moving walkways, minimum walking distances, transport schedules correlations, guidance signs and commercial and social facilities etc.) lead to an increased intensity of use of such facilities with major implications in enhancing intermodality that is so necessary in urban environment. (Stefanica, 2013)

The weak links in the overall Intermodal passenger transport chain are considered to be the Intermodal Terminals, as often inadequate planning leads to the reduction of the level of service of the means using the station, thus resulting in partial or total disdain for its users and the shift of the latter to other transport modes, mostly to private vehicles. Instead, an integrated design with emphasis on Intermodal Terminals which acts as the interface between the different modes not only increases the proportion of commuters who use urban public transport but also consolidates the overall public transport system of an urban area. (Pitsiava-Latinopouloua, 2012)

The main objective of a exchange pole is the integrated and efficient transfer of passengers between various routes and different modes of transport. In order to ensure the effectiveness of this essential function, a terminal should provide:
- reliable and adequate level of service of the means involved in the operation of the terminal
- satisfactory level of facilities serving the transfer
- provision of low cost travel (less than or equal to the cost of travel without transfers)
- adequate accessibility of the site for all users (especially the disabled)
- reduced travel time compared to that needed for the same trip without transfer
- direct access between two different platforms for almost all platforms of different modes of the terminal
6. Case Study

The Bucharest like every other world capitals is facing the problem of congested and damaged road infrastructure and with neglected rail infrastructure. The competition between public transport modes, especially between regional and local transport operators has led to a lack of connections between regional and local networks. The authorities allowed regional minibus to enter in city centre.

In this case study I analysed the regional minibus routes and their stop points in Bucharest city to see what influence they have over the traffic growth.

In order to analyse solutions for improvement of the interconnectivity one has to identify the key problems of poor connectivity in Bucharest. They can be enumerated as follows:

- Non provision (or inadequate standard) of the infrastructure for local links;
- Poor design, maintenance or operation of modal interchange points;
- Inefficient procedures for interchange (e.g. delays while waiting for luggage);
- Inadequate provision of local transport services (e.g. no fast public transport from an airport to city centre);
- Local transport services exist but do not serve the needs of connecting long distance travellers (e.g. time tables are uncoordinated, nearest bus stop requires a long walk);
- Inadequate provision of information;
- Unavailability of integrated tickets (covering the local as well as the long distance parts of the journey).

In Bucharest there are 32 stop point for regional minibus which are presented in the figure 2. It can be seen that the stop points are located all over the city.
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![Figure 2. Regional bus stop point](image)

About regional minibus stop point I can say they aren’t organised as an interchange terminal, being organised even in a house yard.

It can be seen in the picture that regional minibus routes are spread on all city. There are situation when minibus travel 20km on the congested road infrastructure creating additional traffic.

Knowing the timetable of each regional transport line the traffic flow were calculated (on every national road). This are presented in Tabel 1.

<table>
<thead>
<tr>
<th>DN1</th>
<th>DN2</th>
<th>DN3</th>
<th>DN4</th>
<th>DN5</th>
<th>DN6</th>
<th>DN7</th>
</tr>
</thead>
<tbody>
<tr>
<td>5,1</td>
<td>19,3</td>
<td>2</td>
<td>8,9</td>
<td>7</td>
<td>6,3</td>
<td>3,7</td>
</tr>
</tbody>
</table>

The biggest hourly average flow is on national road 2 (DN2), (120 standard vehicles – 80 minibuses), at every 45 seconds a minibus leaves from Bucharest regional minibus stop point.

This is alarming and requires measures to reduce or even eliminate these flows. A first step to reduce these flows would be the prohibition of using of minibuses and replace them with buses. A regional bus has the capacity to transport a minimum of 50 seats, which means it can take passengers transported in 2.5 minibuses (they having capacity up to 20 seats). In this way, additional traffic flows will be reduced by 2.5 times.
Besides this solution it is important to rethink the bus stations locations through
the city, so that no longer allow minibuses enter in the capital. These regional bus
stations should be placed in the key points of transport system and activity system.

Transforming the regional bus station in interchange terminals means granting a
major importance interconnections between local and regional transport networks
and encourage intermodality. This involves either placing them in a hub or in a local
public transport terminal or near one or rethinking their uniform locations of future
transport terminals by converging both means of transport surface and underground
and regional transport.

For the new bus station to be considered intermodal terminals they must have the
following features
- Facilities necessary for the proper functioning of the bus station;
- Shopping center;
- Spaces for the operation of urban transport networks;
- Park&Ride to encourage modal shift between private vehicle and public
  transport;
- areas with urban functions - entertainment areas, restaurants, banks.

To say that the bus terminal is an interchange terminal it needs to make a good
interconnection between different transport networks. This can be achieved by
correlating the regional bus programs with local transport programs.

For rational located bus stations we should take into account:
- To be at the periphery of the capital;
- to be located near or in an urban transport network node providing travelers
easy access as the local and regional network;
- Near railway stations or passenger station buildings;
- Near the commercial and administrative center of the village;
- Routes coaches must be separated from roads carrying heavy traffic (with
  large traffic flows).

Under these requirements a solution would be to have an interchange terminal
for each of the seven national roads. For coaches departing and arriving from the bus
stations do not create congestion inside the city they should be located near the exit
of Bucharest.

For transfer from one interchange terminal to another make easy, ideally they
should be located near the railway line belt or passenger station building. Thus
travelers who want to go from one side to another side of country and have to change
regional bus in Bucharest will not cross the center will not create additional traffic
and they save time. Another condition that must be fulfilled is to be near a
commercial and administrative center. This could be achieved by building a
shopping centre in the terminal building - supermarket or bus station in the parking
lot of a supermarket location.

In the case study I propose creating 7 intermodal terminals located like it can be
seen in the picture below.
The distances traveled by buses on city streets will be following: DN1 - 5 km, DN2 – 9.8 km, DN3 – 4.7 km, DN4 -3.5 km , DN5 – 3 km, DN6 – 5.1 km, DN7 – 2.6 km. This locations have a benefit on decreasing traffic congestion on Bucharest streets because of the effect on encouraging the public transport use, this terminals being located in next to local transport terminals, and next to shopping centre.

Figure 3. New locations for regional bus station

7. Conclusions

Lifestyles and travel behaviours are constantly change. Mobility is vital for quality of life in a city, and beyond, and it is expected to grow. There is not enough to find solutions to meet the urban mobility by increasing the supply of transport. It is necessary to identify interdisciplinary solutions based on link between transport and urban planning through which spatial solutions related to the development of transport lead to reduced need for mobility without suppressing user access to services and activities, and to encourage travel on short distance leading to a non-motorized transport more attractive. The integration of public and private transport, but also the integration of urban and suburban transport by development of
interchange terminals which include urban functions and which are located in the passenger transfer points is a satisfying solution for urban mobility that will lead to change in travel behaviours and decrease need for mobility. Interchange terminals are places characterized by accessibility, attractiveness, and nodality. Identifying new locations for interchange terminals, starting from the correlation between transport and urban development will lead to a strong urbanization around their location and it will determine a changing on urban form and on urban structure leading to a high urban density and a mix of urban functions, especially to a compact city.

8. References


2. Dragu V., Roman V. C., Roman Eugenia Alina: ACŢIUNI ASUPRA CERERII DE TRANSORT ORIENTATE CĂTRE O MOBILITATE URBANĂ DURABILĂ, Buletinul 78 AGIR nr. 2/2014 • aprilie-iunie


6. Roman Eugenia Alina, Roman V. C.: SOLUŢII INTERDISCIPLINARE PENTRU SATISFACEREA MOBILITĂŢII ÎN MARILE AGLOMERĂRI URBANE, Buletinul 112 AGIR nr. 2/2014 • aprilie-iunie


8. Stefanica C. Et all: Connections between Bucharest underground and rail networks, 15th WSEAS International Conference on Automatic Control, Modelling & Simulation (ACMOS’13), Brasov, Romania, June 1-3, 2013, pp. 92-97

A Performance Indicator Like Punctuality for Metrobus (BRT)

Dr. Abdullah Onder Turkoglu

Abstract

The bottleneck-shape of the city walls forces the necessity to develop alternative methods for the optimum use of roads. Public transportations main concern is to carry citizens. The ITS System for public transportation basically supplies classified and analyzable data to operators. Governors can manage their fleet strategically by the data provided, while simultaneously sharing this data with the citizens.

On the other hand, BRT is a bus network but cannot be analyzed as regular bus lines. AVL based system supplies some advantage to develop new algorithm for measure reliability of the network.

In this paper, some obtained operation and information from computerization of field operation process is discussed. Digitalization of the real world information is required some assuming. It is seen that, after computer aided bus fleet management system installation, measurable and controllable effective business process can be modelled and reorganized. Then an algorithm will be offered and measured for regularity of a BRT network according to Istanbul Metrobus.

Introduction

Traffic management is the basic goal of city management since ancient ages. The wheel and the speed get results with unstable and uncontrollable movement. While the city area and its infrastructure are constantly increasing, wheel based transportation density also increases, especially after the machine age. Increasing movement and transportation vehicles have come with traffic accidents and self-inflicted deaths.

Within the last 50 years, traffic is not only evaluated as the aftermath of accidents, but also considered as the complexity and difficulty of transportation. As the city density reaches its limit, transportation roads lose the opportunity for reconstruction, however the vehicles entering into traffic increases exponentially day by day. (Ergun, 2009, pp. 38-43)

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These conditions bring optimization researches for traffic management transportation. The factors that slow traffic down are investigated, and some solutions are offered according to the analysis. This means that computers must enter into traffic management.

Computer based traffic management is called ITS (Intelligent Transportation Systems) (Akbas, 2009 pp: 23-29). ITS gives a plan to the City Board for the most effective use of roads to manage the citizens, as well as the most economic transportation, through technological facilities (Torday, 2009, pp: 85-94). For example, traffic light durations can be adjusted with the detection of change in the roadway density. Centralized control of the roads is achieved with speed-detecting and red light violation detecting cameras and temperature sensors on roads, which also indicate the areas in the city with traffic crises. Traffic bottleneck information gives a chance to drivers and passengers to detect alternative routes for their journey (Ertaş, 2009, pp: 70-77).

On the other hand, to improve of the bus network capacity, some operational models develop. Most famous model is BRT. There are a lot of BRT networks in the world. These are based on, basically, bus dedicated roads.

Rapidly grooving cities could not satisfy citizen transportation demands at the end of 20th century. BRT is enforced by the conditions of large cities, so congested traffic and problematic transportation is facilitated.

To obtain citizen satisfaction, operators of the BRT must tracks and calculate of the network performance and must associate with customer satisfaction.

Railway transit system has own isolated control center and special operation model. So it is possible to improve both the performance measurement models, as well as possible to watch and follow.

Also classical (regular) bus networks run many decades. Although there is not a common standard of measurement for performance indicators, each city and each
networks has own KPI’s, many of them are like others.

Basically there are 3 operational indicators for bus networks: Scheduled trip completion ratio, Punctuality, Regularity. For calculation, deviation ratio for time based indicators must be taken 1-2 minutes level. So especially BRT networks, if the headway is between two busses less than 2 minutes, classical regularity calculation cannot meet purpose of the indicator.

**Some Related Works**
There are a lot of works about ITS and PTs.

In the Paris, there are a lot of tram and metro lines. Sometimes a specific line requires annual maintenance. Or sometimes maintenance requirements of the some roads or cross section affected with the tramway line occurs. Governors want to make line and time optimization for during maintenance time. They want to know traffic effects of each decision. For example, what will happen when changing light duration or road lane direction? So they made some simulation. After computer simulation they decide for operations. (Torday, 2009, pp: 85-94).

Similar study, effects of re-arrangement of lane of the roads and public transportation alternatives is simulated for Tokyo for 2016-Olympics by the governors. London simulation is made for metro exit and pedestrian ways for traffic affects. (Torday, 2009, pp: 85-94).

According to Main University works: If the ITS solution is applied to PT, accident cost decreases %44, Time lost decreases %41, Fuel oil emission decreases %6, operational cost decreases %5 ... (Akbas, 2009 pp: 23-29)

IETT and Bahcesehir University made an international panel about Intelligent Transportation Systems and Applications at the Public Transportation) (Akbas, 2009 pp: 23-29 ant others)

Kocaeli Municipality Bus Department studied about modelling and measurement public transportation performance. (Kumbar, 2011, pp: 230-244)
Izmir Municipality studied about public bus line planning by the smart card information. (Tinaztepe, 2011, pp: 356-369)

IETT of Istanbul shares project pre-results about GPS based fleet management and analysis. (Turkoglu,1, 2011 pp:20-25)

Also there are a lot of applications on the world. All bus fleet operators make some assuming, try some integration to computerize their system and try improvement of their performance.

**IETT**

IETT is the Bus Public Transportation Authority of the Istanbul Municipality. The Istanbul metropolitan has near 15 million citizens, and is divided into two semi-Islands which are connected by two bridges. Because of the geographic conditions, there are two main traffic blockages on the east-west directions. IETT runs the public transportation fleet with 5200 buses; 2700 public buses and 2500 private buses owned by six partner companies and 500 busses for BRT.

In the conventional method of fleet management, schedule plans are made and distributed to vehicles, drivers and dispatchers via depots.

The Dispatcher gives their decision under the conditions of the declared plans, passengers, etc. At the end of the work day, he writes a summary of the day in the form of a report.

Central reporting service collects each dispatchers report and produces boarding reports for tactful decisions and corporation KPIs. For example, some KPIs are punctual for the departure time from the terminal (according to the declared schedules), performed a ratio of the plans, a ratio of the ‘death kilometers’ (non-revenue distance travelled by buses)

In the IETT ITS project, the first step is based on real time information collecting about the fleet and its operations through computer based management. The next step will be computer aided fleet management with decision support mechanisms. (Turkoglu,2, 2009, pp: 78-84)
Metrobus

Metrobus is brand-name of Istanbul BRT network. ITS gives detailed analysis facility. For example figure -1,

![Figure-1 Bus Group location vs. time in the Metrobus line.](image)

Figure –1 shows a specific bus group running in the BRT road. It is expected that buses which have approximate boarding times to each-other must have same slope (the parallel lines located in the figure). The figure also shows revenue/non-revenue trips, operation efficiencies, etc. If there are no outstanding conditions, the engineers try to make the arrival time of a specific route to the last terminal to boarding time of other routes as close as possible.

According to classical regularity calculation:

“Given a generic bus stop j at time period t along the direction d of a route r, once data have been validated and criticality have been addressed, we calculate the Cv_h as follows:

\[ \text{Cv}_{j,t,d,r} = \frac{\sum_{j,t,d,r} f_{j,t,d,r}}{h_{j,t,d,r}} \]  

(Eq-1)
Where:

\( \sigma_{j,t,d,r} \) is the standard deviation of the differences between actual and scheduled headway at bus stop j, time interval t, direction d and route r; the values used for the evaluation span over a monthly planning horizon.

\( h_{j,t,d,r} \) is the average scheduled headway at bus stop j, time interval t, direction d and route r.

In many transit agencies, the standard time interval is one hour. Since transit agencies may add or remove some bus trips to better serve the changing demand in this paper \( h_{j,t,d,r} \) is computed as the average of headways of scheduled transits times, to account for these additional trips and possible gaps.” (Barabino)

If we take maximum 2 minutes for differences between actual and scheduled headway at bus stop is a regular trip, our BRT, Istanbul Metrobus has a good performance.

![Figure-2 Metrobus Regularity Graph](image-url)

*Figure-2 Metrobus Regularity Graph.*
Figure-3 shows excess wait time of BRT system. As shown excess wait time is near 1.3 minutes so, it is under 2 minutes.

But there is a significant point that scheduled headway is new 20 seconds. So regular lines type indicator is not sensitive for ultra-high frequency networks.

**Cross-Section Transition Performance for BRT**

To improve of sensitivity of the BRT network regularity, Cross section transition can be used.

Given a generic cross-Section \( j \) at time period \( t \) along the direction \( d \) of a route \( r \), once data have been validated and criticality have been addressed, we calculate the \( R_{vh} \) as follows:

\[
R_{vh}^{j,t,dr} = \left\{ \left\langle 0 \right| t \right\} \quad \text{(Eq-2)}
\]

Where:

\( \rho_{vh}^{j,t,dr} \) is the transition of the bus count passing through cross-section \( j \), time interval
t, direction d and route r; the values used for the evaluation span over a monthly planning horizon.

$s^{j,t,d,r}$ is the scheduled transition of the bus count passing through cross-section j, time interval t, direction d and route r.

If we apply eqn-2 to BRT

![Cross-Section Transit Regularity](image)

Figure 4 shows Cross section Transit model regularity measurement. It is near also customer satisfaction level.

**Cross-Section Capacity Performance for BRT**

In the “Cross-section Transit Regularity” performance, algorithm eliminates bus transition under scheduled transition in a time period. For example according to time plan table, if 25 busses pass through one direction in 10 minutes time interval while waited 28 busses, Calculation takes as 0 (zero) for this time period. So one performance indicator, also, must include capacity vs. scheduled capacity for a time interval.
To improve of sensitivity of the BRT network regularity, Cross-section transition can be used.

Given a generic cross-Section \( j \) at time period \( t \) along the direction \( d \) of a route \( r \), once data have been validated and criticality have been addressed, we calculate the \( P_{v_h} \) as follows:

\[
P_{v_h}^{j,t,d,r} = \frac{r_{j,t,d,r}}{s_{j,t,d,r}} \quad \text{(Eq-3)}
\]

where:

- \( r_{j,t,d,r} \) is the transition of the bus count passing through cross-section \( j \), time interval \( t \), direction \( d \) and route \( r \); the values used for the evaluation span over a monthly planning horizon.

- \( s_{j,t,d,r} \) is the scheduled transition of the bus count passing through cross-section \( j \), time interval \( t \), direction \( d \) and route \( r \).

<table>
<thead>
<tr>
<th>Time Interval</th>
<th>Scheduled Transit</th>
<th>Completed Transit</th>
<th>Interval Regularity</th>
<th>Capacity Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>08:00</td>
<td>12</td>
<td>15</td>
<td>1</td>
<td>100%</td>
</tr>
<tr>
<td>08:10</td>
<td>13</td>
<td>11</td>
<td>0</td>
<td>85%</td>
</tr>
<tr>
<td>08:20</td>
<td>12</td>
<td>12</td>
<td>1</td>
<td>100%</td>
</tr>
<tr>
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<td>12</td>
<td>17</td>
<td>1</td>
<td>100%</td>
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</tr>
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<td>09:00</td>
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<td>10</td>
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</tr>
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<td>82%</td>
</tr>
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<td>9</td>
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<td><strong>Total</strong></td>
<td><strong>100%</strong></td>
<td><strong>58%</strong></td>
<td><strong>88%</strong></td>
<td></td>
</tr>
</tbody>
</table>

*Table-1 Performance calculation for sample cross-section \( j \) direction \( d \) and route \( r \)*

Table -1 shows performance calculation with sample data at the cross-section \( j \) direction \( d \) and route \( r \). According to table, transition is completed nearly same with
scheduled time table, also, 100 percent capacity in one hour interval.

If we apply eqn-2 and eqn-3 to BRT of Istanbul for 5 cross-section points for 10 minutes time interval in specific a day, we obtain falling table;

<table>
<thead>
<tr>
<th>Cross-Section</th>
<th>Transit Regularity toWest</th>
<th>toEast</th>
<th>Capacity Regularity toWest</th>
<th>toEast</th>
<th>Serviced Capacity toWest</th>
<th>toEast</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>62%</td>
<td>66%</td>
<td>85%</td>
<td>88%</td>
<td>98%</td>
<td>100%</td>
</tr>
<tr>
<td>#2</td>
<td>59%</td>
<td>62%</td>
<td>85%</td>
<td>88%</td>
<td>98%</td>
<td>100%</td>
</tr>
<tr>
<td>#3</td>
<td>64%</td>
<td>72%</td>
<td>88%</td>
<td>87%</td>
<td>98%</td>
<td>100%</td>
</tr>
<tr>
<td>#4</td>
<td>63%</td>
<td>71%</td>
<td>91%</td>
<td>93%</td>
<td>98%</td>
<td>99%</td>
</tr>
<tr>
<td>#5</td>
<td>58%</td>
<td>64%</td>
<td>84%</td>
<td>86%</td>
<td>97%</td>
<td>98%</td>
</tr>
</tbody>
</table>

Table -2 One day Metrobus performance calculation

In Table-2 it is seen that, east direction performance is better than west direction for the selected date. Also we can calculate daily performance with a summarization method:

<table>
<thead>
<tr>
<th>Average Daily Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross-section Transit Regularity</td>
</tr>
<tr>
<td>Cross-section Transit Capacity</td>
</tr>
<tr>
<td>Daily Serviced Capacity</td>
</tr>
</tbody>
</table>

Table -3 One day Metrobus performance

Table 3 shows 3 performance indicators and their results. Also it is seen, Cross-section Throughput Capacity for BRT indicator is nearly same with “completed KM vs scheduled KM” indicator of regular buses network. Istanbul BRT (Metrobus) has high level performance for this classical indicator.

Cross-section Transit Capacity and Cross-section Transit Regularity indicators say that there are some areas for potential for improvement of the Performance. For example Cross-section #5 must be evaluated because of weak service level.

Conclusion
The ITS System for public transportation basically supplies classified and analyzable data to operators. Governments can manage their fleet strategically by the data provided, while simultaneously sharing this data with its citizens.
Computer aided fleet management stores all of the digitized data forever. This data can be accessed whenever you want, can be report whatever any type.

Correct and clean data near to operation time gives great opportunity for tactical level decision support.

Also Ultra High Frequency performance indicator must be derivate for common standards. Our cross-sectional transition regularity can be improved with new technics.

References


PLANNING OF TRANSIT-ORIENTED DEVELOPMENT CITIES FOR GREATER MOBILITY

Muslihah Mustapha\textsuperscript{1} and Abdul Azeez Kadar Hamsa\textsuperscript{2}

\textbf{Abstract}: With the fast growing changes in the economic structure and the need for improved economic growth, it is imperative to indulge in greater mobility of the people for economic benefits. The increasing use of private vehicles in the cities has affected the mobility of people significantly not only during peak hours but also off-peak hours. A number of literatures have stated about negative implications to the cities as a result of the effects on mobility. To improve the mobility of the people, it is very important to provide efficient, attractive and reliable public transportation system to induce a shift from the use of private to public transport. Planning of transit-oriented development (TOD) cities is an important initiative to address the growing needs of urban mobility. Urban mobility can be effectively addressed through the provision of efficient and effective public transportation system. In order to encourage greater use of public transportation system especially rail-based, it is highly necessary to plan the location of rail transit station at areas which could attract the use of rail transit services. It is learned that high density development, mixed land uses and efficient pedestrian infrastructure are the determining components for the surge in the use of public transit system. This paper analyses the land use characteristics of the selected transit stations along one of the existing Light Rail Transit (LRT) system in Kuala Lumpur to understand its possible effects on the passenger ridership.

\textbf{Keywords}: transit-oriented development, rail transit, mobility, passenger ridership, land use characteristics, Kuala Lumpur

\textbf{1.0 Introduction}

Increase in population and rapid urbanization especially in developing countries has been contributing to increase in travel in major urban areas which leads to urban mobility problems such as traffic congestion. To handle this growing problem, it is very imperative to provide efficient and effective transportation system to address the increasing travel demand. Increasing road infrastructure supply to cater for the increase in travel demand especially by private vehicle use may not necessarily addresses the congestion problems in the long run. Moreover, the increase in road infrastructure in major towns and cities requires adequate land, economic and other related resources which are always not possible to provide for. Furthermore, it raises the question of

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attaining sustainable transportation if land resources are fully utilized to develop road and related infrastructure to cater for increase in travel demand by private transport. The increase in private vehicle use will increase the air pollution levels and thus greatly induces environmental degradation affecting the living quality of the population.

It is noticeable that many cities in developing countries share some common characteristics with respect to transport and traffic conditions. To exemplify, mixed traffic conditions, low travel speed and unhealthy environmental pollution are few among them. On the other hand, public transportation system plays a very important role in providing not only urban mobility for a greater population but also helps to relieve some of the common traffic problems in developing cities. The poor public transport services in these cities, however, do not support these beneficial advantages to a larger extent. This is predominately seen in Kuala Lumpur and other major cities in Malaysia. The less competent public transportation system in terms of lack of coverage areas, low frequency, inadequate public transport network and infrastructure and lack of versatility in the form of public transportation system has further aggravated the worsening traffic conditions along many major roads leading into the cities. This has resulted in the increased share of private vehicle use in Kuala Lumpur and other cities.

It is widely agreed that transit-oriented development can increase the use of public transit system through careful planning and design of public transportation system, pedestrian and bicycle facilities and high density mixed use development around the rail stations. The reduction in the number of trips, trip length (person and vehicle miles) by private transport and increase in passenger ridership by public transportation through transit-oriented development has been realized in many developed countries. In the recent past, transit-oriented development has gained momentum in many developing countries because of the benefits that it renders in relieving congestion, pollution and protecting from further environmental degradation. In Malaysia, new initiatives and multiple efforts have been taken by the government authorities to improve the public transportation system under the National Key Result areas (NKRA) especially in Kuala Lumpur in an attempt to shift from the use of private to public transportation. The ongoing construction of Mass Rapid Transit (MRT), Bus Rapid Transit (BRT) and the extension of Light Rail Transit (LRT) in Klang valley are some of the major public transportation projects which are undertaken to address the growing travel demand of the population. The location of the stations and design characteristics around the stations are important indicators which should be considered to encourage users to shift from private to public transportation. The success of the public transport use is largely depends on how attractive the system is to the commuters especially in terms of the location of the stations, infrastructure at the stations, the characteristics of land use and pedestrian infrastructure surrounding the station. This paper analyses the impact of land use characteristics on passenger ridership of public transportation system by selecting few stations along the Kelana Jaya LRT line.
2.0 Literature Review

2.1 Role of Public Transport

Public transportation is an important transportation mode used by transportation planners to solve various transportation problems, particularly traffic congestion in urban areas. Public transport refers to public vehicles which are being used to carry passengers, where the passengers pay a fare for the services provided to make the journey (Ibrahim Wahab, 1991). Transit provides mobility and accessibility to the employment, community facilities, medical care, and recreational activities. The role of public transportation in providing a form of public good (White, 1995) and as a provision of mobility for the young, elderly, handicapped and poor (Isaac, 1995) is important to include in the planning considerations of any human settlements. Thus, transit becomes more important as cities grow. In smaller cities transit primarily serves disadvantaged riders (people cannot use an automobile), but as cities grow in size and density, transit tend to serve more choice riders (people who have the option of driving). As a result, it provides more benefits to the community by reducing traffic problems and supporting more efficient land use patterns.

2.2 Definition and Evolution of Transit-oriented Development

Transit-oriented development (TOD) is a planning technique that aims to reduce automobile use and promote the use of public transit and human-powered transportation modes through high density, mixed use, environmentally-friendly development within areas of walking distance from transit centres (Wann-Ming Wey and Yin-Hao Chiu, 2013). In a nutshell, transit-oriented development is a compact, pedestrian-friendly high-density development near transit stations (Ming Zhang et al., 2012). One of the keys in the definition indicates “an integrated, comfortable (in terms of level of service), easily available and reliable mass rapid transit services” which may encourage shift from personal vehicles to mass rapid transit (Litman, 2009) as reported in Vimal Gahlot et al., (2012). The transit services provided in transit-oriented development could be bus-based or rail-based. Literature shows that countries are engaged in constructing Bus Rapid Transit (BRT) as the main rapid transit mode for cities with populations under five million and rail-based technologies for cities with populations over five million (Vimal Gahlot et al., 2012). Anastasia Loukaitou-Sideris (2010) has reported, as stated in Calthorpe, 1993; Cervero, 1993; Bernick & Cervero, 1996, that when the idea of transit-oriented development entered the lexicon of planning in the late 1980s, it was enthusiastically endorsed by some planners and academics who viewed TODs as a way of mitigating the ubiquity of sprawl and as a strategy for smart growth. Actual implementation of projects, however, was slow to follow as developers and funding institutions were hesitant about the level of public acceptance and marketability of such projects especially in regions that seemed to be married to the private automobile.
(Boarnet & Crane, 1998; Loukaitou-Sideris & Banerjee, 2000), as reported in Anastasia Loukaitou-Sideris (2010). Twenty years later the concept of TOD is no longer ‘academic’. Many housing and mixed-use projects have appeared in close proximity to stations and more are on the drawing boards or at various stages of the approval and development process (Dittmar & Ohland, 2004), as reported in Anastasia Loukaitou-Sideris (2010). Stefano Gori, et.al.,(2012) highlights the comparison between transit modal share in trip generation and attraction with average distance from the mass rapid transit stops in Rome, Italy. For distances lower than 500 m, the transit modal split is larger than 35% for generated trips and is about 30% for attracted trips. On the other hand, for distances higher than 1 km, the average value of the transit modal split decrease in a very important way (Stefano Gori, et.al., 2012).

2.3 Interaction between Land use and Transport

Transportation and land-use are irreversibly linked, as public transit is only viable and cost-effective with urban land-use forms that maintain a number of density (Pushkarev and Zupan 1977, 1980). Of all the built environment factors, transit use varies primarily with development densities and secondarily with the degree of land use mixing (Cervero, 1996; Ewing, et al. 2010). Many land use factors overlap. For example, mix, transit accessibility and parking management all tend to increase with density, so analysis that only considers a single factor may exaggerate its effect (Stead and Marshall 2001). Ewing, Pendall and Chen (2002) also had developed a sprawl index based on 22 specific variables related to land use density, mix, street connectivity and commercial clustering. The results indicate a high correlation between these factors and travel behavior; a higher sprawl index is associated with higher per capita vehicle ownership and use, and lower use of alternative modes. Beaton (2006) found, as stated in Litman (2012), that in the Boston region, transit ridership increased with local land use density. Neighborhoods that were developed around commuter rail stations but lost rail services after 1970 have retained relatively high rates of transit ridership, indicating that local land use factors such as density and mix have a significant impact on travel. Beaton (2006) found, as stated in Litman (2012), that neighborhood density has a greater effect on transit ridership than household income. According to Tumlin and Millard-Ball (2003), density is paramount. The reason is that “all else being equal, the more housing and jobs within a short walking distance to the transit station, the greater the ridership.” According to a national report by the Transit Cooperative Research Program (1996), ten percent increase in population density around transit stations was found to increase ridership by five percent, while doubling density was shown to reduce vehicle travel by up to 20 percent. According to Rosenbloom and Clifton (1996), the evidence for a positive relationship between population density and transit ridership is “fairly well established”. Pushkarev and Zupan (1977) were the first to report on urban residential densities and their capability to positively influence transit demand and thus to reduce car ownership and use. Ewing (1995), Kockelman (1995) and Ewing and
Cervero (2010) conclude, as stated in Litman (2012), that density itself has relatively little impact on travel. They found that other factors which are associated with density, such as regional accessibility, land use mix and walkability, actually have far greater impacts on travel behavior. Studies at the metropolitan region level have found density to be a significant factor in system ridership levels (Rosenbloom & Clifton, 1996) as well as at the station-area level (Parsons Brinckerhoff Quade & Douglas, 1996). Empirical studies show that people living in denser areas use transit more frequently (Cervero, 1993). Indeed, a meta-analysis of 17 primary travel studies found that population density and employment density exert a strong influence on travel behavior (Leck, 2006). Generally, types of density can be divided into 3 categories which are low density, medium density and high density. Low density can generally be understood as referring to approximately 40 or less dwelling units per hectare (gross), medium density to approximately 40–100 dwelling units per hectare (gross), and high density to around 100 or more dwelling units per hectare (gross). Furthermore, population density is measured by dividing total population with total land use area. Besides, the two elements to measure population density according to the type of development are total number of development units and total land area (development area).

Other than that, the other factor such as land use characteristics for instance, mixed land use also may influence on the travel demand and transit ridership. Land use mix refers to locating different types of land uses (residential, commercial, institutional, recreational, etc.) close to each other. Mixed-use developments are those with a variety of offices, shops, restaurants, banks, and other activities which are intermingled amongst one another (Cervero, 1988). Cervero, et al. (2004) found that increased residential and commercial density and improved walkability around a station increase transit ridership. Thus, the main advantage of a mixed use area, in transportation terms, lies in the proximity of the activities, which shortens traveling distances between them. Interesting enough, recent literatures suggest that the aforementioned higher densities are the most beneficial to transit ridership when they result in a mix of residential, commercial, and office uses (Cervero, 2002).

Stefano Gori, et.al., (2012) has stated that important changes in urban features strongly modified the quantity and quality of the mobility system: the continuous spread of residences and activities have increased the length of trips and the use of private transport; the usual mobility habits have been changed by more complex behaviours (trip chaining) (Stefano Gori, et.al., 2012). The automobile is often considered the only transport mode while transit became less and less used with strong impacts on environment and sustainability (Stefano Gori, et.al., 2012). The interaction between land-use and the transport system has been heavily dealt with by the research community recently and, in this section, the literature review represents the synthesis of some interesting analysis about this interaction focusing on the relationships between land use characteristics (such as urban densities, neighborhood design schemes and
mixed land-use) and transit ridership (Stefano Gori, et.al., 2012). This is a very controversial topic because different thesis are already present: some studies establish that such variables seem to have an impact on auto ownership and use, but other studies quantify the impact as, at best, marginal (Stefano Gori, et.al., 2012).

The importance of a high quality access system to transit stops is underlined also by Schlossberg and Brown (2004), as reported in Stefano Gori, et.al. (2012). Extensive debates are also related to the role played by the population and activities densities to explain the level of car and public transport use. Sinha (2003), as reported in (Stefano Gori, et.al. (2012), demonstrates, with the collection of different data from 46 cities in United States, Australia, Canada, East Europe and Asia, that a high urban population density seems to be a primary element to increase transit boardings. The transit boardings per capita per year increase with the rise of the number of persons per hectare, while the car kilometers of travel per capita per year decrease.

3.0 Research Methodology

3.1 Methods of Data Collection

The primary data for this study was collected by the observational survey and passenger volume count. The data collected from observational survey were land use details surrounding the selected rail stations. The details of land use data include: types of land use and intensity of land use density surrounding the three chosen LRT stations. Besides, the movements of LRT users also were observed and recorded by taking photographs. Photos were also taken to show the existing conditions of the study area. The data from this survey are illustrated by maps, diagrams and photos.

The passenger volume data was collected at the three LRT stations namely Asia Jaya, KL Sentral and Gombak station by using passenger volume count method. Each station is classified into one of the three groups: station which falls within CBD area, middle area and outer-area with respect to the degree of land use density and types of land use surrounding the stations. The outer area station constitutes Gombak station, CBD area KL Sentral station, while middle area Asia Jaya station. This survey was administered by positioning the enumerators at the entrance/exit point of the stations. The passenger volume was counted on weekday (Friday, 15/4/2011) and on weekend (Saturday, 16/4/2011) for a duration of two hours covering both peak (8am-10am) and off-peak hours (2pm-4pm). The data during peak and off-peak hours was collected to compare the passenger ridership during these two different time periods.

3.2 Methods of Analysis

The existing land use patterns surrounding the LRT stations were identified by land use maps and observation. Next, the number of development units surrounding the selected
LRT stations was counted. The number of development units and its area for each type of land use at each station is shown in the form of a table. The density of land use (in population per hectare or number of dwelling units per hectare) at each of the selected stations was measured and documented in tables.

The passenger volume trends at each of the stations during peak and off-peak hours on weekday and weekend is shown by using bar charts. The analysis on the relationships between land use characteristics and passenger ridership was made by comparing the land use characteristics and passenger ridership at each of the three selected stations.

4.0 Study Area

The Kelana Jaya line is one of the two Light Rail Transit (LRT) lines in Kuala Lumpur Rail Transit System operated by RapidKL Rail network. The line was formerly known as PUTRA LRT (Projek Usahasama Transit Ringan Automatik Sdn Bhd), and was officially changed from Putraline to Kelana Jaya line in July 2005.

The alignment of the Kelana Jaya line passes through Selangor (Petaling and Gombak Region) and Kuala Lumpur (figure 1). It consists of a single line from Kelana Jaya to Gombak that primarily serves the Petaling Jaya region in the south; southwest and central Kuala Lumpur, and Kuala Lumpur City Centre in the centre; and various low density residential areas further north of Kuala Lumpur. The Kelana Jaya line is mostly an elevated route running through many high-density residential and commercial areas on a dual-track guideway. In 2002, the LRT system has carried its 150 millionth passenger, with an average of 160,000 passengers riding the system daily. Today, it carries over 190,000 passengers a day and over 350,000 a day during national events. It is considered to be the world’s largest, fully automatic driverless system using linear induction motors.

The Kelana Jaya line has 24 stations (5 stations underground, 18 elevated, 1 at-grade) at 1.1 km intervals along its 29 km (18 mi) length. It was constructed in two sections; Lembah Subang to Pasar Seni/Central Market (14.1 km = 21 mins), and Pasar Seni to Ampang Park and Terminal Putra in Gombak (14.9 km = 24 mins). This system provides commuters living in the city's eastern and western suburbs (Gombak) a fast and efficient service. The east-west route bypasses some of the most congested roads servicing some of the most affluent and heavily populated areas. The journey from one end to the other takes about 45 minutes, skirting areas which are heavily congested, and helps alleviate early morning jams. However, only three stations were selected namely Gombak station, KL Sentral station and Asia Jaya station for this study (figure 2).
5.0 Research Findings

5.1 Land Use Characteristics

The three stations for this study were selected based on the type of areas surrounding the stations which are categorized into 3 types of areas namely inner areas, Central Business District, and outer areas. It is shown in table 1.

<table>
<thead>
<tr>
<th>Group</th>
<th>Area Category</th>
<th>Station</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Inner-areas</td>
<td>Asia Jaya</td>
</tr>
<tr>
<td>B</td>
<td>Central Business District</td>
<td>KL Sentral</td>
</tr>
<tr>
<td>C</td>
<td>Outer-areas</td>
<td>Gombak</td>
</tr>
</tbody>
</table>

A 500 m radius from each LRT station was selected as an acceptable catchment area to define the boundary of the areas for data collection. This defined catchment area surrounding the selected rail stations serves not only as an ideal walking distances for the pedestrians to access the stations but also facilitates to collect data on land use activities. The total area of land use at each of the three stations, within the catchment area, is 78.54 ha. The three stations were surrounded by different types land use density and land use mix as shown in table 2.
activities. The total area of land use at each of the three stations, within the catchment area, is 78.54 ha. The three stations were surrounded by different types land use density and land use mix as shown in table 2.

Table 2 Land use surrounding station A, B and C

<table>
<thead>
<tr>
<th>Station</th>
<th>Land use</th>
<th>Unit</th>
<th>Hectare (ha)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Residential (terrace houses)</td>
<td>220</td>
<td>11.99</td>
<td>15.27</td>
</tr>
<tr>
<td></td>
<td>Light Industry</td>
<td>35</td>
<td>33.44</td>
<td>42.60</td>
</tr>
<tr>
<td></td>
<td>Commercial (office lot)</td>
<td>2</td>
<td>2.29</td>
<td>2.92</td>
</tr>
<tr>
<td></td>
<td>Educational Institution</td>
<td>1</td>
<td>4.05</td>
<td>5.16</td>
</tr>
<tr>
<td></td>
<td>Open Space</td>
<td>-</td>
<td>11.97</td>
<td>15.24</td>
</tr>
<tr>
<td></td>
<td>Road</td>
<td>-</td>
<td>14.80</td>
<td>18.84</td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
<td>258</td>
<td>78.54</td>
<td>100</td>
</tr>
<tr>
<td>B</td>
<td>Residential (bungalow houses)</td>
<td>70</td>
<td>9.11</td>
<td>11.60</td>
</tr>
<tr>
<td></td>
<td>Commercial centre</td>
<td>40</td>
<td>35.51</td>
<td>45.21</td>
</tr>
<tr>
<td></td>
<td>Mixed Development (shophouses)</td>
<td>211</td>
<td>6.52</td>
<td>8.30</td>
</tr>
<tr>
<td></td>
<td>Sport Complex</td>
<td>1</td>
<td>1.77</td>
<td>2.25</td>
</tr>
<tr>
<td></td>
<td>Institution</td>
<td>10</td>
<td>6.64</td>
<td>8.45</td>
</tr>
<tr>
<td></td>
<td>Public Facilities</td>
<td>11</td>
<td>7.33</td>
<td>9.33</td>
</tr>
<tr>
<td></td>
<td>Open Space</td>
<td>-</td>
<td>1.27</td>
<td>1.62</td>
</tr>
<tr>
<td></td>
<td>Road</td>
<td>-</td>
<td>10.39</td>
<td>13.23</td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
<td>343</td>
<td>78.54</td>
<td>100</td>
</tr>
<tr>
<td>C</td>
<td>Residential (bungalow houses)</td>
<td>447</td>
<td>32.22</td>
<td>41.02</td>
</tr>
<tr>
<td></td>
<td>Residential (low cost-village)</td>
<td>185</td>
<td>12.95</td>
<td>16.49</td>
</tr>
<tr>
<td></td>
<td>Commercial</td>
<td>3</td>
<td>1.36</td>
<td>1.73</td>
</tr>
<tr>
<td></td>
<td>Open space</td>
<td>-</td>
<td>3.36</td>
<td>4.28</td>
</tr>
<tr>
<td></td>
<td>Road</td>
<td>-</td>
<td>28.65</td>
<td>36.48</td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
<td>635</td>
<td>78.54</td>
<td>100</td>
</tr>
</tbody>
</table>

5.2 Land Use Density

The land use characteristics in terms of population density, building density and types of land use vary between one station to another. The population density at station A (Asia Jaya) was the highest, which accounts for 91.7 people per hectare followed by station C and station B. It is shown in table 3. Station A is located at inner areas just outside the Central Business District (CBD) with major land uses of residential and industrial activities. Several residential areas especially in the form of terrace houses were located near to station A at an acceptable walking distance to the station. However, other development densities including industrial and commercial areas were small and calculated to be 1.05 du/ha for industrial areas and 0.87 du/ha for commercial
areas. The low development density of these activities at station A has attracted less number of people to use LRT services at station A.

Station B (KL Sentral) is located at the Central Business District (CBD) areas and it is one of the main transportation hubs in Kuala Lumpur. It integrates different types of road and rail-based public transportation system including long distance rail services. This station is surrounded with both high rise residential and commercial activities. It covers the highest commercial floor area ratio (FAR) including offices, hotels and cafes. However, station B has the lowest population density (residential units) compared to the other two stations with a population density of 38.4 people per hectare.

Station C (Gombak) is located at the outer-areas of Kelana Jaya Line which consists of mainly residential and forested areas. Besides, there are also many undeveloped open areas near to this station. The existing commercial density within the catchment area of station C only covers about 2.21 du/ha. However, the population density (based on residential units) at this station was higher than station B with a population density of 69 people per hectare. As station C is the closest LRT station serving a wider Gombak area, it attracts many people from outside the catchment area to use this LRT station which is also provided with “park and ride” facility to cater for these users.

Table 3 Land use density within the catchment area at station A, B and C

<table>
<thead>
<tr>
<th>Station</th>
<th>Land use</th>
<th>Unit</th>
<th>Hectare (ha)</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Residential (terrace houses)</td>
<td>220</td>
<td>11.99</td>
<td>91.7 people/ha</td>
</tr>
<tr>
<td></td>
<td>Industry</td>
<td>35</td>
<td>33.44</td>
<td>1.05 du/ha</td>
</tr>
<tr>
<td></td>
<td>Commercial (office lot)</td>
<td>2</td>
<td>2.29</td>
<td>0.87 du/ha</td>
</tr>
<tr>
<td>B</td>
<td>Residential (bungalow houses)</td>
<td>70</td>
<td>9.11</td>
<td>38.4 people/ha</td>
</tr>
<tr>
<td></td>
<td>Commercial centre</td>
<td>40</td>
<td>35.51</td>
<td>1.13 du/ha</td>
</tr>
<tr>
<td></td>
<td>Mixed Development</td>
<td>211</td>
<td>6.52</td>
<td>32.36 du/ha</td>
</tr>
<tr>
<td>C</td>
<td>Residential (bungalow houses)</td>
<td>447</td>
<td>32.22</td>
<td>69.37 people/ha</td>
</tr>
<tr>
<td></td>
<td>Residential (low cost-village)</td>
<td>185</td>
<td>12.95</td>
<td>42.86 people/ha</td>
</tr>
<tr>
<td></td>
<td>Commercial</td>
<td>3</td>
<td>1.36</td>
<td>2.21 du/ha</td>
</tr>
</tbody>
</table>

5.3 Relationship between land use characteristics and passenger ridership

Based on the findings of passenger ridership during peak hour, station B shows the highest number of passenger ridership on weekday and weekend compared to station A and station C as shown in figure 3. It is due to the location of this station which is being located within the CBD area and the presence of high density commercial and mixed
use development such as houses, offices, retail shops, hotels, restaurants, and cafes. According to Selangor Structure Plan 2000-2020 and Draft Kuala Lumpur Structure Plan 2020, Kuala Lumpur city centre contributes the highest employment distribution in Klang Valley for the year 2010 and it is expected to contribute further in 2020. The increase in the development density attracts more employment opportunities which provide an avenue for an increase in the number of passenger ridership by rail transit. Research in Houston (Rice Center, 1987) found that “CBD workers are five times more likely to use transit than workers on other activity centers”. Besides, Kuala Lumpur Sentral is the multi-modal public transportation hub connecting several inter-rail and intra-rail transit services such as KLIA Ekspres, KLIA Transit, KTM Intercity, KTM Komuter, Putra LRT and KL Monorail. These rail services contribute to the increase in the passenger ridership at station B. Additionally, the ongoing construction of a new shopping mall near to the KL Sentral station would further increase the number of passenger ridership at this station in the future. Thus, the location of dense commercial activities and land use mix near to Station B plays an important part in the increase in the number of passenger ridership at this station. Ewing and Cervero (2010) found that land use mix reduces vehicle travel and significantly increases walking. They also found that increased proximity of land use mix to transit stop would increase transit travel.

The passenger volume (1-hour volume) at Station A and Station C was 465 and 580 on weekday and 570 and 713 on weekend respectively as shown in figure 3. Despite the fact that station C is located at the outer areas, the number of passenger ridership or passenger volume at this station was slightly higher than Station A (located at inner areas). The types of land use surrounding Station C such as residential areas and education institutions such as International Islamic University Malaysia, Sek.Men. Teknik Gombak and Islamic College were the contributing factors towards high LRT passenger ridership at station C. Moreover, as station C is located far from the city centre, people who are living in the catchment area of this station prefer to travel to the city centre by LRT rather than private vehicles. The increase in the number of passenger ridership at station C is also due to the provision of “park and ride” facility at this station which eventually attracts people from a wider catchment area to use LRT line at this station. Even though, the residential density at station A is the highest as compared to other two stations, but the passenger ridership at this station was low. The likely reason for this trend is the inappropriate location of this station which resulted in high use of private vehicles to the city centre.
The passenger ridership (1-hour volume) for the Kelana Jaya Line during off-peak hour on weekday and weekend was also high at station B accounting for 1040 and 1125 respectively as shown in figure 4. The number of passenger ridership at this station was higher than station A and station C because of its function as a transportation hub. The passenger ridership (1-hour volume) at station A and station C was 241 and 256 on weekday and 365 and 450 weekends respectively.

Some of the factors for the low passenger ridership at station A were firstly, the location of this station is situated near to the KL city center which makes the residents within this catchment area to drive by using private vehicles, as private vehicles are normally the preferred mode of transport among KL commuters and secondly, the location of this station was very close to the next rail station along this line which is Universiti station. Moreover, the Universiti station is provided with other types of public transport such as taxis and feeder buses and thus provides more transport choices to the users. Furthermore, despite this station is located near to the residential areas but its location was found inappropriate as it provides opportunities for criminal and other untoward activities. People were felt unsecured to park at this station even though this station is provided with adequate park and ride facilities.
Station A = Asia Jaya Station; Station B = KL Sentral Station; Station C = Gombak Station

Figure 4 Number of passenger ridership during off-peak hour on weekday and weekend

6.0 CONCLUSIONS AND RECOMMENDATIONS

High population and growing size of cities can lead to main urban mobility problems such as traffic congestion which is a common problem faced by the developing countries. In developing countries, many cities and metropolitan areas including Kuala Lumpur do share some common characteristics with respect to transport and traffic conditions. Nowadays, Light Rail Transit (LRT) usage has been encouraging and increasingly becoming a major mode of transport. However, there are still many factors which influence people not to use LRT services for travel due to various reasons. This paper has identified how the land use factors influence the use of LRT services. The number of passenger ridership was totally influenced by the presence of mixed land uses surrounding the selected stations. The presence of residential activities together with commercial activities has played an important part for the high passenger ridership at station B (KL Sentral). The number of passenger ridership at this station was predictably high as commercial centres can create a force of attraction and thus eventually increase the number of LRT users. The passenger volume during peak hour and off-peak hour on both weekday and weekend at station C (medium population density) was slightly higher than station A (high population density). Even though, the major type of land use surrounding station C is predominantly residential, this station has attracted even people who live outside the catchment area for their travel to the city centre by LRT. The land uses outside the catchment area also influence the users...
especially from residential and educational institutions to use Kelana Jaya LRT line. Consequently, the passenger volume at Station C was higher than Station A despite the fact that the population density at station C was lower than station A. Nevertheless, the land use characteristics such as land use density and mixed land use were found to have an impact on passenger ridership or passenger volume. Thus, integrating land use development and transportation system is considered very important to increase the number of transit passenger ridership. Even though, the number of LRT passenger ridership varies at the different selected stations, it is important to have workable strategies to increase transit ridership at all the stations along the LRT line. Some of the strategies such as intensification of developments in terms of mixed use development with high commercial plot ratio, medium to high residential density development, integrated community and business facilities surrounding the LRT stations and well-connected pedestrian infrastructural facilities to and from the rail stations were some of the measures proposed to further strengthen the integration between land use and transportation system. The proposed measures are aimed to further increase transit passenger ridership especially among the choice riders. Additionally, more “park and ride” facilities should be planned in the vicinity of the station terminal and key stations to encourage more private vehicles users to shift from using their own vehicles to LRT and other public transportation system for their travel to city centres.

REFERENCES


DETERMINANTS OF LAND USE CHANGE ALONG UNDER CONSTRUCTION OF MRT PURPLE LINE IN BANGKOK METROPOLITAN REGION

Sathita Malaitham 1, Varameth Vichiensan 2, Atsushi Fukuda 3 and Vasinee Wasuntarasook 4

Abstract

There has been an increasing interest in the interaction between urban land use and transportation developments in the past decades. Many substantial attempts have been made to empirically investigate how the connection among those activities for developed countries can be interpreted, yet few studies have been made in developing countries. This paper aims to examine the influencing factors that driving land use change in the adjacent areas of under construction’s rail transit corridor, namely MRT Purple Line. A logistic specification combined with geographically weighted regression (GWR) technique will be applied. Furthermore, its result will be compared with that of the standard logistic regression (Logist) model. The results show that the GWRLogist outputs explained considerably more variance in the relationship of the explanatory factor compared to the Logist model and provided significantly better results. It also found the presence of spatial non-stationarity in the study area and led to conclude that the rail transit has substantial predictive power to the future urban development.

Keywords: Land Use Change, Logistic Model, GWR, Bangkok Metropolitan Region, MRT Purple Line

1. Introduction

Since 1960, Bangkok has rapidly grown from being a small compact city located on the eastern area of the Chao Praya River to a large sprawling urban area due to the emphasized plans of transportation infrastructure development such as roads, bridges and expressway networks. These developments had unavoidably become one of the important factors in accelerating the growth of suburbanization. Such situations unavoidably generate a huge amount of travel demand. However, insufficient public transports lead Bangkokians who can afford traveling in a private car, rather than traveling on crowded bus. This claimed to be the cause of a car dependent city that made Bangkok has faced critical traffic congestion (Rujopakarn, 2003). Rail transit system has been introduced to alleviate the traffic issues and mainly serves people between suburban to the central part of Bangkok.

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Nowadays, there are three lines of the rail transit that have been operated in the BMR, including BTS Skytrain, MRT Blue Line, and Airport Rail Link. An important function of any rail transit system is to provide for people accessibility to residences; places for employment, recreation, shopping and so on; and for public goods and services. Consequently, the structure and capacity of rail transit networks affect the level of accessibility. Then, the adjacent areas of the rail transit corridors especially around the stations, which are the premium of transit accessibility, become attractive areas for commercial developments and residential developments, which lead to increased land values as competition for the sites rises. For example, the rail transit has a large influence on its surrounding area, especially around the stations. After the BTS Skytrain in Bangkok opened, many buildings (e.g. office buildings, hotels, condominium, etc.) had been renovated and constructed by developers, and land prices along the corridor have remarkably increased (Vichiensan et al., 2011). It was claimed that the premium of transit accessibility adding to the property value is approximately US$10 for every meter closer to the station (Chalermpong, 2007). More recently, the BMR has developed a long-range transportation master plan and placed the top priority to rail transit investments. Those benefits due to rail transit development also impact the areas which are announced for future extension. Such benefits make integrated models of land use and transportation very relevant for prediction of future urban structures. Land use model has received considerable attention in developed countries for many years, but less investigated in areas of developing cities like Bangkok.

This paper proposes the logistic specification augmented by geographically weighted regression (GWR) technique in determining the influencing factors of land use change in the adjacent areas of MRT Purple Line which will be finished in 2015. We hypothesize that the effects of that rail transit make an adjacent area relatively more accessible that attract the developers which, in turn, contribute to change the urban form. Thus, Satellite image in a given area is employed to investigate the conversions between 2004 and 2010 (before and after construction announcement) by comparing the conversions at the same place but different year whether it changed or not while controlling the covariates such as local transportation accessibility, work and non-work accessibility and land attribute.

The rest of this paper is organized as follows. Section 2, an overview of previous land use change studies and related variables will be presented. Various data used for the analysis and descriptive statistics will be presented in section 3. Section 4 provides an introduction of model specifications. Section 5, the models are estimated with the sample data. Finally comes the conclusion.
2. Literature review

2.1 Modelling of land use

Many substantial attempts have been made to empirically investigate the connection between transportation investments and urban land development forms for more than 30 years. Bell (1974) and Knight (1980) are perhaps the well-known among earlier inquires of urban structure and land use pattern. Moreover, there is a numerical of studies that attempt to estimate the impacts of transportation investments on land use change. These studies are common and/or different in the model structure utilized, the types of properties, the significant determinants factor and the findings as follows.

Some studies in the early work used the simply statistic data and compared in order to conclude the land use change impacts (Knight and Trygg, 1977, Knight, 1980, Dueker and Bianco, 1988, Giuliano, 1989). Some previous literatures have been tested with the most common functional forms, namely discrete choice model or so-called multinomial logistic model (Haider and Miller, 2000, Verburg et al., 2004, Cervero and Kang, 2011, Iacono and levinson, 2009, Meng and Zhang, 2011). Several studies attempted to capture the capitalization of transportation improvements using Markov analysis (Bell, 1974, Bell and Hinojosa, 1976, Weng, 2002, Levinson and Chen, 2005). In general, those methods assume a relationship is constant over space. In realistic, it often might vary across space. In addition, the measurement of the relationship depends in part on where the measurement is taken (Fotheringham et al., 2002). Therefore, it is natural to suspect the spatial effect, namely spatial non-stationarity association between land use change and its influencing factors.

Geographically weighted regression (GWR) model that allows estimating a model at each observation point was applied to estimate in many previous research in view point of hedonic price analysis, i.e. the relationship between property price and its attributes (Fotheringham et al., 2002, Du and Mulley, 2006, Farooq et al., 2010). However, GWR technique combined with a logistic specification is still absent in literature of land use change. Only a few studies were found to recognize spatial non-stationarity effects in their researches, for example, McMillen and McDonald (1999) combined GWR technique with logistic model to study the impact of transportation access on the conversion of five land use combinations in Chicago including all residential, all commercial, all manufacturing, commercial and residential, and manufacturing combined with some other land use. And the result indicated higher access to transport facilities was statistically associated with mix uses of land.

Likewise, Wang et al. (2012) combined logistic specification with GWR technique to discrete response data set, then, analyze land use change at the parcel level in Austin, Texas. Five categories of land use change consist of undeveloped, single-family plus multi-family residential, commercial, office and industrial uses were anticipated while controlling for parcel geometry, slop, regional accessibility, local population
density, and distance to downtown and various roadway types. Results of this model suggested spatial variations has significantly influenced on these covariates, especially roadway vicinity and regional access.

2.2 Determinants of land use change

Previous literature pointed to the location and neighborhood characteristics (e.g. accessibility to schools, commute time) where each land is located. Location refers to the specific placement of a land parcel which affects the developers’ investment. Since the land parcel is fixed in location, it differs in terms of its surroundings (neighborhood and community setting). Good locations and neighborhoods command higher demand than those in bad locations and neighborhoods.

Carrión-Flores and Irwin (2004) indicated that parcels located within approximately 14 miles of the outer boundary of the Cleveland urbanized area, the probability of conversion decreases at a decreasing rate with distance from Cleveland, however, parcels located beyond this distance, the probability of conversion increases with distance from the urbanized boundary. Also, the probability of conversion increases as distance from the nearest town increases. Similarly, it was clear that new residential areas are preferably located with easy access to towns and cities (Verburg et al., 2004). Iacono and Levinson (2009) showed that high level of accessibility to job are associated with a higher likelihood of transition to commercial land use but slightly effect in the change of residential land use. In contrast, the result suggested that land development is more likely to emerge away from the CBD, where land development restrictions are likely to be fewer, land values lower and construction costs lower (Wang and Kockelman, 2006). Likewise, residential and office land uses are more likely to appear in undeveloped parcels near the city fringe (Zhou and Kockelman, 2008).

The most destinations including recreation, shopping center, and the scenery areas (e.g. coast, river, park, city hall, etc.) were also examined. For example, Lo and Yang (2002) indicated that proximity to shopping mall has become important factors promoting the growth of edge cities in Atlanta. (Newburn et al., 2006) indicated that the percentage of open space do not appear to significantly affect residential conversion. Cervero and Kang (2011) showed that distance to city hall is statistically associated with condominiums and mixed uses conversions, albeit no clear or discernible pattern but park density ratio are less easy to explain and likely reflect local idiosyncrasies of Seoul’s commercial real estate market. Ferdous and Bhat (2013) indicated that parcels located within close proximity of a park (distance ≤ 2 miles) and/or a lake (distance to a lake ≤ 5 miles distance) are perceived by land owners as providing high returns to development relative to parcels located farther away from such natural amenities.

Among neighborhood density, Hardie and Parks (1997) indicated that increases in population density shift land away from farm and forest use to urban/other uses. The result revealed that population density is important in determining the land use
changes in Atlanta, Georgia (Lo and Yang, 2002). However, population density is found to convey a negative effect, suggesting that new development is less likely to locate in densely develop areas (Carrión-Flores and Irwin, 2004). Newburn et al. (2006) indicated that the importance of zoning for residential conversion is high density due to it increases rents per acre associated with residential uses. The school quality, land value, median income and land value, incidence of crime, the noise level, number of markets and shopping centers, number of children’s playground, number of recreation facilities, and number of parking facilities in the neighborhood were also chosen to be a representative attributes of locations and neighborhoods effect on the conversions of land with their methods. Previous research has provided mixed evidence including large positive, small positive as well as negative effects (Serneels and Lambin, 2001, Weng, 2002, Pacheco-Raguz, 2010, Cervero and Kang, 2011).

3. Model specification

The probability of land use conversions, are generated based on logistic specifications, which assumes constant over space. Most previous and present studies, especially for case studies in developing countries, have seldom investigated the spatial effect.

An application of logistic model is designed to estimate the parameters of a multivariate explanatory model in situations where the dependent variable is dichotomous or categories. This method yields coefficients for each variable based on a sample data that is land use parcels. The model specification (Schneider and Pontinus, 2001, Serneels and Lambin, 2001) can be written as in equation 1.

\[ P_{nj} = \Pr(Y_n = j \mid x_n) = \frac{\exp(x_n \beta_j)}{1 + \sum_{k=1}^{K} \exp(x_n \beta_k)} \]

where \( n \) denotes parcel observation, \( j \) indexes outcome land use type (if \( j = 0 \) indicating the base alternative: that is undeveloped land parcel), \( \beta \) is parameter which reflects the relation between the explanatory variables and the land use category, and \( P \) is the probability of a converting undeveloped land in 2004 to other land use categories \( j \) in 2010. A log likelihood function for converted parcels is defined as follows:

\[ \ln L = \sum_{n=1}^{N} \sum_{j=0}^{K} I_{nj} \ln \left( P_{nj} \right) \]

where \( I_{nj} \) is an indicator variable for land use type \( j \) at parcel \( n \) and \( I_{nj} = 1 \) if parcel \( n \) is of land use category \( j \) and 0 otherwise (Wang et al., 2012).
On the other hand, geographically weighted regression (GWR) is an extension of weighted least squares method and used to describe a family regression model in which the coefficients, $\beta$, are allowed to speculate on the relationship that might not be constant over space (Fotheringham et al., 2002). In case of continuous response (e.g. land price, property value), GWR model can be rewritten for each local model at observation location $i$ at the coordinates $u,v$ as follows.

$$Y_i = \sum (u,v) + \sum (u,v)X_i + \cdots + \sum (u,v)X_i + \sum$$

where the sub-index $i$ indicates an observation point where the model is estimated. The coefficients are determined by examining the set of points within a well-defined neighborhood of each of the sample points. The parameters $\beta(i)$ for this point can be determined following the framework of global regression, the local parameter estimation can be obtained:

$$\beta(i) = (X'W(i)X)^{-1}X'W(i)Y$$

where $W(i)$ is the geographical weight of each of the $n$ observed data for point $i$. This weight matrix is the point that differs from the standard model ($w_{ij} = 1$ for all values of $i$ and $j$). To calculate the matrix, a simple function may be defined such as $f(d) = \exp(-d^2/h)$, where $d$ is the distance between the focus point and other points, and $h$ is a parameter, the so-called bandwidth. This neighborhood is essentially a circle at the bandwidth distance interval around each data point. However, if $h$ is treated as a fix value in which all points are regarded as of equal importance, it could include every point (for $h$ large bandwidth) or alternatively no other points (for $h$ small bandwidth). Instead of using a fixed value for $r$, it is replaced by a distance-decay function.

As noted, in this study, the response is category outcome. The log likelihood function used is that applied by McMillen and McDonald (1999) and Wang et al. (2012) as shown in equation 5.

$$\ln L_i = \sum_{n=1}^{N} w_{in} \sum_{j=0}^{K} I_{nj} \ln \left( P_{nj} \right)$$

where $w_{in}$ is the weight for the $n$ data point with respect to the $i$ regression point and $P_{nj}$ is the probability of converted land use category $j$ for undeveloped land parcel $n$. To ensure that the bandwidth interval can circle adequate sample sizes in densely and sparsely distributed data, the tri-cube weight for pairs of points, which was proposed by McMillen and McDonald (1999) were applied to estimate bandwidth, expressed as in equation 7:
\[ w_q = \frac{1}{q!} \sum_{d_{ij} \leq q} \] (6)

where \( q_i \) represents the distance of the \( q \)th nearest neighbor to observation \( i \) (otherwise \( w_q \) equals zero).

4. Case study of land use change

4.1 Study area and data collection

The area within 3 kilometers from the corridor of MRT Purple Line, which located in the suburban area of Bangkok and it will be served the passenger to the inner city are, was tracked and observed the conversions of land between 2004 and 2010 as shown in Figure 1. To obtain land use change, satellite images were employed to derive land use change information between 2004 and 2010 by dividing it into rows and columns, which form a regular grid structure of equal proportions. Then, the effects of under construction’s rail transit, i.e., MRT Purple Line, evaluating whether land use change occurred or not was examined by focusing undeveloped land parcel (vacant land parcel) as an initial state.

In this paper, land use change model will be estimated based on two choices: converted or not as stated, meaning that the conversions from undeveloped land in Khlong Bang Phai Bang Yai Intersection Nonthaburi Intersection Sai Ma Bang Rak Yai station Tha It

Figure 1 Study area

Results of dividing land as grid cells, 35 x 35 meters was presented in Table 1. The total number of grid cells for undeveloped land in the year 2004 was 2,858 grid cells. Among of them, after the plan of MRT Purple Line was announced, it was found the conversions from undeveloped or vacant land parcels to residential use about 32% (914 grid cells) and non-residential land parcels around 3% (91 grid cells). However, around 65% (1,853 grid cells) remained undeveloped or vacant areas.

Table 1 Number of land parcels changed between 2004 and 2010

<table>
<thead>
<tr>
<th>Land Use</th>
<th>Code</th>
<th>No. of Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unchanged: Undeveloped</td>
<td>0</td>
<td>1,853 (64.84%)</td>
</tr>
<tr>
<td>Changed: To residential</td>
<td>1</td>
<td>914 (31.98%)</td>
</tr>
<tr>
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<td>1</td>
<td>91 (3.18%)</td>
</tr>
<tr>
<td>Total</td>
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<td>2,858 (100%)</td>
</tr>
</tbody>
</table>

Descriptive statistics of land use change and its attributes were briefly summarized in the Table 2. For local transportation accessibility, the results show the conversions from undeveloped land to non-residential areas tended to be near the main roads, stations, and expressways, while the conversions of residential areas tended to occur further as expected. Then, the statistics present the changes of undeveloped land to residential, and non-residential areas emerged farther to the central business district (CBD) which is the city center of Bangkok Metropolitan Region, e.g., on average, the conversions of residential and non-residential parcels were found within 19.835 kilometers and 19.755 kilometers, respectively. The conversions of non-residential areas tended to occur far from the shopping center approximately 9.611 kilometers and the conversions of residential areas occurred within 10.427 kilometers. Finally, the descriptive statistics indicated that the non-residential developments were found in the higher land value areas than the residential developments, e.g., on average, 28,681 baht/sq.m for non-residential areas, versus 27,347 baht/sq.m for residential areas.
2004 to residential and non-residential areas in 2010 were grouped together in the same code 1 (in term of “Changed”) while remaining of undeveloped lands in 2010 was assigned zero as their code.

Results of dividing land as grid cells, 35 x 35 meters was presented in Table 1. The total number of grid cells for undeveloped land in the year 2004 was 2,858 grid cells. Among of them, after the plan of MRT Purple Line was announced, it was found the conversions from undeveloped or vacant land parcels to residential use about 32% (914 grid cells) and non-residential land parcels around 3% (91 grid cells). However, around 65% (1,853 grid cells) remained undeveloped or vacant areas.

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<td>91 (3.18%)</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>2,858 (100%)</td>
</tr>
</tbody>
</table>

Table 1 Number of land parcels changed between 2004 and 2010

4.2 Descriptive statistic: land use change along MRT Purple Line

Descriptive statistics of land use change and its attributes were briefly summarized in the Table 2. For local transportation accessibility, the results show the conversions from undeveloped land to non-residential areas tended to be near the main roads, stations, and expressways, while the conversions of residential areas tended to be occur further as expected. Then, the statistics present the changes of undeveloped land to residential, and non-residential areas emerged farther to the central business district (CBD) which is the city center of Bangkok Metropolitan Region, e.g., on average, the conversions of residential and non-residential parcels were found within 19.835 kilometers and 19.755 kilometers, respectively. The conversions of non-residential areas tended to occur far from the shopping center approximately 9.611 kilometers and the conversions of residential areas occurred within 10.427 kilometers. Finally, the descriptive statistics indicated that the non-residential developments were found in the higher land value areas than the residential developments, e.g., on average, 28,681 baht/sq.m for non-residential areas, versus 27,347 baht/sq.m for residential areas.
Table 2 Descriptive statistics based on land use categories

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Undeveloped</td>
</tr>
<tr>
<td><strong>Local transportation accessibility</strong></td>
<td></td>
</tr>
<tr>
<td>DIST_MR Distance to main road (km)</td>
<td>0.857</td>
</tr>
<tr>
<td>DIST_STA Distance to station (km)</td>
<td>1.292</td>
</tr>
<tr>
<td>DIST_EXP Distance to expressway (km)</td>
<td>13.665</td>
</tr>
<tr>
<td><strong>Work and non-work accessibility</strong></td>
<td></td>
</tr>
<tr>
<td>DIST_CBD Distance to CBD (km)</td>
<td>19.627</td>
</tr>
<tr>
<td>DIST_SHP Distance to shopping center (km)</td>
<td>9.775</td>
</tr>
<tr>
<td><strong>Land attribute</strong></td>
<td></td>
</tr>
<tr>
<td>L_PRICE Land price (baht/sq.m)</td>
<td>25,950</td>
</tr>
</tbody>
</table>

5. Estimation results

This section summarizes and interprets estimation results in examining the factors that influencing land use change from geographically weighted logistic regression (GWRLLogist) model. The goodness-of-fit is evaluated by Rho-square. Also, the result presents log-likelihood values.

As mentioned, the standard logistic regression model is estimated where the resulting coefficients are global, i.e., the coefficients are constant over the study area (Table 3). On the other hand, the GWRLLogist model in this paper gives local parameters for each observation point, i.e., a total 2,858 set of estimation coefficients were obtained. However, the result in Table 4 shows only minimum, maximum and average value along with statistical values. Table 3 and Table 4 the statistical results suggest that the GWRLLogist model has much better predictive powers than the Logist model. The results of the final specifications are discussed as follows.
Table 3 Summary of parameter estimates for Logit model

<table>
<thead>
<tr>
<th>Beta</th>
<th>Constant</th>
<th>DIST_MR</th>
<th>DIST_STA</th>
<th>DIST_EXP</th>
<th>DIST_CBD</th>
<th>DIST_SHP</th>
<th>L_PRICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>P-value</td>
<td>0.000***</td>
<td>0.028**</td>
<td>0.000***</td>
<td>0.000***</td>
<td>0.000***</td>
<td>0.000***</td>
<td>0.000***</td>
</tr>
<tr>
<td>Elasticity</td>
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<td>0.501</td>
<td>-0.582</td>
<td>-405.638</td>
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<td>288.145</td>
<td>0.905</td>
</tr>
<tr>
<td>log-likelihood</td>
<td></td>
<td>-1610.576</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Rho-square</td>
<td></td>
<td>0.1310</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*** = significant at 1% level

** = significant at 5% level

* = significant at 10% level

n/s = no significant
### Table 4 Summary of parameter estimates for GWRLogist model

<table>
<thead>
<tr>
<th></th>
<th>Constant</th>
<th>DIST_MR</th>
<th>DIST_STA</th>
<th>DIST_EXP</th>
<th>DIST_CBD</th>
<th>DIST_SHP</th>
<th>L_PRICE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Beta</strong></td>
<td>0.603</td>
<td>-3.069</td>
<td>-3.233</td>
<td>6.605</td>
<td>-4.426</td>
<td>6.963</td>
<td>1.033</td>
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### Mean

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### Minimum

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*** = significant at 1% level  
** = significant at 5% level  
*  = significant at 10% level  
n/s = no significant  

---

Local transportation accessibility variable refers to the proximity to transportation including urban rail transit station, main road and expressway entrance access. As pointed out in previous studies, the demand for properties should be greatest near transportation system, thus, the proximity to the rail transit station, main road and expressway facilities are used to capture the potential of local transportation accessibility on the conversions of land. The proxy was computed using the Geographic Information System (GIS) tools from every parcel to rail transit stations, main roads and expressway entrance ramps as the straight line distance and then the shortest distance was selected.

Not surprisingly, the probability of the conversions were more likely to appear closer to main road, i.e., holding everything else constant, proximity to main road appears to significant for land developments as expected (Verburg et al., 2004, Zeng et al., 2008). In addition, the results of the GWRLogist indicated that a 1-percent increase in “DIST_MR” is associated with a 1.8% decrease in the probability of land developments. Also, the proximity to the nearest MRT Purple Line station (DIST_STA) has negative effect to the conversion of undeveloped to other category. A 1-percent decrease in “DIST_STA” is estimated, on average, to increase the probability of the conversions by 3.6%, reflected by the elasticity of 3.641. Next, distance to expressway access (DIST_EXP) has positive impact, meaning that the distance to expressway did not increase the likelihood of conversions. This was supported by a dis-benefit created from being near access point to expressway (Malaitham et al., 2013).

Since GWRLogist estimates a model at each land parcel, the number of estimated parameters is equal to the number of data points available. For ease of presentation, the results illustrated in the contour map as shown in Figure 2 and Figure 3. These maps interpolated the elasticity of each covariates using inverse distance weighting method. Obviously, the coefficients vary substantially within the study area, indicating that there is a varying spatial relationship in the model parameters.
5.1 Local transportation accessibility

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5.2 Work and non-work accessibility

In the current context of Bangkok structure, there is functional differentiation among areas with clusters of shopping centers, job centers, and other facilities separated from each other. However, the largest work employment is still in the CBD. As there
was a difficulty to identify the boundary of the CBD, Siam Square area was assigned to be the CBD. Many previous studies indicated the proximity to CBD plays the significant role in examining the factors that influencing land use change (Wang and Kockelman, 2006, Zhou and Kockelman, 2008, Ferdous and Bhat, 2013). Not surprisingly, the conversions from undeveloped land to others had emerged in area ease access to the central business district (CBD). Estimation result reveals that the elasticity with respect to the distance to CBD is approximately -49.420, meaning that a percentage increase in “DIST_CBD” is estimated to decrease that probability by 50%. On the other hand, short distance to the closest shopping mall is an indication of non-work accessibility. In addition, the shopping center in this study means a building forming a complex of shops, recreations, amusements, etc. Nevertheless, undeveloped land near the shopping center in this area is more likely to be converted to other types as indicated in Figure 4.

Figure 4 Impact of distance to shopping center on land developments

5.3 Land attribute

Land attribute refers land price (baht/sq.m). Unfortunately, land price data, obtained from the assessed land value reports, which were published by The Treasury Department, Thailand, does not distinguish types of land use. Certainly, this variable is generally an unrealistic value. Although the assessed land value is not a true market value, it is used in this study because the market transaction price data is not consistent and reliable in Thailand. The results suggest that lower land value is greatly linked with land developments as illustrated in Figure 5.
6. Conclusion

This paper proposes the geographically weighted logistic regression (GWRLogist) to examine the factors that influencing land use change in the area near the stations of the under construction rail transit, namely MRT Purple Line in Bangkok Metropolitan Region.

Firstly, the GWRLogist model has much better predictive powers than the Logist model. Furthermore, the factors influencing land use change are myriad. For example, the model confirms the greater influencing of the proximity to main road and rail transit station intended to increase the probability of land developments. Due to the GWRLogist model, it is found these impacts varies substantially along the corridor, on average, 1.8% for closer to main road, versus 3.6% for closer to rail transit station. This result confirms that undeveloped or vacant land parcels being located near the stations attract developers than those located closer to main road in this study area. Not surprisingly, the GWRLogist model indicated that undeveloped land being located near the CBD is associated with the likelihood of land developments, reflected by a percentage increase in proximity to CBD is estimated to decrease that probability by 50%. As the distance to shopping center decreases, the probability of converting from undeveloped land to others tends to increases. According to the model, the result of this study suggests that a logistic specification combined with geographically weighted regression (GWR) can reasonably applied to determine the influencing factors associated with land use change because its benefit allows estimating and capturing the variations of impact across the areas. Such method can provide helpful insights into the future land predictions in term of

Figure 5 Impact of land price on land developments
transportation developments. However, analysis of the spatial dependence is left for further study.

7. References


Research Record: Journal of the Transportation Research Board, 1977, pp. 112-120.


PARKING POLICY AS A COUNTERMEASURE TO PROMOTE PUBLIC TRANSPORT USAGE: CASE STUDY OF NEHRU PLACE DISTRICT CENTRE IN NEW DELHI, INDIA

Ravi Gadepalli ¹ and Anusha Vaid ²

Abstract

The paper presents ways to harness the potential of a commercial district by developing transport policy and planning interventions which would improve the urban quality of the area and its surroundings. Parking is a key driver towards this objective. Introducing parking-pricing as a countermeasure to discourage private vehicle usage and induce mode shift to public transport is presented taking Nehru Place, an important commercial district in New Delhi, as a case study. Nehru Place, spread across 380,000 square metres, is well connected to the rest of the city. It attracts approximately 130,000 visitors daily, accessing the area through the two connecting arterial roads, twenty four city bus routes and two metro stations.

Within Nehru Place, the mobility provisions are skewed towards users of private transport, primarily cars and two-wheelers. Low-cost parking is available closer to buildings, while public transport stops are located at the periphery. In addition, certain non-motorised modes are restricted to enter the area. As a result, the usage of cars and two-wheelers to Nehru Place wheelers has been increasing over the years. The parking demand currently exceeds the planned capacity, resulting in parking spill over to roads, encroaching pedestrian spaces. The area also has a few upcoming establishments which are likely to worsen the situation further. Therefore strong counter measures are necessary to improve the urban quality (efficiency in space-use and accessibility) of the area and to discourage car and two-wheeler usage.

Data collection methods to capture the mobility patterns to the area are non-existent. The survey methodology and the sampling methods needed to estimate the parking demand patterns, user characteristics and their willingness to shift to public transport based on various countermeasures are presented. A disaggregate analysis of the current parking demand has been carried out to identify various trip-purposes such as office, retail etc. and their corresponding parking durations. A pricing strategy is devised to reflect the true value of land currently being used for parking and reduces the demand to 85% of the existing supply. Three levels of countermeasures have been identified to reduce the parking demand, thereby creating space for other activities: The overall parking space to be provided

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in the area is estimated based on a desirable mode share of 80% trips made by public transport and non-motorised transport, the resultant parking demand is accommodated in a few multi-level car parks which are priced appropriately. In such a scenario, the parking demand, even including the upcoming establishments, is likely to come down by 50% and these trips shift to public transport. Also, an additional space of 18,000 sq. m. is reclaimed from parking, which can be used to create vibrant people friendly spaces within the commercial district.
1. Introduction

India has an urban population of 377 million, which includes 53 metropolitan cities which have a population of more than a million inhabitants. This is estimated to increase to 600 million by 2030 and will include up to 110 cities with a population of more than a million (Census, 2011, HPEC, 2011). Urban transport will play an important role in the form and functioning of these cities. It is therefore important that these cities encourage low-carbon mobility patterns to ensure their sustainable development. Traditionally, urban transport in India is characterised by high mode shares of non-motorised transport (NMT) and public transport (PT) trips that have a low carbon footprint (Wilbursmith, 2008). However, due to increasing per-capita incomes and a subsequent increase in vehicle ownership rates, there is an increasing propensity for NMT and PT users in Indian cities to shift to Cars and Two-wheelers. This is further accentuated by the infrastructure provision and pricing choices made by cities for various modes. Cities have been investing increasingly in creating more road space for cars and two-wheelers but do not have adequate usage charges for these modes and provide free or nominally charged parking spaces. At the same time, the infrastructure and operational support needed for non-motorised and public transport users has been totally lacking. Such practices have significant climate change and air-quality implications since private motorised modes have the highest per-capita emissions.

The city of Delhi is no different and it follows a similar pattern of development as the other cities. It has the highest per-capita income in the country and 60% of its households own at least a Car or a Two-wheeler. 25 % of its area is allocated to roads, which is the highest in the country (GNCTD, 2013). The pricing mechanisms followed in the city are also skewed since parking for private modes is provided at a nominal price while public transport users are charged much higher (CSE, 2012). With increasing access to private vehicles and such enabling road infrastructure, the city has witnessed an incremental shift towards cars and two-wheelers. Table 1 gives the comparison of mode shares in the city between 2001 and 2007 (RITES, 2011). It is observed that the combined mode share of Cars and Two-wheelers has increased by 4% while the public transport mode share in the city i.e. bus, metro and rail has reduced from 40% to 29% in just six years. This is a worrying trend and has already resulted in severe deterioration in the ambient air quality in the city (WHO, 2014). The master plan of Delhi acknowledges the need to shift towards and has set called for reversing this trend in such a way that 80% of the motorised trips in the city are made by public transport i.e. metro, bus and auto rickshaw (DDA, 2014).
Work, social and recreational trips together comprise of 90% of the Car and Two-wheeler trips are made for purposes (RITES, 2011). The current paper looks at the planning and pricing practices needed in the commercial areas of the city, where most of these trips are destined to help discourage their usage. The parking space allocation for various modes and their pricing mechanisms are reviewed using a case study and ways to use parking as a counter measure to address these issues are presented.

Government policies implemented in India in the last few years have done little to reduce the existing parking chaos seen in the larger cities. Classic examples would be low taxes levied on private vehicles as compared to buses and easy financing schemes available for the purchase of cars. In Delhi, a bus is charged about 43 times more road taxes than cars (CSE, 2009). While efforts may be undertaken to evaluate solutions, increasing or creating supply of parking space will never help. The apt solution would be to reduce parking demand and simultaneously shift users to more high occupancy and eco-friendly modes of transportation. It is vital to restrict use of cars and two wheelers. This would be possible when either users have no/minimum parking spaces in various city/commercial centres or the parking fee is very high.

Taking examples from across the world, it was found that reduction in supply with increase in pricing reduces demand for travel by private modes. Parking pricing can be used as a strategy to reduce vehicle traffic and parking problems in a particular location. In Singapore, pricing is such that it covers the full social cost of automobile use i.e., the cost of owning (and using) a car is many times that of its manufactured price. In Tokyo, although there is high car ownership, the parking provision is less than 0.5 ECS per 100 sq meters in the commercial areas. It was found that 0.28 to 1.19 per hour reduced VMT – 11.5% and emission -9.9% (Madhu, 2011). Similarly in Paris, since 2003 the on-street parking supply has been reduced by more than 9% and almost 95% is paid parking, resulting in 13% reduction in parking demand. (Simicevic et al., 2010) The main objective is to set prices to achieve 85% occupancy
target so that every time a user finds a parking slot and there is no time delay or emission in cruising for parking space. This is called performance-based or responsive pricing (Pierce and Shoup, 2013). Many cities are aiming to reduce car use by removing or restricting on-street parking in central areas, and charge a high price for the remaining spaces. Parking pricing can be more effective and beneficial if it is well integrated with proper user information and stronger enforcement.

Defining maximum parking space in an area, pricing it accordingly and enforcing the parking maximums are key countermeasures to be put in place to address the problems faced due to parking in commercial areas. The current paper aims to translate these principles on parking pricing and demand management to the Indian context. This involves understanding the existing parking situation in all its complexity i.e. various modes, user groups and their existing supply systems and developing context specific solutions. A representative case study has been selected and implementing the parking plan and pricing has been demonstrated through it.

2. Data collection and analysis

Nehru Place, a commercial district located in the south east of Delhi, is the case study for the current paper. Spread over 380,000 sq. m., Nehru Place is the second largest among the 23 commercial districts that exist in the city (DDA, 2014). Figure 1 shows a key map of the Nehru Place area, showing the existing and upcoming developments in its precinct. The existing development includes offices, commercial establishments and entertainment zones attracting work, shopping and recreational trips while the land use for the upcoming developments is undecided yet. The map also shows the locations of bus stops, metro stations, parking lots, pedestrian connectivity through sidewalks and Foot over Bridges (FOB). Due to its varying land use types and multi-modal connectivity, Nehru Place forms a representative case study of various commercial districts in Delhi.

Nehru Place is well connected with the rest of the city by two arterial roads, two metro stations, a bus terminal which attracts 24 city bus routes from various parts of the city, various intermediate public transport (IPT) solutions like shared three-wheeled auto rickshaws, battery operated cycle rickshaws and non-motorised modes like walk, bicycles, manual cycle rickshaws. The area acts as a public transport hub for neighbourhoods within a two km radius.

However, the Nehru Place precinct is also characterised by the unlimited supply of parking provided in the area. While there are a few designated parking zones created in its precinct, vehicles are accommodated on the sidewalks and along the streets even after the designated parking lots are full. This creates an unsafe and uncomfortable access environment for public transport (PT) and non-motorised transport (NMT) users. The price charged for parking is also nominal, which further results in more and more car and two-wheeler owners inclined to use their personal modes of transport rather than public transport.
Such a situation is typical of most commercial areas in Delhi and also in other Indian cities. Hence a solution that can be a best case model and one that can be replicated in other such areas needs to be developed in this area. The current paper explores the means to arrive at such a solution and presents an example solution taking Nehru Place as a case study.

Figure 1 Existing and proposed development map of Nehru Place

2.1. Sample surveys for Baselining

Baseline data on the spatial characteristics of Nehru Place, number of visitors to the area, their socio-economic characteristics, travel behaviour, parking requirements, paying capacity etc. is needed to understand the existing scenario based on which a solution for the future can be proposed. There is no secondary source of information on these issues. Therefore, sample surveys were carried out in August, 2013 to estimate these numbers for various modes and are explained in this section.

2.1.1. Number of visitors to the area:

Nehru Place has multiple entry points for vehicles, pedestrians, bus, metro and auto-rickshaw users, it was difficult to identify a few points to measure the number of visitors to the area. A Geographic Information Systems (GIS) based spatial representation of the area was carried out to understand the circulation pattern of vehicles and people within the Nehru Place precinct. The aggregate number of daily
visitors to the area was estimated through volume counts at all the entry and exit points. Volume counts have been carried out for 16 hours i.e. between 7.00 AM to 11.00 PM on a typical working day. The area is mostly inactive for the remaining hours of a day and hence this survey gives a god understanding of the total number of visitors to the area. A combination of various other surveys was needed to disaggregate the total number of visitors to the area by various modes.

2.1.2. Number of visitors using public transport

Entry points to the precinct for each mode have been identified and separate 16 hour volume counts for one typical working day have been carried out at each of them. This includes pedestrian volume counts for the metro users, boarding-alighting counts at the bus terminal, its peripheral bus stops and IPT stops. Figure 2 gives the key map showing the mode-wise survey locations for public transport users.

![Figure 2 Survey locations for the Nehru Place precinct](image)

2.1.3. Parking Survey

The number of visitors through cars and two-wheelers were estimated through a two stage process. Parking accumulation surveys were needed to estimate the number of
vehicles entering the area. The average passenger occupancy for these vehicles was then used to derive the daily number of car and two wheeler visitors to the precinct.

A 16 hour survey between 7.00 AM to 11.00 PM for parking has been carried out on a typical working day to understand the existing parking demand for the area. It was observed that the area had four key zones with designated off-street parking. In addition based on extra demand during the peak hours the operators allow on-street parking of vehicles and charge them at the same rates as off-peak parking. Figure 3 shows the various on-street and off-street parking locations within the Nehru Place precinct where the surveys have been carried out.

The survey collected information on the number of vehicles accumulating in each parking zone by counting the vehicles entering and exiting the area at a 10 minute interval. The survey was conducted manually by positioning enumerators at the entry and exit points of each of the parking lots. For the on-street parking, a few floating enumerators were placed, who would move along the roads in the study area and note down the on-street parking accumulation of cars and two-wheelers. The pricing mechanism followed for these parking lots has also been captured during the surveys. The occupancy data is derived through questionnaire surveys for visitors in the precinct which also captured other information as explained in the section below.

2.1.4. User perception surveys
User perception surveys that capture the socio-economic and travel patterns of various visitors to the area have also been carried out for the study. A questionnaire based survey was carried out through manual interview method for a sample size of 2000 users. The questionnaire collected information regarding the existing demographic, socio-economic and travel characteristics of various types of users. It also collected information on user’s perception towards parking pricing, their willingness to pay for better parking and the price at which car and two-wheeler users will shift to public transport. Users were selected through a random sampling technique by enumerators who were positioned all across the study area to capture as many user groups as possible. The data was collected at various times of the day between 7.00AM to 11.00PM on a typical working day to capture as many user types as possible. The data from these surveys has been analysed to derive the occupancy data for cars and two-wheelers, needed to estimate the total daily visitors through these modes. User’s perception on parking and their willingness to shift data is used in developing a pricing strategy for the area.

2.2. Findings from the survey

Data from the above mentioned surveys was compiled to understand the socio-economic and travel patterns of the visitors to the Nehru Place precinct. The total number of daily users, their mode wise disaggregation and the socio-economic and travel characteristics of users of each mode is presented in the current section.

Table 2 provides the number of vehicles and passengers visiting Nehru Place on a typical working day. It is observed that the area attracts more than 130,000 visitors daily and is a huge commercial destination within the city. Up to 56% of the trips are made by public transport modes like bus, metro and three-wheeled auto rickshaws while up to 44% of the trips are made by cars and two-wheelers. Walk and cycle contribute a minority of the total trips made to the area.

The low mode shares for walk and cycle, the modes with the shortest trip length, show that Nehru Place is not just a neighbourhood commercial district but one which has significance for the entire city. The trip length numbers also show that the travel patterns of private modes i.e. cars and two-wheelers and public transport modes like bus and metro are similar and based on the policy, planning and pricing mechanisms adopted, there is a significant potential for users to shift between these modes.
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Figure 4 gives the trip purpose wise disaggregation of the trips attracted to Nehru Place. The disaggregation has been made for both user and area characteristics i.e. occupation of the visitor and land use type for which the trip was made. It is observed that employees of the offices and retail outlets present in the area form the majority of trips attracted to the area, contributing to a total of 32% of the total visitors. These users stay in the area for the entire duration of the day while other trip purposes like visitors to offices, retail outlets, shopping and leisure are more short-term trips. Between cars and two-wheelers, the two modes contributing to the parking demand, majority of two-wheeler demand is generated by employees who use the space for long durations while majority of car trips are generated for the short-term trips like visitors to the offices and shopping trips.

Figure 4 Trip purpose disaggregation of various modes visitors to Nehru Place
2.2.1. Parking accumulation

Parking accumulation data collected at 10 minute intervals is aggregated to estimate the hourly parking demand in the Nehru Place precinct. The average space occupied per car is 8 sq.m. while that of a two-wheeler is 2 sq.m. Therefore each 2-wheeler is considered to be occupying 0.25 equivalent car spaces (ECS). This data is overlapped with the findings from user surveys to disaggregate the hourly demand based on trip purpose. Table 3 gives the hourly variation of parking demand disaggregated by the duration of parking. The peak hour for parking demand is 4.00 PM and 5.00 PM i.e. when the short-term (less than two hours) shopping and leisure trips add on to the long term office bound parking demand. While the capacity of all formal parking spaces put together is only 5540 ECS, the demand during peak hours far exceeds this and reaches up to 6621 (ECS). The excess demand is not restricted for entry and is accommodated on the streets encroaching on to the pedestrian circulation spaces.

<table>
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<tr>
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<td>14:00-15:00</td>
<td>4770</td>
<td>328</td>
</tr>
<tr>
<td>15:00-16:00</td>
<td>4794</td>
<td>486</td>
</tr>
<tr>
<td>16:00-17:00</td>
<td>4799</td>
<td>430</td>
</tr>
<tr>
<td>17:00-18:00</td>
<td>4730</td>
<td>304</td>
</tr>
<tr>
<td>18:00-19:00</td>
<td>4310</td>
<td>57</td>
</tr>
<tr>
<td>19:00-20:00</td>
<td>2576</td>
<td>184</td>
</tr>
<tr>
<td>20:00-21:00</td>
<td>401</td>
<td>366</td>
</tr>
<tr>
<td>21:00-22:00</td>
<td>68</td>
<td>512</td>
</tr>
<tr>
<td>22:00-23:00</td>
<td>50</td>
<td>254</td>
</tr>
</tbody>
</table>
It is observed that Car and 2-wheeler demand by the employees in the area peak by 11.00 AM and occupy the parking space for the entire day. Even during the peak hour, they form 81% of the total parking demand. The nominal parking charge in the area i.e. Rs 5 ($ 0.25) per ECS per hour coupled with the lack of any regulation on the number of cars and two-wheelers entering the area is likely to encourage more and more users to shift to private modes, as soon as they can own and can afford the fuel costs. This needs to be reversed and a pricing mechanism that encourages people to shift away from cars and two-wheelers needs to be introduced.

3. Parking demand management strategy

As explained above, it is proven that pricing is a key strategy in reducing demand. A pricing mechanism that reverses the current trend of increasing parking demand and promoting the usage of public transport modes needs to be implemented in the area. The implementation of such a pricing mechanism would also need enforcement measures like restricting the vehicles entering the area beyond the planned capacity. In the current study, a scenario analysis is presented that evaluates the likely increase in parking demand in a Business As Usual (BAU) scenario i.e. if no parking related interventions are made in the area and proposes a pricing strategy that reduces the demand to a desirable level.

The Master Plan of Delhi (MPD) (DDA, 2014) has targeted 80% of the motorised trips in the city to be made by public transport and the transport systems in the city to be designed for these mode shares. Nehru Place currently has only 54% of its trips made by public transport and needs to design the area as per the master plan targets. To reach the target, the parking supply to be provided in the study area and the pricing that leads to reducing the demand reducing to this level is to be worked out. A disaggregated pricing mechanism that addresses the parking demand generated for each category of users i.e. short term (less than 2 hours), medium term (2-8 hours) and long term (more than 8 hours) is proposed.

3.1. Demand projection

The parking survey estimated the parking demand generated by the existing establishments in the Nehru Place precinct. The upcoming establishments, planned to be in place by 2021, will attract more visitors to the area. In a Business as Usual (BAU) scenario, the mode share is also expected to shift towards cars and two-wheelers. Based on these assumptions, the following methodology was adopted to estimate the future parking demand for the area:

- The existing parking demand (in ECS) estimated from the parking survey is taken as the base case scenario and 2021, the year by which the proposed establishments will be built is taken as the horizon year
- Parking demand as a function of the built up area i.e. ECS per 100 sq. m. of built up area is derived
Based on the Travel Demand Forecasting Study (TDFS) for Delhi (RITES, 2011), the growth rate for car and two-wheeler trips is 3%.

Based on the above two criteria, the likely parking demand for the horizon year is calculated.

Table 4 gives the disaggregated analysis of the projected parking demand of the Nehru Place precinct area. The peak hour demand in a BAU scenario is estimated to be 9,530 ECS. The long-term parking demand for the employees entering the area is disaggregated further into office and retail outlet employees. This is because the retail employees have separate income and travel characteristics that make them less likely to shift to public transport. The master plan has identified that limiting parking space is a key intervention towards reducing car and two-wheeler usage in the city. Consequently, the Nehru Place precinct is recommended to have a maximum of 5,500 ECS of parking to achieve the targeted 80% public transport mode share.

The total reduction in parking demand needs to be split further to identify the demand reduction to be achieved for Cars and Two-wheelers separately. A backcasting method for identifying the mode share in such a scenario has been carried out to identify the demand reduction needed for various modes. The mode-wise demand reduction is disaggregated further based on the duration of parking to identify the demand reduction to be achieved in short-term, medium-term and long-term parking.

Table 4 Projected parking demand for horizon year (BAU Scenario)

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>Employees (&gt;8 hrs)</th>
<th>Duration of stay wise demand (in ECS)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Office</td>
<td>Retail</td>
</tr>
<tr>
<td>8:00-9:00</td>
<td>645</td>
<td>0</td>
</tr>
<tr>
<td>9:00-10:00</td>
<td>2983</td>
<td>707</td>
</tr>
<tr>
<td>10:00-11:00</td>
<td>5369</td>
<td>848</td>
</tr>
<tr>
<td>11:00-12:00</td>
<td>5966</td>
<td>943</td>
</tr>
<tr>
<td>12:00-13:00</td>
<td>5966</td>
<td>943</td>
</tr>
<tr>
<td>13:00-14:00</td>
<td>5966</td>
<td>943</td>
</tr>
<tr>
<td>14:00-15:00</td>
<td>5966</td>
<td>943</td>
</tr>
<tr>
<td>15:00-16:00</td>
<td>5966</td>
<td>943</td>
</tr>
<tr>
<td>16:00-17:00</td>
<td>5966</td>
<td>943</td>
</tr>
<tr>
<td>17:00-18:00</td>
<td>5966</td>
<td>943</td>
</tr>
<tr>
<td>18:00-19:00</td>
<td>5966</td>
<td>943</td>
</tr>
<tr>
<td>19:00-20:00</td>
<td>3579</td>
<td>566</td>
</tr>
<tr>
<td>20:00-21:00</td>
<td>547</td>
<td>155</td>
</tr>
<tr>
<td>21:00-22:00</td>
<td>107</td>
<td>18</td>
</tr>
<tr>
<td>22:00-23:00</td>
<td>94</td>
<td>0</td>
</tr>
</tbody>
</table>
3.2. Area allocation for parking

The base year parking i.e. 6,621 ECS is all at-grade and therefore occupies 14% of the total precinct area i.e. 48,000 sq. m. If the practice of providing all parking at-grade is continued, the proposed parking for 5,500 ECS in the precinct area will require up to 40,000 sq. m. of parking space i.e. 12% of the total precinct area. Since the objective of the study is to reduce the amount of space occupied by parking and using it for pedestrian circulation, it is proposed that only 500 ECS of parking is provided at-grade and the rest of the parking is provided through multi-level car parks (MLCP) located across the precinct area as shown in Figure 5. The 5000 ECS of parking is distributed across four MLCPs, the locations and areas occupied by which are shown in the figure.

By implementing such a space allocation strategy for parking, the 5,000 ECS of parking can be accommodated in 30,000 sq. m. i.e. 8% of the total precinct area. Therefore, a total of 18,000 sq. m. can be freed up of parking by implementing this strategy. The area can be used for activities like pedestrian and public transport circulation, place making, accommodation of hawkers and vendors, which add vibrancy to the area and make it more people oriented.

Figure 5 Proposed parking locations for the future
3.3. Results for the pricing strategy analysis

The pricing strategy is devised such that the peak hour parking demand reduces to 85% of the 5,500 ECS of parking capacity i.e. 4,700 ECS. This is to ensure the availability of parking spaces even for the vehicles entering during the peak hour. Therefore, the pricing should aim to reduce the parking demand from 9530 to 4700 ECS i.e. by 4,800 ECS. Such a pricing mechanism is derived based on findings of the stated preference data collected as a part of the user-perception survey. Car and Two-wheeler users have indicated the price point at which they are likely to shift to public transport.

![Figure 6 Parking demand in the precinct with increasing prices](image)

These prices are compared with the other policy documents of the city and the parking mechanisms proposed in literature. The pricing strategy for is derived for various durations of parking i.e. short-term, medium-term and long-term parking. Also, it is important that a differential pricing strategy is adopted between at-grade and the multi-level car parks (MLCP). Unless the MLCP is priced cheaper, vehicles are inclined to park at grade therefore spilling over to the streets, repeating the existing situation. Hence, the pricing for surface parking in Nehru Place which was three times more than multi-level car parking charges.

Table 5 gives the pricing proposed for various durations of parking and also for the differential parking price to be followed for at-grade and multi-level parking. While the shift away from Cars and Two-wheelers is estimated from the user surveys, the shift between at-grade and multi-level parking is estimated based on the duration of parking. Parking in an MLCP is time consuming and the short-term parkers are less likely to move there. Therefore, the 500 ECS that can be accommodated within the at-grade parking is used for short-term parking, while the rest the demand is shifted to MLCP. Effective implementation of such a plan depends on the enforcement of low-parking space and restricting any unauthorised at-grade parking.
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<table>
<thead>
<tr>
<th>Parking Duration</th>
<th>Base year Demand</th>
<th>Proposed Supply Scenario</th>
<th>Shift from existing parking</th>
<th>Proposed Pricing</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;30 mins</td>
<td>164</td>
<td>236</td>
<td>224</td>
<td>5%</td>
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<tr>
<td></td>
<td></td>
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<td>95%</td>
<td>Rs 50</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Rs 30</td>
</tr>
<tr>
<td>30-1 hr</td>
<td>436</td>
<td>628</td>
<td>236</td>
<td>5%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>360</td>
<td>5%</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>Rs 30</td>
</tr>
<tr>
<td>1hr-2hr</td>
<td>791</td>
<td>1139</td>
<td>649</td>
<td>5%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>95%</td>
<td>Rs 30 (first hr)+ Rs 15 (next every hr)</td>
</tr>
<tr>
<td>2hr-8hr</td>
<td>430</td>
<td>619</td>
<td>294</td>
<td>5%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>95%</td>
<td>Rs 30 (first hr)+ Rs 15 (next every hr)</td>
</tr>
<tr>
<td>&gt;8 hrs (Office Employees)</td>
<td>4145</td>
<td>5966</td>
<td>2081</td>
<td>65%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>35%</td>
<td>Rs 30 (first hr)+ Rs 15 (next every hr)</td>
</tr>
<tr>
<td>&gt;8 hrs (Retail Employees)</td>
<td>655</td>
<td>943</td>
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<td>100%</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Rs 30 (first hr)+ Rs 15 (next every hr)</td>
</tr>
</tbody>
</table>

<p>| | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>6,621</td>
<td>9,530</td>
<td>460</td>
<td>4,327</td>
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</tbody>
</table>
Such a pricing strategy will initially arrest the current trend of increasing Car and Two-wheeler usage. In the long run, if these prices are updated regularly according to the increasing purchasing power of users, it is expected to induce mode shift of private mode users towards public transport.

4. Conclusions

The paper presents parking pricing as a countermeasure to induce mode shift from private modes to public transport, thereby reducing emissions and improving air quality in the city. It presents a methodology to estimate mode-wise parking demand in a typical commercial area in Indian cities. Methods to estimate the demand disaggregated by user groups, their trip purposes and socio-economic characteristics are discussed. The Business as Usual versus a sustainable transport scenario has been presented and the pricing strategy that will lead to achieving this strategy is derived. Parking pricing as a key counter-measure towards reducing private vehicle usage and increasing public transport usage has been established.

Taking a typical commercial district in New Delhi as a case study, a disaggregated analysis of the parking demand, the pricing strategy needed to reduce the demand and methods in allocating the parking space to the reduced demand are presented. The additional space that can be reclaimed from parking through such measures are demonstrated which in turn can be used to create a vibrant people friendly atmosphere within the commercial district. This methodology can be replicated in other commercial districts within Delhi and also other cities with similar user and mobility characteristics.

5. Acknowledgements

The findings presented in the paper were part of the ‘Nehru Place revitalisation project’ carried out by Innovative Transport Solutions (iTrans) Pvt. Ltd. The authors would like to acknowledge the support provided by Shakti Sustainable Energy Foundation to carry out the required surveys presented in the paper and the inputs provided by the remaining partners of the project.

6. References


WILBURSMITH 2008. Study on traffic and transport strategies and policies in india. Ministry of Urban Development (MoUD), Government of India.
CHARACTERISTICS OF AGRO RETAIL LOGISTICS IN METROPOLITAN CITY OF DELHI, INDIA

Sanjay Gupta1

Abstract

Agro-industries are an engine for growth in rural economies and the agro industrial sector plays a central role in the economic development of low- and middle-income countries. Indian agro products and food-processing sector is responsible for $6,940 billion out of the total $1.8 billion retail sector in India. The agri-food sector in India employs over half of the country's population and is crucial to maintaining and accelerating economic growth. The traditional agro supply chain which is highly fragmented with several intermediaries is slowly being replaced with emergence of planned retail outlets particularly in large with little dependence on intermediaries. Changing economic dynamics, diverse choices in products and services, numerous shopping formats and unparalleled access to information has empowered customers to expect more from their retail experience. While agro-retail outlets are on rise in India very little efforts have been made to appreciate their characteristics in terms of physical, operational and user aspects which can provide meaningful guidelines for policy planners to plan such facilities in an optimal manner.

This paper is based on an empirical study carried out by the authors on the characteristics of selected agro retail outlets of premium companies in metropolitan city of Delhi in 2008 and 2014 respectively. The study reveals that the average catchment of the case study retail outlets was nearly 1 km. It was also observed from the study that there were changes observed in the travel patterns of shoppers in terms of frequency of travel, travel distance and modes use owing to changed shopping behavior on account of advent these outlets. In particular it has been observed from the study that the advent of retail outlets has had an effect on the mode used by customers for shopping. While the share of car trips have decreased from 35% to 30% the share of two wheelers has gone up from 8 % to 16%. The vehicle km of cars and two wheelers involved in shopping activity too have reduced by 56% and 33% respectively in before and after retail stores situation resulting in a reduction in carbon emissions. While the advent of planned agro-retail outlets is likely to overcome ills of existing highly fragmented and inefficient supply chain loaded with several intermediaries its rational planning in urban neighbourhoods is yet to find a place in the master planning practices observed in cities in India.

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1. Introduction

Agro-industries are an engine for growth in rural economies and the agro industrial sector plays a central role in the economic development of low- and middle-income countries. Already around 80% of global food and beverage sales consist of processed products, with 60% being consumed in high income countries. Although households in developing countries spend a large share of total expenditures on food, most is on non-processed products. In 2002, per capita retail sales of packaged food in high income countries were more than 15 times the value found for low income countries. But growth in consumption of packaged food is fastest in the developing countries: 7% in upper middle, 28% in lower middle and 13% in low income countries, compared to just 2 to 3% per year in high income countries. Ongoing population growth and growth in per capita consumption (changing diet and increasing variety and quality of products with rising incomes) drive demand for processed foods and services embodied within the products. Increased ownership of refrigerators and microwave ovens promote greater household purchases of perishable and frozen foodstuffs, and higher consumption of prepared foods and ready meals. Internationalization of retail supports a shift in consumption patterns. Urbanization (population growth in developing countries is increasingly an urban phenomenon) increases the importance of food preservation and convenience. Further demographic changes (e.g. increasing participation of women in the labour market, ageing of the population and rising importance of single-person households) is likely to drive sales of ready meals, convenience food and food services.

According to BMI India Retail Report organised retail accounts for 5% of the sales. The Indian retail sector accounts for over 20% of the country’s gross domestic product (GDP) and contributes 8% to total employment. Changing economic dynamics, diverse choices in products and services, numerous shopping formats and unparalleled access to information has empowered customers to expect more from their retail experience. According to PWC report (2012) India’s retail market is expected to cross 1.3 trillion USD by 2020 from the current market size of 500 billion USD. Modern retail with a penetration of only 5% is expected to grow about six times from the current 27 billion USD to 220 billion USD, across all categories and segments. The penetration level of modern retail (currently 5%) will increase six-fold from the current 27 billion USD to 220 billion USD in 2020. The Indian retail sector is expected to grow at a CAGR of 15 to 20%. Factors which drive the organised retail sector include the following:

• Higher incomes driving the purchase of essential and non-essential products
• Evolving consumption patterns of Indian customers
• New technology and lifestyle trends creating replacement demand
It is estimated that the Indian agro products and food-processing sector is responsible for $6,940 billion out of the total $1.8 billion retail sector in India (Saionton Basu, Simon Bickerdik, 2014). The agri-food sector in India employs over half of the country's population and is crucial to maintaining and accelerating economic growth. The enormous potential for food retail has led to large corporate houses such as ITC, Reliance, Aditya Birla, etc.; to diversify in a big way in the food retail segment in order to increase the portfolio of offerings to the urban consumer coupled with the assurance of quality and convenience. Very recently, large global retailers such as Wal-Mart and Carrefour have also evinced great interest in participating in this sector through joint ventures and partnerships. The growth of agro retail market has been significant in recent years because greater number of higher and middle income Indians prefer to shop at agro retail outlets as they get many facilities like, good quality at reasonable price, various varieties of products, higher standards of hygiene and attractive ambience, all under one roof. Factors such as growing population and disposable incomes coupled with increased health consciousness of the consumers, have led to a shift in the food preferences of the population.

India has been rather slow in joining the organized retail revolution. This was largely due to the excellent food retailing system that was established by the ‘kirana’ stores that continue to meet all the retail requirements albeit without the convenience of the shopping as provided by the retail chains; and also due to the highly fragmented food supply chain that is cloaked with several intermediaries (from farm-processor-distributor-retailer) resulting in huge value loss and high costs. Further the supply chains are underdeveloped and are not well integrated with the cold storage infrastructure. This is fast becoming a critical item for action in India, as at present there is wastage of 30-40% between the farm and the retailer. It has been estimated that direct procurement format resulted in an increase in farmers’ net income by eight per cent, while consumers paid six per cent less and transportation wastage fell by seven per cent. This could further improve if supply chain logistics is strengthened.

2. Delhi and its Agro – Retail profile

Delhi, the national capital of India, has a distinct and a unique character. It is a growing & expanding magnet of attraction for people from all across the country and also a hub for the region surrounding it. The National Capital Territory (NCT), Delhi has an area of 1483 sq. kms., with a maximum length of 51.9 km. and greatest width of 48.48 km. In 2011, the population of Delhi, as recorded by Census of India stood at 16.75 million on 1st March 2011 as against 13.85 million as on 1st March, 2001. The annual growth rate of population of Delhi during 1991-2001 has been recorded as 4.6% which declined to 2.2% during the period 2001-2011. The gross population
density of Delhi, as in 2011 is 11,300 persons per sq.km. as against 9340 persons per sq.km. in 2001. The city had a registered vehicle population of 7.45 million in 2011-12 having increased from 3.16 million in 1999-2000. Two wheelers accounted for 62.5% share while cars accounted for 31.5% share respectively of the total registered vehicles in 2011. The overall road network of Delhi has increased from 28508 km in 2000-01 to 32663 km in 2011-12.

The Gross State Domestic Product of Delhi at current prices was estimated to be Rs. 3107.36 billion during 2011-12 indicating a growth of 18.84 per cent over the previous year. The contribution of tertiary sector in state GDP is nearly 85%, indicating the importance of trade and commerce as a pivotal role in promoting growth of Delhi’s economy by making significant contribution in terms of tax revenue and providing gainful employment. There are, as per the estimates, 24,000 wholesale shops & establishments in the city (Delhi Development Authority, 2001). Out of that, 60% of the markets are concentrated in congested parts of Old Delhi (Shahjahanabad). The wholesale markets in Delhi deals with 27 different types of commodities of which seven are major ones. These commodities, along with their principal markets are:

- Textile & its products (Chandini Chowk)
- Auto Parts & Machinery (Kashmere Gate)
- Fruits & Vegetables (Azadpur)
- Hardware & Building Materials (Chawri Bazar)
- Iron & Steel (Naraina)
- Paper & Stationary (Nai Sarak)
- Food grains (Naya Bazar)
- Timber (Kotla, Kirtinagar)

With the Indian retail industry poised to become a $637 billion sector by 2015, the capital city is emerging as the largest consumer market in the country consisting of a booming middle class. As per the Economic Survey of Delhi 2011-12 (Delhi Government, 2012), there were about 0.39 million trading enterprises in Delhi with an employment of 1.05 million. Marketing of agricultural produce in Delhi is through network of regulated markets. The Delhi Agricultural Marketing Board (DAMB) controls eight agricultural produce markets all over Delhi. The wholesale trade for fruits and vegetables is located in Azadpur on GT Road, a regulated marketed entrusted to Agricultural Produce Marketing Committee (APMC). New Azadpur Sabzi Mandi is the biggest fruit and vegetable market in Asia and also ranks
first in terms of arrival in the world. Retail chains are sourcing produce through three routes namely

- Village market or mandis
- APMC yard or whole sale market and
- By linking directly with farmers

3. Case Study Area and Data Collection

Some of the major retail outlets dealing in agro retail in Delhi include Big Apple, 6 Ten, Reliance Fresh, Big Bazaar, Save max and Sabka Bazaar. The fruit and vegetable organized retail market has been quite successful in Delhi resulting in a major shift from local vendors and grocery stores to the local outlets. Their sales have grown much more rapidly, at almost triple the rate. This high acceleration in sales through modern retail formats is expected to continue during the next few years, with the rapid growth in numbers of such outlets due to consumer demand and business potential. In the present study one retail outlet each of Reliance Fresh and Big Apple have been chosen to elicit customer behavior shopping at these outlets.

Reliance Fresh and Big Apple have 67 and 57 retail outlets respectively in entire Delhi. The average area of retail outlets varies between 2500-4000 sq ft. in case of Reliance Fresh and 2000-2500 sq ft. in case of Big Apple and these are taken on rent by both the companies. Both these companies have two warehouses in Delhi from where supplies are made to various retail outlets. The warehouses for Reliance Fresh and Big Apple are located at Gurgaon/Rana Pratap Bagh and Azadpur/Naraina respectively. An estimated Rs 1.2 million and Rs 0.9 million are incurred per month on transportation including transport from supplier to warehouse by trucks and from warehouse to retail outlets by LCV’s.

The two case retail outlets chosen in the present study are of Big Apple and Reliance Fresh located on C.V. Raman Marg near Gurudwara intersection in Maharani Bag of South Delhi. The built up area of case Reliance Fresh and Big Apple retail stores were 4000 sq ft. and 2000 sq ft. respectively managed by a staff of 22 and 7 employees respectively generating an average footfall rate of 3.10 and 1.66 persons per sq ft built up area. The average distances from the warehouse to retail stores varied from 34.1 km in case of warehouse in Gurgaon to 17.7 km from warehouse in Naraina to the retail store.

Customer surveys were carried out at these two case retail outlets on weekday and weekend to assess their footfalls, shopping behavior as well as their mobility pattern for shopping. As per the study estimates the daily footfalls observed at the two case outlets are between 600-700 at Reliance Fresh while it is between 300-350 at Big
Apple respectively. For the present study about 91 customers were enumerated in all on weekday and weekend at the case outlets based on random sampling approach. In addition secondary data was also collected related to retail outlet operational details such as daily inflow of fruits and vegetables, customers handled, peak demand hours, number of employees, number of shifts per day and arrival /departure times of delivery vehicles visiting the outlets. A temporal analysis of the data collected from the present study has been made with an empirical study carried out by Amani (2008) to assess the variations in customers shopping behavior and mobility patterns.

4. Customer Characteristics

4.1 Personal Attributes

Gender and Occupation

It was observed that 68% of the customers surveyed are males and 32% are females. Further it was observed that customers who were in private jobs constitute nearly 42% of total daily footfalls while comparative proportion for customers engaged in public jobs was a meagre 9% only which indicates that private sector employees with potential larger disposable income are more used to shopping at such retail outlets.

Monthly income

The average household income of customers shopping at such retail outlets in the study area is Rs. 44,721 per month with the distributions of various income groups almost similar at the two outlets. Nearly 68% of customers had average monthly income in excess of Rs 30,000 per month.

4.2 Shopping Behaviour

Total time spent on purchase

More than 70% of the customers visiting the two outlets reach in less than 10 minutes from their place of residence. While 51% of the customers spent time between 15-30 minutes about 22% of them spent more than 45 minutes at the outlets. The average time spent in the outlets for shopping is 37 minutes.

Source of purchase (before)

Majority of the customers (53%) prior to these outlets purchased from the local vendors/shops, mostly unorganized, while only 20% of them consumers purchased from wholesale market at Okhla.
Frequency of purchase

It was observed that weekly shopping tendency, mainly from wholesale markets, seem to have reduced from 54% to 37% with the advent of these retail outlets considering the fact that these facilities are within easy reach of customers to access them more frequently.

Quantity of purchase

The average quantity purchased per customer per trip before is 6.86 kg which is marginally lesser than 7.20 kg purchased per customer per trip from other sources such as shops and wholesale markets. Table 1 shows the average quantity purchased per trip (kgs.) by trip frequency. While daily and alternate day customers’ purchases per trip have increased from earlier cases the weekly customers’ purchases have shown a decline over the past shopping behavior.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Reliance</td>
<td>Big Apple</td>
</tr>
<tr>
<td>Daily</td>
<td>3.56</td>
<td>4.18</td>
</tr>
<tr>
<td>Alternate Day</td>
<td>5.67</td>
<td>5</td>
</tr>
<tr>
<td>Weekly</td>
<td>9.84</td>
<td>9.79</td>
</tr>
</tbody>
</table>

4.2 Trip characteristics

Daily Footfalls

The cumulative footfalls at the two case retail stores per day were observed to be in the range of 1000 to 1200 persons. While on weekday 1060 footfalls were observed the number went up to 1222 footfalls on the weekend. The peak demand of customers was observed from 0800 hrs to 1100 hrs in the morning and between 1700 hrs to 2000hrs in evening.

Mode of Travel
The advent of retail outlets has had an effect on the mode used by customers for shopping. While the share of car trips have decreased from 35% to 30% the share of two wheelers has gone up from 8% to 16% largely owing to availability of these retail stores at shorter distances with limited parking compared to earlier shopping environment making two wheeler a more viable and convenient option. The walk trips too has decreased from 44% to 31% possibly as earlier shoppers were shopping from informal markets within easy walking distances while the organized retail stores are located beyond walking thresholds from the residences requiring vehicular use for majority of the customers. Noticeably the share of non motorized hired modes such as cycle rickshaws has increased from 5% to 16% to account for customers who are dependent on such modes taking into account factors such as access distances to the stores, non-availability of personalised modes and the shopping quantity.

**Trip Lengths**

The retail stores have also impacted the trip lengths of various modes used by customers in their shopping activity. While the car trip length showed a decline from 3.67 km in earlier shopping environment to 1.63 km at present, the two wheelers too decreased from 1.88 km to 1.37 km respectively. These declines in average leads predominantly are on account of availability of such retail stores at much lesser travel distances now compared to earlier days of shopping by the customers. Interestingly these stores have also encouraged use of NMT modes such as cycle and cycle rickshaws for shopping with average leads of 1.2 km and 1.42 km respectively.

**Vehicle Kms**

The share of personalized motorized vehicle km per customer per day in total vehicle km has shown a decline from 79% in earlier case to 57% in present situation. Overall the total vehicle km performed per day by the sampled customers has also decreased from 28.92 km in earlier scenario to 21.06 km in present situation. The vehicle km of cars and two wheelers involved in shopping activity have reduced by 56% and 33% respectively in before and after retail stores situation indicating the positive impact of retail outlets on the environmental quality. As a result there has been a reduction in carbon emissions with the advent of retail outlets.

**Access Distance to outlets**

Access distances to retail outlets is extremely important in attracting higher footfalls besides deciding the mode usage patterns of shoppers. It was observed that maximum percentage of the customers (63%) visiting these outlets travel within a distance range of 0.5-1.0 km from the retail store people while only 10% of the customers...
were in distance band exceeding 2 km. About 15% of the customers were observed to be within the most accessible distance of less than 0.5 km.

5. Temporal Variations in Characteristics of Customers

5.1 User Characteristics

A temporal analysis of case retail outlet users in 2008 and 2014 has been attempted to assess the dynamics of consumer behavior and their mobility patterns towards agro retail stores. The analysis reveals that the proportion of males in the shoppers has increased over time from 58% in 2008 to 68% in 2014. The proportion of shoppers below distance of 1 km from the outlet too has increased from 66% in 2008 to 78% in 2014. Over time it is seen that the percentage of customers within 10 minutes distance of the retail outlets has increased from 66% to 78% during the above mentioned period indicating the influence of these stores on its immediate catchment population’s shopping behavior. In terms of access distance to retail outlets the percentage of customers lying between 0.5 – 1 km has increased from 50% in 2008 to 63% in 2014 (Fig. 1).

![Temporal Variations in Customer Distribution by Access Distance to Retail Outlets (%)](chart.png)

**Fig. 1: Distribution of Customers by access distance to retail outlets**
The average time spent in shopping too has gone up from 20 minutes in 2008 to 45 minutes in 2014 largely due to more variety of goods available at these stores forcing shoppers to spend more time and also the fact that the servicing time per shopper has increased due to the mismatch between the demand and requisite service facilities offered by these stores. It is further observed that the shoppers in income band of Rs 30000 to Rs 50000 accounts for 42% share in 2014 compared to 18% in 2008. The proportion of shoppers shopping 7 kg or more has increased from nil in 2008 to 32% in 2014 indicating higher purchases possibly due to rise in disposable incomes. Consequently the annual turnover at current prices has increased by 67%

In terms of mobility patterns of shoppers it is observed that the cumulative share of cars and two wheeler users to case retail outlets has increased over the years from 29% in 2008 to 46% in 2014 which may be partly due to the convenience factor associated with personal vehicles in shopping related travel (Fig 2). It is also noticeable that the walking environment over the years has deteriorated over the years resulting in decline in walk share from 60% in 2008 to 31% in 2014

![Temporal Variations in Modal Split](Fig. 2: Temporal Variation in Modal Split)

The average trip lengths of personalized modes such as cars and two wheelers have marginally increased over the years (Fig 3).
Fig. 3: Temporal Variations in Average Trip Lengths

However the walk trip lengths has increased from 0.63 km in 2008 to 0.93 km in 2014 while for cycle rickshaws too it has increased from 0.8 km to 1.42 km respectively. Fig 4 shows the temporal variation in trip length distribution. The proportion of trips in distance band 0.5-1 km and 1-2 km have increased over time. It is also noticeable that the walking environment over the years has deteriorated over the years resulting in decline in walk share from 60% in 2008 to 31% in 2014.

Fig. 4: Temporal variation in trip length distribution
It is also noticeable that the walking environment over the years has deteriorated over the years resulting in decline in walk share from 60% in 2008 to 31% in 2014.

6. Conclusions

Planned retail outlets are slowly replacing the traditional agro-retail sector, largely unplanned and informal in nature, particularly in large cities in India such as Delhi due to factors such as higher incomes driving the purchase of essential and non-essential products, evolving consumption patterns of Indian customers and availability of good quality diverse at reasonable price and convenience. In the present study the customer shopping behavior before and after the advent these agro-retail outlets reveal that advent of retail outlets has had an effect on the mode used by customers for shopping. While the share of car trips have decreased from 35% to 30% the share of two wheelers has gone up from 8 % to 16%. The vehicle km of cars and two wheelers involved in shopping activity too have reduced by 56% and 33% respectively in before and after retail stores situation resulting in reduction in carbon emissions.

While the advent of planned agro-retail outlets is likely to take care of the highly fragmented and inefficient supply chain loaded with several intermediaries its rational planning is yet to find a place in the master planning practices observed in cities in India. As a result these outlets are mushrooming at various places in urban neighbourhoods largely driven by the inter-se completion amongst various interested service providers and market driven land forces without taking into cognisance the planning requirements for locating and sting such facilities in urban neighbourhoods. There is an urgent need for city authorities in developing countries to incorporate the planning needs of such retail outlets in various neighbourhoods taking into account their possible location impacts on bounding network, their rational space allocation planning possibly in planned local shopping centres, and facilitating use of NMT modes as far as possible to access these outlets in order to enhance the environmental quality of residential neighbourhoods.

References

1. Rana Amani (2008), Impact of Retail Logistics in Urban Areas, Unpublished Master’s Thesis, School of Planning and Architecture, New Delhi
3. Delhi Development Authority (2001), Mater Plan for Delhi


FREIGHT TRANSPORT MANAGEMENT MEASURES IN THE RICE INDUSTRY IN THE MEKONG DELTA: AN OVERVIEW AND POLICY CONSIDERATIONS

MSc. Nguyen Thi Binh¹ and Dr. -Eng. Vu Anh Tuan²

Abstract

Vietnam is known as the world’s sixth largest producer of rice and the second largest rice exporter. The Mekong Delta has been contributing about 50% of total rice production and 90% of Vietnam’s rice export. The dependency on the freight transport system has been a key issue for the Mekong Delta rice industry. This study attempts to explore and understand the freight transport system in the Mekong Delta and its issues, and identifies the potential policies for the future of the Mekong Delta rice industry. The methodology of the study is based on a comprehensive literature review on freight transport management measures, and field surveys and observations. The surveys focus on the application of the freight transport management measures in the Mekong Delta. An interview survey is conducted with three specific companies in the rice supply chain, namely food company, transport company, and port company. The preliminary results show that the building of a high-performance inland waterway system, relocation/formation of rice warehouses and distribution centres, and various road freight transport management measures may be effective to improve the efficiency of the rice freight transport system.

Keywords: Freight Transport Demand, Traffic Management, Rice Industry

1. Introduction

Vietnam is known as the second largest rice exporter in the world. Half of the Vietnamese rice is produced from the Mekong Delta, and 90% of Vietnam’s rice export comes from this area. Although Vietnamese rice export achieved some successes, but the value of rice export is not corresponding with the increase of volume. Rice export price of Vietnam is often lower than the one of Thailand about 100-200USD/ton (VFA, 2011). The reason is the process of rice production, logistics and transportation still has some inefficiency. The rice industry has just concentrated primarily on the production planning to increase the volume. The decisions of production are often made without considering the impacts of traffic and transport system. So far, there have been a number of studies on the rice supply chain in Vietnam (Son, 2013; Loc, 2011; ADB, 2011; Thanh, 2006; Can et al., 2011).

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these studies focused mainly on the description of the rice supply chain and the calculation of the value created at each step of the supply chain. Some of them concentrated on technical analysis of rice production (Khai & Yabe, 2011) while the other tried to analyse the actors involved in the rice industry and their reciprocal relationship (Phuong, 2013). Those studies have not yet mentioned the impacts of transport and traffic measures on the rice production and distribution.

The main objectives of this study are to gain an in-depth understanding of the freight transport system in the Mekong Delta and its issues, and identifying the potential policies for addressing the issues. The structure of this paper includes four parts. The second part presents the methodological approach of the study. It consists of a literature review, surveys, and observations. The third part presents the initial results, with an emphasis on the deficiencies of freight transport activities in the rice industry. In parallel, it attempts to compile applied and potential transport management measures in the context of the rice industry in the Mekong Delta. The issues and policy considerations are discussed to help formulate a decision-support system for rice freight transport management. The last part concludes and recommends a further study.

2. Methodology and Data

The study is based on a comprehensive literature review on freight transport management measures, and field surveys and observations conducted by the authors. The literature review focuses on freight transport management measures, which are already applied in the world. The current practices and applicability of those measures are examined against the transferability to Vietnam. The application of the freight transport management measures in the Mekong Delta are also examined at both firm and network levels.

The survey method is employed to understand the practical application of freight transport management. An interview survey is conducted with three specific actors involved in the rice supply chain, including food company, transport company, and port company. The questionnaires are slightly differentiated by the type of actors. The content and structure of each survey questionnaire are improved based on discussions with academics and practitioners. The questionnaire consists of four main parts: (1) Profile of organization and business (type of company, year company established, kinds of service provided); (2) Rice procurement and distribution activities (source to purchase, distance to distribution centres by road and inland waterway, modal share in the rice distribution, etc.); (3) Profile of fleets and their operational costs (total vehicle, average trip distance, main commodities transported, average fuel consumption, average maintenance and repair cost, etc.); (4) Main barriers to implement the freight transport management measures. The authors did the interview with three big port companies in the Mekong Delta, namely Can Tho port, Tra Noc port and My Thoi port. These ports play very important role in rice transshipment of the region. Four food companies and eight transport companies are also interviewed in the field trip in the Mekong Delta.
To help understand the impacts of freight transport management measures on the rice industry, the research employs the concepts of “traffic management” and “freight transport demand management measures” developed by Boltze (2003) and Boltze et al., (2012). Traffic management can be interpreted as “to influence the transport system with a bundle of measures to bring transport demand and supply in an optimized balance”. Freight transport demand management is a part of traffic management aiming at influencing the demand for freight transport by implementing a bundle of measures with the target of optimizing the positive and negative impacts of traffic and transport.

While following the concept, the freight transport management measures in this study are specifically addressed from the perspective of transport engineering and classified by its potential impacts, namely avoiding traffic, shifting traffic, and controlling traffic.

![Figure 1: Transport management measures and its impacts](source: Adapted from Boltze (2003))

**Avoiding freight traffic** means reducing the freight transport demand in the targeted area by combining, modifying and substituting trips. The mechanisms of combining trips are applied to reduce the number of trips and their trip length. Modifying trip is related to trip chain and multi-purpose trip. The freight traffic demand also can be reduced by substituting a trip to non-commuting form by telephone or teleconference. **Shifting freight traffic** aims to shift freight traffic demand between different modes, times and destinations. The mechanism of shifting traffic involves in shifting to high capacity freight transport modes or shifting to off-peak hours to reduce the peak period traffic, or shifting destination close to trip origin to reduce the average trip length. **Controlling freight traffic** focuses on augmenting the network (infrastructure) to meet the existing freight demand, or controlling vehicle or transport users to stabilize traffic condition of a specific area.

There are a number of studies on freight transport demand management measures and their impacts (Anderson et al., 2005; Boltze et al., 2012; Castro & Mario, 2010; Francesco Russo, 2011; Taniguchi, 2002). This study considers not only freight transportation demand management measures but also measures to influence the
transport supply, such as road network construction or new logistics hubs. This is because supply measures also have indirect influence on the demand.

3. Results

3.1. Freight transport system in the Mekong Delta

The Mekong Delta is located in the lower reaches of the Mekong River, which includes thirteen provinces and cities with nearly four million acres of land used for agricultural purposes, 700 km of coastline, 400 km of the border and hundreds of islands. The population of the whole region is over 17 million, account for 20% of the total population of the country. This region has been contributing about 50% of food production, 90% of the rice export volume, 70% of fruit manufacturing, 52% of seafood output and 20% GDP of the whole country (SIWRP, 2011).

![Figure 2: Transport networks of the Mekong Delta](http://cuulongcipm.com.vn/Trangchu/tulieu/0026a2.aspx)

The freight transport infrastructure system in the Mekong Delta is dominated by two modes, inland waterway (IWT) with 58.9% and road with 34.2% (Figure 3). The region is generously endowed with extensive networks of rivers, lakes and canals. Therefore, IWT has always been its primary mode of transportation in the region. Road transportation is mainly concentrated on some arterial highways and often fragmented by canals.
3. Results

3.1. Freight transport system in the Mekong Delta

The Mekong Delta is located in the lower reaches of the Mekong River, which includes thirteen provinces and cities with nearly four million acres of land used for agricultural purposes, 700 km of coastline, 400 km of the border and hundreds of islands. The population of the whole region is over 17 million, account for 20% of the total population of the country. This region has been contributing about 50% of food production, 90% of the rice export volume, 70% of fruit manufacturing, 52% of seafood output and 20% GDP of the whole country (SIWRP, 2011).

The transport volume in the Mekong Delta has increased quickly from 59 million tons in 2005 to 87 million tons in 2010 (GSO, 2011). The average growth rate of transport volume in the whole period is about 11%/year. Transport performance (ton.km) of the whole region has been also an appreciable increase in the period of 2005-2010, from 4.3 billion ton-km in 2005 to nearly 7.3 billion ton.km in 2010. The average growth rate is about 9.2%/year. In comparison with other regions and the whole country, the growth rate of transport volume and transport performance in the Mekong Delta is lower than the one of the Red River Delta (14.3%/year), and even lower than the average one of the whole country (12.8%/year). However, it is forecast that the cargo volume in the Mekong Delta will increase pretty quickly in the period of 2020-2030, even exceeds the average growth rate of the Red River Delta and the whole country. Detail is presented in the Figure 4 as below.

The Mekong Delta is projected to be one of the most rapid growth rate regions and become a focal economic zone, contributing greatly to the volume of key export items of Vietnam in the period 2020-2030 (MOT, 2010).
3.2. The rice industry in the Mekong Delta

For long, rice became a dominant food item of approximately 55% of the world population, widely distributed from Asia to Africa, and the Americas. The Europe and North America only use rice as food additives, but the volume of import to millions tons per year. From the early 1990s until now, Vietnam has been ranked in the three leading countries in rice exportation in the world.

The rice industry in Vietnam is distributed on six basis economic zones such as the Red River Delta, Midland and Northern Mountains, North Central and Central Coast, Central Highlands, Southeast and the Mekong Delta. The contribution of each region to the total rice production of the country is as follows:

![Figure 5: Rice production by region in Vietnam, 2010](source: GSO (2011))

The Mekong Delta has been contributing to over 50% of the total rice volume of Vietnam. There are two kinds of rice supply chain in the Mekong Delta, domestic and export rice supply chain. The following figure shows the relationship among key stakeholders of the rice supply chain:

![Figure 6: Rice supply chain in the Mekong Delta](source: Adapted from Loc (2010))
After harvesting, farmers sell almost paddy (93.1%) to collectors. In the Mekong Delta, collectors are a very important and indispensable component in the rice supply chain. They often use small boats to visit the field and collect paddy/rice. Then, they resell paddy/rice to millers (30.3%) for milling and polishers (47.8%) for polishing. Only 15% of total volume are processed directly by the collectors and then transported to wholesale and retail for domestic consumption. Once the rice milling and polishing process is finished, rice either is delivered to food/export companies (21% and 3.5%) or to domestic wholesales and/or retailers (1.3% and 7.2%). So far, up to 70% of rice volume in the Mekong Delta is for export, while only nearly 30% are consumed domestically.

As shown in the Figure 7, IWT and road are considered as the main transportation modes in the rice industry. Motorcycles are used mainly for purchasing the material inputs such as fertilizers, pesticides.

![Figure 7: Transport modes used in the rice supply chain](source: Own illustration based on data from Loc (2010) and field survey in the Mekong Delta (2013))

It becomes apparent that IWT is very popular in transporting rice to export ports whereas road is primarily used to distribute rice to domestic market. Currently, the share of IWT and road transportation in the rice industry is 90% and 10%, respectively (MOT, 2014). However, road transportation is forecast to increase quite quickly when road infrastructure network of the Mekong Delta is improved and upgraded remarkably in the period of 2020-2030. Particularly, the change in the road modal share of the rice industry is projected as follows:
Rice commodity is often transported by small vessel (less than 1000 tons) and/or large truck (15 tons) to Hochiminh City (HCMC). The haulage characteristics of long-distance trips from cities in the region, for instance Can Tho city (the centre of the Mekong Delta), to HCMC is given in Table 1:

<table>
<thead>
<tr>
<th>Haulage characteristics</th>
<th>Estimated value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age of truck (year)</td>
<td>17.2</td>
</tr>
<tr>
<td>Truck weight without cargo (ton)</td>
<td>12.7</td>
</tr>
<tr>
<td>Actual average load (ton)</td>
<td>21</td>
</tr>
<tr>
<td>Average overload (ton)</td>
<td>8.3</td>
</tr>
<tr>
<td>Average load/truck weight</td>
<td>1.7</td>
</tr>
</tbody>
</table>

Source: WB (2010)

It is found that most of shipments from the Mekong Delta to HCMC are overloaded. The trucking industry in Vietnam is, actually, very competitive and shippers mostly care about transport costs at the expense of inventory carrying costs, so truckers often tend to drive transport cost down at the expense of service quality. Consequently, it damages the road and deteriorates infrastructure network quickly.

3.3. Freight transport management measures in the rice industry

To solve the increasing problems of freight transport problems in the Mekong Delta, various traffic management measures need to be considered and applied. Table 2 presents a compilation of management measures that have already been applied and considered to be potential measures.
Table 2: Compilation of traffic management measures in the context of rice industry

<table>
<thead>
<tr>
<th>No</th>
<th>List of candidate freight transport management measures</th>
<th>To avoid traffic</th>
<th>To shift traffic</th>
<th>To control traffic</th>
<th>Already applied in the rice industry</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Combination</td>
<td>Modication</td>
<td>Substitution</td>
<td>Time</td>
</tr>
<tr>
<td>M1</td>
<td>Harvesting time</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M2</td>
<td>Time window for truck entering the city</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td></td>
</tr>
<tr>
<td>M3</td>
<td>Time window for loading and unloading at curb-side parking places</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td></td>
</tr>
<tr>
<td>M4</td>
<td>Incentive for off-peak delivery</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M5</td>
<td>Promotion of intermodal transport, the use of road and inland waterway transport</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M6</td>
<td>Image campaigns, concept for “Green Logistics”</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M7</td>
<td>Low-emission zones</td>
<td>○</td>
<td></td>
<td>○</td>
<td></td>
</tr>
<tr>
<td>M8</td>
<td>Vehicle restrictions (weight -, width-, emission - based)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M9</td>
<td>Promotion of regional products</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M10</td>
<td>Business cooperation</td>
<td>○</td>
<td></td>
<td>○</td>
<td></td>
</tr>
<tr>
<td>M11</td>
<td>Loading/unloading areas</td>
<td>○</td>
<td></td>
<td>○</td>
<td></td>
</tr>
<tr>
<td>M12</td>
<td>Truck routes/Freight – exclusive lanes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M13</td>
<td>Freight centre and consolidated deliveries</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M14</td>
<td>Co-operative freight transport system</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M15</td>
<td>Ban on trucks</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M16</td>
<td>Speed limit</td>
<td>○</td>
<td></td>
<td>○</td>
<td></td>
</tr>
<tr>
<td>M17</td>
<td>Load factor control</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>M18</td>
<td>Road pricing schemes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M19</td>
<td>Telematics-route planning and electronic guidance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M20</td>
<td>Infrastructure capacity improvement (inland waterway, road, port)</td>
<td></td>
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</tr>
</tbody>
</table>

Sources: Boltze et al., 2012; Loc, T.T, 2011; Castro & Mario, 2010; JICA, 2009; Browne et al., 2007; Holguín-Veras et al., 2007; Hung, 2006; Castro & Kuse, 2005; Taniguchi, 2002

The following part reviews the detailed contents of seven measures that have been applied in the rice industry in the Mekong Delta.
M2) Time-window for truck entering the city: Prohibition of trucks from more than 2.5 ton load or total load of 5 tons to enter HCMC from 6:00 am to 12:00 pm
This measure aims at reducing the incoming traffic volumes to HCMC at peak-hour. Urban day-time bans on the truck are applied along the corridor of Saigon Bridge-Nguyen Huu Canh -Ton Duc Thang- Nguyen Tat Thanh. The primary impact of the measure is time shift of trucks to off-peak hours and night time. This measure has been applied for two years and relieved partly traffic congestion on the main routes into the city. However, it also has a large effect on the transport companies due to the increase of transportation cost.

M5) Promotion of intermodal transport: The transport master plan in the Mekong Delta approved by the Prime Minister in Feb 10th, 2012
This measure aims at developing the comprehensive transport network, meeting the increase of transport demand in the Mekong Delta. The main contents of this measure are transport mode planning, transport infrastructure planning, and list of priority investment projects for transport development. The measure promotes the use of intermodal transport with the emphasis on the combination of road and inland waterway transport. So far, some main highways such as My Thuan-Can Tho highway, national highway 91 have been completing and making a considerable contribution to improvement of freight transport between the Mekong Delta and HCMC.

M9) Promotion of regional products: The establishment of centralized areas for the paddy-production (large farm, high productivity, Viet GAP (Good Agriculture Production) Standard)
The objective of the measure is to promote the development of regional products. The change in destination of transport demand can be addressed as one of the most important impacts of this measure. The measure has been applied in An Giang, Tra Vinh, Tien Giang, Dong Thap, Hau Giang and Bac Lieu provinces. The preliminary results have shown that this model can bring high economic efficiency for the region.

M10) Business cooperation: The co-operation of collectors and millers and export companies in An Giang province
The objective of the measure is to control the rice-purchasing price from time to time according the market and simultaneously reduce the intermediate stages in the rice supply chain. The co-operation of these stakeholders helps to shift trip destination close to trip origins, thereby reducing the average trip lengths.

M13) Freight Centre and consolidated deliveries
This measure is conducted in the form of construction of the rice logistics centre in Chau Thanh A (Hau Giang province) and in Tan Duong (Dong Thap province) and Cai San (An Giang province). The centre can be viewed as a specific facility where concentrate highly transport and logistics activities in large infrastructure. The objective of the measure is to improve the ability of rice procurement and promote consolidated deliveries in the Mekong Delta.

M14) New market (co-operative freight transport system)
This measure is widely applied in Can Tho city and Long An, Tien Giang, Dong Thap provinces. The measure aims at constructing major markets for paddy/rice that can act as not only collecting and purchasing agricultural products, but also a key terminal to promote the consolidation delivery.

M20) Infrastructure capacity improvement
This measure concentrates on upgrading the infrastructure system in the Mekong Delta. It may refer to some typical projects like inland waterway projects (upgrading Cho Gao channel, dredging in Dinh An channel (for Hau River), digging in Soai Rap Channel) or port projects (building Cai Cui Terminal, New Port Cat Lai, Nam Du Transhipment Port) or road projects (forming major corridors connecting the Mekong Delta to Southeast regions and the country, upgrading provincial roads and national highway Nam Du Transhipment Port). The measure belongs to the management of transport supply. However, it may also impact on traffic demand in terms of shifting trip mode or trip destination.

3.4. Challenging issues of the rice freight transport

3.4.1. Increase in road freight transport
It is the fact that within the transport sector of Vietnam, about 92% of the CO2 emissions originated from road transport and about 5% from waterborne transport (IWT and coastal shipping). Based on Blancas & M. Baher (2014), the emission factor for road and IWT freight transport in Vietnam is estimated as bellow:

Table 3: Estimated emission rates by freight transport modes

<table>
<thead>
<tr>
<th>CO₂ Emission Factors</th>
<th>2010</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truck (gCO₂/ton. km)</td>
<td>110</td>
<td>80</td>
</tr>
<tr>
<td>IWT (gCO₂/ton. km)</td>
<td>71</td>
<td>50</td>
</tr>
</tbody>
</table>

Source: Data from Blancas & M. Baher (2014)

Apparently, the heavy dependence on road transportation will lead to an increase of GHG emissions as road freight transport generally generates much higher CO2 emission rate than IWT. Besides, fuel consumption is significantly influenced by the size and age of the vehicles deployed. The larger vehicle or vessel engine, the higher fuel efficiency per unit of service it is. Particularly, on average, barge transport is 4.0 times more fuel efficient than truck transport on ton-km (Blancas & M. Baher, 2014). Furthermore, the road-intensive situation could become a potential danger of the increase of traffic accidents. The statistics on traffic safety of Vietnam has shown that the road traffic is much more dangerous than waterway traffic as total number of road accidents is approximately 65 times higher than IWT accidents.
Generally speaking, the tendency of IWT-to-road modal shift has been challenging the sustainable development of the rice industry in particular and Vietnam in general. To solve this problem in the long term, measures to improve performance of waterway sector should be introduced.

### 3.4.2. High transport and logistics costs

In the rice industry, it seems that transport cost is more important than time-response. In fact, to transport rice from the Mekong Delta to HCMC it takes one day and two days by road and IWT, respectively (Binh, 2013). The transport time between the two modes is not so different. However, transport cost is highly critical. Figure 9 shows that transport cost makes up the largest proportion (59.3%) of the total logistics cost. This can be explained by the fact that Vietnamese rice supply chain is complicated with many relations. Rice is mostly exported via ports in HCMC, located about 200 km far from the Mekong Delta. Only a small quantity is exported via ports in the region, such as Can Tho and My Thoi port, due to limited shallowness of the Hau river. Therefore, the “last mile” of the rice supply chain has been increased, leading to the rise of transport cost. The case of Thailand is more efficient. Once the rice polishing process has completed, it is conveyed into tug-boat and then transported by large ship for exportation (Wilasinee et al., 2010).

![Figure 9: Breakdown of the total rice logistics in Vietnam](source)


Table 4: Traffic safety in Vietnam, 2006

<table>
<thead>
<tr>
<th>Mode of transport</th>
<th>No of accidents</th>
<th>%</th>
<th>Fatality</th>
<th>%</th>
<th>Injured</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road</td>
<td>14161</td>
<td>96.2%</td>
<td>12373</td>
<td>97.0%</td>
<td>11097</td>
<td>98.3%</td>
</tr>
<tr>
<td>Railway</td>
<td>292</td>
<td>2.0%</td>
<td>136</td>
<td>1.1%</td>
<td>158</td>
<td>1.4%</td>
</tr>
<tr>
<td>IWT</td>
<td>215</td>
<td>1.5%</td>
<td>210</td>
<td>1.6%</td>
<td>18</td>
<td>0.2%</td>
</tr>
<tr>
<td>Maritime</td>
<td>59</td>
<td>0.4%</td>
<td>38</td>
<td>0.3%</td>
<td>13</td>
<td>0.1%</td>
</tr>
<tr>
<td>Total</td>
<td>14727</td>
<td>100%</td>
<td>12757</td>
<td>100%</td>
<td>11286</td>
<td>100%</td>
</tr>
</tbody>
</table>

Source: JICA (2009)
3.4.3. Overloading in long-distance freight transport

As mentioned, loading factor of the road freight from the Mekong Delta to HCMC is averagely 1.7. Freight companies tend to reduce transport cost to compete with each other by overloading. Monitoring and management system for long distance freight is so weak that it makes the issue more severe. Ministry of Transport of Vietnam has recently strengthened the control of road freight loading factor by Decision No 1526/QD-BGTVT dated 5th June 2013. This scheme also proposed short-term and long-term measures to control road factor for long-distance freight. It included strengthening state management on road load factor, strict punishment on oversized and overloaded vehicles, restructuring rationally transport modal share of the economy. Initially, this scheme has been bringing some impacts. On the one hand, the transport market is more transparent since the road transport price goes back to its true value, and the deterioration of road infrastructure is better controlled. On the other hand, the regulation may increase the total transportation cost born by the carriers. As a result, the price of goods and services could go up. In the short-term, road traffic volume is forecasted to grow to meet the commodity flows.

In short, the rice industry in the Mekong Delta has been facing various problems related to emission, safety, and energy. This necessitates a better management of freight transport system to address the problems, thus maintaining the role of the rice industry in the future.

3.5. Policy considerations

To address wholly the issues, it requires comprehensive measures. However, it is important to determine a number of specific measures addressing the current issues. The literature and practical review set a solid ground for recommending specific measures as follow.

**Improving the capacity of the IWT system (M20)**

This is the first measure to be considered. It is expected to deal with two problems, namely reducing the share of road freight and lowering transport cost. This measure has been well implemented in many countries, such as Netherlands (ECMT, 2006), China, Bangladesh, Indonesia (WB and MOT of China, 2009; Tuan, 2011). IWT is seen as a competitive and alternative mode to road and rail transport because it is efficient, safe, and environmentally friendly. It contributes to the decongestion of the overloaded road network in densely populated regions.

In Mekong Delta, it should be focused on dragging canals along the Hau River to accommodate big vessels (more than 10,000 DWT) and provide access to the regional ports (e.g. Can Tho, Cai Cui, Tra Noc, My Thoi) (see Figure 2). This would reduce the amount of commodities in the region being transported by road or IWT to HCMC for domestic consumption and export. In addition, it is also important to encourage a shift from small to big and cleaner vessels by financial support and incentives.
Such measures could help to shift mode from road to IWT, and to shift the destination of the rice supply chain from HCMC back to the Mekong Delta. Quantitatively, there has not been any research on socioeconomic and environmental impacts of the recommended measures. In the qualitative sense, however, it can contribute to reducing the greenhouse gas emission since the emission factor of IWT is usually lower than the truck. In the Netherlands, for example, the promotion of IWT for both passenger and freight transport is estimated to reduce CO2 emissions per ton-km by 13% in ten years between 1995-2005 (Blancas & M. Baher, 2014). This measure also results in traffic safety improvement since IWT is generally safer than road traffic (fewer accidents and fatalities per ton-km). For instance, in the Netherlands, safety valuation for the road and IWT is 0.07$/vehicle.km and 0.05$/vehicle.km, respectively. Besides, an increase of scale within shipping also contributes to reducing accidents because of the reduction in shipping traffic (as fewer ships are required to move the same volume of cargo).

The impact of destination shift of the measure has very meaningful in reducing “last mile” of the rice supply chain, which would result in a lower sum of transport cost and time cost of the supply chain. Importers and exporters would gain economic benefit with the intervention of shifting destination from HCMC to the Mekong Delta.

**Freight centre and consolidated deliveries (M13)**

The literature shows that the concept of freight centre and consolidated deliveries is considered as a specific area where all the activities relating to transport, logistics and goods distribution are carried out, to promote consolidated deliveries within that area. This scheme has been addressed in some countries such as Germany (Wagener, 2008) and Japan (Taniguchi, 2002). It was suggested that the use of a freight centre and consolidated deliveries can potentially result in reductions in the number of vehicle trips; improvements in volume/weight utilization rates for vehicles from the centre, thereby reducing the unit costs of transportation for the final delivery stage.

In the case of the rice industry in the Mekong Delta, the measure on forming the freight centre and consolidated deliveries aims at establishing logistics facilities located close to rice production areas to improve the ability of rice procurement and to promote rice consolidated deliveries within this area. The technical impact of this measure is to allow farmer selling paddy directly to the distribution centre and reducing the role of middlemen, which would result in reduction of freight transport demand in the region. The case of Germany (Kohler, 1997) has shown that application of this scheme led to distance travelling within the city centre decreased by 60% and the load factor increased to 60% from 25%. Freight costs were also estimated to reduce by 10-15%.

**Load factor control (M17)**

The concept of the load factor is commonly used in traffic management in urban areas. Load factor is one of the most important performance indicators for the
efficiency of freight transport. So far, there are only two European cities, Amsterdam and Copenhagen, who implemented the load factor schemes (Taniguchi, 2002). The objective of such measure in the past is to encourage maximum utilization of truck capacity. Load factor schemes are similar to other schemes that were used by policy makers in cities like Prague, Budapest, Maribor, Paris and Stockholm to manage the flow of truck traffic within a city like the truck ban and weight/size/time restrictions (Browne et al., 2007; Castro & Mario, 2010; Kohler, 1997). For the case of the Mekong Delta, however, load factor control is recommended to apply for long-distance transportation. That is because most of shipment transported by road from the Mekong Delta to HCMC is overloaded, which enable the increase of road competitiveness in term of cost.

This measure is expected to help better management of transport mode and to shift transport mode. Obviously, it would cause an increase in road transport cost, thereby reducing its competitiveness of the road system. One could argue that traffic on the highways will likely increase since the more trucks used to transport all the goods. Consequently, the traffic condition may not improve as expected. According to the experience of some countries, this solution should coexist with the road pricing scheme which can manage traffic congestion efficiently (Teo et al., 2014). By application of those measures, transport companies may consider modal shift from road to waterway to achieve more efficiency.

4. Conclusions

The problems in the rice industry necessitate the forming of freight transport management schemes. The current work of this study has contributed to the initial understanding of freight transport management decision making in the context of a specific industry and anticipated impacts. The preliminary results show that traffic management measures can be employed to improve the efficiency of logistics and production processes in the rice industry. Particularly, some key measures should be addressed within this sector, including promotion of IWT; relocation/formation of rice warehouses and distribution centres, and road freight transport management measures. This study could be considered as the first step to a decision support system for freight transport management measures focusing on the rice industry in Vietnam. Especially in developing countries such as Vietnam, improved understanding of the influences of public decisions on rice production and logistics systems can contribute to a sustainable development

In the next step, a survey would be conducted to examine impacts of the proposed measures. Besides, an investigation should be conducted to examine the role of IWT in facilitating mobility and accessibility to goods and services and adapting to the climate change.
5. References

VFA. Vietnam Food Association.


Wagener, N. The German logistics experience with freight village - it is appropriate for Ukraine? Presented at the the International conference Kiev Investment and Innovations in Logistics Infrastructure of Ukraine, Kiev, Ukraine, 2008.


EVALUATION FOR URBAN FREIGHT TRANSPORT (UFT) PROJECTS

Tatiana Graindorge¹, Dominique Breuil ² Lobna Haouari³ et Fouad Riane⁴

Abstract

The aim of this paper is to optimize the adaptation of best practices in the field of Urban Freight Transport (UFT). This was possible based on the results obtained by engineering school, EIGSI La Rochelle, in several European projects (eg CIVITAS program, TRAILBLAZER) and French projects(CGOODS, COLIS URBAINS, PRODIGE) and experience learned from organizations and associations dealing with this subject.

During these projects, EIGSI has participated firstly to develop an approach that allows building DSPs (Delivery & Service Plans) at the municipality level and secondly to evaluate the impacts and the transferability to other similar cities. DSPs describe coherent and holistic sets of actions intending to optimise Urban Freight for one or several organisation. They are materialised by key strategy documents outlining how a public or private sector organisation deals with its need to generate freight transport efficiently, safely and in a sustainable way. The actions included in DSP can affect the distribution itself, the maintenance of the fleet, the supply of goods, the interoperability of information systems, etc.

The developed approach has been tested and validated in several projects which have included different European cities' contexts like La Rochelle, Sutton, Preston, Borlange, etc.

This paper describes the evaluation framework applied in the cities partners of the TRAILBLAZER project in order to determine the parameters most appropriate for impact evaluation of DSP actions in the context of emerging countries, especially its use in the context of two Moroccan cities.

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1. Introduction

The situation today in most of the cities is characterized by the growing awareness of the troubles caused by urban freight transport (UFT). The conflict between the increase of the goods flows and limitations of the urban environment has resulted in significant problems associated with UFT. These include traffic congestion, local air pollution, greenhouse gas (GHG) emissions, noise disturbance, and safety.

Several projects in Europe (Trailblazer, CityMove, CityLog, Bestufs1&2, Mosca, Fleat, Civitas initiative, etc) and elsewhere have pointed out key urban freight transport problems and have experimented various solutions. Achievements were more or less successful but experience and knowledge on bad/good practices are being constructed from all the lessons taught. Among the successful solutions, Delivery and Servicing Plans (DSPs) proved to provide a good framework for implementing a set of complementary UFT improvement's measures.

The objective of the TRAILBLAZER project (TRansport And Innovation Logistics By Local Authorities with a Zest for Efficiency and Realisation, www.trailblazer.eu) was to transfer knowledge and experience on city logistics from the group of experienced organisations (Trailblazers) to the Pathfinders, a group of 4 less experienced authorities. To achieve this goal, several actions (measures) were defined by pathfinder cities, encompassed in local DSPs. These DSPs have been implemented and the process was analysed through evaluation procedures developed at local level according to a general framework.

1.1. Concept of DSP

DSPs describe coherent and holistic sets of actions intending to optimise Urban Freight for one or several organisation(s). They are materialised by key strategy documents outlining how a public or private sector organisation deals with its need to generate freight transport efficiently, safely and in a sustainable way (Trailblazer, 2013). DSPs are designed to cut CO₂ emissions, congestion, collisions and overall freight costs by reducing delivery and collection journeys an ensuring use of safe and loading facilities (Brown, 2012).

The potential measures contained in a DSP can be classified in two categories:
- The measures related to procurement concerning the number of suppliers, use of local suppliers, consolidating suppliers and centralised online ordering system;
- The measures relating to operational efficiency concerning the management of deliveries (online delivery system, out of hour’s deliveries and servicing), road trip efficiency and waste management.
These measures involve several stakeholders and address multiple beneficiaries, public and private institutions. Organisations can work together with their suppliers and sub-contractors to secure operational benefits through effective management of deliveries and servicing. The success of DSPs lies on the coherence between several actions designed and implemented according to an homogeneous framework based on the integration of UFT in city transport strategy.

DSPs implementation follows a standard process, from the definition of the measures based on the analysis of the situation and benchmark of possible improvements to the elaboration of planning and definition and resources then the set up of improvements and their adaptation according to the remarks, evolutions of the stakeholders. This implementation must contain an evaluation process which helps to measure the real impact of the actions and to determine the required adaptations.

1.2. Examples of DSP implementation

Different successful implemented DSP measures can be identified in European cities: Sutton (United Kingdom) - Implementation of a DSP for the London Borough of Sutton; Borlänge (Sweden) - Consolidation of deliveries to four Swedish municipalities with a new logistic model for the transportation of food; Bordeaux (France) – An urban consolidation Centre just outside of Bordeaux city centre, etc…According to the results and experiences of different cities, a well-managed methodology including several key factors must be considered to achieve successful implementation of city logistics projects.

In the context of TRAILBLAZER project, the four Pathfinders cities : Eskilstuna (Sweden), Växjö (Sweden), Vercelli (Italy) and Zagreb (Croatia) have defined and implemented their DSPs. The main objective of TRAILBLAZER was to achieve a 10% reduction in energy used and reduce transport related emissions in urban freight transport.

The DSP actions were implemented in areas of different scales: in historical city centre, in a discrete geographical area of mixed use i.e. an area-wide DSP. The area chosen may also have specific issues affecting freight, delivery and servicing activity e.g. preserving the fabric of a historic city centre, poor air quality, modal conflicts e.g. trams, cycle lanes etc. An area-wide DSP will have greater complexity than smaller scale DSPs, which reflect the defining characteristics of the location.

The Municipality of Eskilstuna was seeking to implement a DSP focused on the deliveries of food to the municipal kitchens, as part of a reorganisation of their procurement process. The purpose of this project was to highlight the costs of goods and services from suppliers to end customer, and try new solutions / requirements for the organization of transport.
The Municipality of Växjö had implemented a consolidation centre for deliveries to its Social Care, Education and other municipality activities. This consolidation centre had decoupled the costs of “last mile” transport of goods from the procurement and transport to the consolidation centre. The responsibility for the transport of goods from the centre to the final destination now belongs to the municipality. To simplify the delivery planning, the municipality has purchased a web-based support system which provides information to the consolidation centre when an order is placed with a supplier.

The Municipality of Vercelli wanted to reduce the environmental impact of freight traffic through the implementation of different measures in the city and especially in the historical city centre. The measures have affected the access in Limited Traffic Zone, time and parking restrictions for delivery bays. Their ultimate aim was to implement an Urban Consolidation Centre to deliver and collect goods in the historic centre, using low emission vehicles.

The DSP in the Municipality of Zagreb covered an area along the main access road to the city centre of approximately 1.8 km. This area hosted a mix of retail and offices activities, with around 326 business units. The street was a mixture of one-way and two-way traffic. To further complicate freight delivery and servicing activities there were tram lines beside each carriageway. The DSP actions in Zagreb had included the traffic management in the target area.

2. Evaluation

Evaluation is defined as a “systematic and objective assessment of an on-going completed project, programme or policy, its design implementation and results” (OCDE, 2010). Evaluation is an essential tool in decision-making as it makes possible to measure, compare and identify the impacts of a specific project (Graindorge, 2012).

Evaluation of transport projects is usually split in two aspects:

- The “impact evaluation” includes the evaluation of a wide range of technical, social, economic and other impacts of the actions undertaken by the partners.
- The “process evaluation” concerns the evaluation of the processes of planning and implementation including the roles of information, communication and participation. These aims of the process evaluation are to identify the forces and weaknesses, the barriers and facilitators which have been encountered during the planning and the implementation of the actions.

In many mobility projects, evaluation processes encountered several difficulties due to various factors like evaluation culture in the municipalities, availability and quality of data or amount of resources allocated to these processes;
Evaluation process for UFT projects faces specific challenges coming from the variety of stakeholders with contradictory objectives, the confidentiality of some data for private companies, the diversity of external influences which may affect the analysis; the heterogeneousness of practices according to the nature of the goods, the city's topology, economy and/or culture. Currently, there is no single, established evaluation method for UFT projects that easily supports robust, transparent and rigorous process although the trends are towards harmonization of those methods.

In TRAILBLAZER, both aspects of the evaluation, impact and process, were built in a common framework approach to ensure a consistent quality of cross-site outputs and to overcome the expected difficulties.

2.1 Framework for impact evaluation

The evaluation framework is developed from the objectives which points out the key impacts that can be associated and the more specific indicators that can be used to assess achievement. A clear framework, agreed among the key stakeholders at the end of the planning stage of the project, is essential in order to carry out monitoring and evaluation systematically.

The evaluation framework includes three elements:

- Indicators to evaluate and compare,
- Data source,
- Assessment methods.

The evaluation framework establishes clear procedures for baseline, business-as-usual and ex-post evaluation.

"Baseline" is the situation at the beginning of the implementation of the measure. All the information collected from this evaluation can be used to design and to fix the objectives of the new project.

Business-as-usual (BAU) scenario is the scenario without measure implementation. Possible ways to estimate the „business-as-usual” situation include forecasting from historical data, or monitoring a parallel site with the same characteristics without applying the project measures to it. In transport projects, this latter scenario is often very expensive and not always very precise or appropriate.

The ex-post or ‘after’ evaluation provides a final set of measurements for evaluation, which will include comparisons with all the before and business-as-usual measurements and will allow interpretation of the results.
2.1.1 Evaluation indicators

Indicators represent a situation or a time evolution relating to a particular concern. They can be quantitative or qualitative and can measure in absolute or relative terms. The definition of indicators needs to take into account three basic requirements (Dziekan, 2013):

- They must clearly reflect the performance or impact of the measure.
- They must match the objectives.
- They are capable of reliable assessment using the experimental tools and measurements choose methods.

Table 1 gives some examples of the evaluating indicators used in TRAILBLAZER (Table 1).

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Evaluation Area</th>
<th>Impacts</th>
<th>Indicator's name</th>
<th>Indicator's description</th>
<th>Data/Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improving the delivery of goods</td>
<td>Transport</td>
<td>Freight traffic</td>
<td>Goods vehicle movements</td>
<td>Total number of vehicle/day in target area</td>
<td>Quantitative/number</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vehicules</td>
<td>Type of vehicles</td>
<td>Number of different categories of vehicles</td>
<td>Quantitative/number</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kilometres</td>
<td>Kilometres per delivery</td>
<td>Average distance traveled per delivery</td>
<td>Quantitative/Km</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total kilometres</td>
<td>Total distance traveled in demo area</td>
<td>Quantitative/Km</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Running time</td>
<td>Total running time in demo area</td>
<td>Quantitative/Hour</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Empty running</td>
<td>The percentage of total vehicle-kilometres which are run empty</td>
<td>Quantitative % of km,</td>
</tr>
<tr>
<td>Load</td>
<td>Delivered tonnage daily</td>
<td>Delivered tonnage daily</td>
<td>Quantitative/tonnes</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Number of stops</td>
<td>Number of stops during the delivery round</td>
<td>Quantitative/number</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Delivery frequency</td>
<td>Number of deliveries/week</td>
<td>Quantitative/number</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Load factor</td>
<td>The ratio of the actual average load to total vehicle freight capacity</td>
<td>Quantitative %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduction in fuel used</td>
<td>Energy</td>
<td>Fuel consumption</td>
<td>Total litres of fuel consumed</td>
<td>Quantitative/liters</td>
<td></td>
</tr>
<tr>
<td>Reduction in greenhouse gas emissions</td>
<td>Environment</td>
<td>Emissions</td>
<td>CO₂ emissions</td>
<td>Total tonnes of CO₂/year</td>
<td>Quantitative/tonnes</td>
</tr>
<tr>
<td>Improved parking and accessibility regulation</td>
<td>Parking service</td>
<td>Parking in Limited Traffic Zone</td>
<td>Parking spaces</td>
<td>Number of parking spaces</td>
<td>Quantitative/number</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vehicle driving &amp; loading/unloading facility</td>
<td>Driver expectations</td>
<td>Qualitative/number</td>
<td></td>
</tr>
<tr>
<td>Accessibility</td>
<td>Accessibility in Limited Traffic Zone</td>
<td>Permissons</td>
<td>Number of permissons per year</td>
<td>Quantitative/number</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Exceptions</td>
<td>Number of space-time exceptions per year</td>
<td>Quantitative/number</td>
<td></td>
</tr>
<tr>
<td>Increase the satisfaction of citizens</td>
<td>Acceptance</td>
<td>Awareness</td>
<td>Acceptance level</td>
<td>Attitude of current acceptance with the changes induced by the improvements</td>
<td>Qualitative/number</td>
</tr>
</tbody>
</table>
For each city, indicators are determined according to the general strategy and objectives and to the specificity of the action. The most important is to be able to compare the “before”, “business as usual” and “after” status of the indicators.

2.1.2 Data source

In UFT projects, the data may be collected from many sources like:
- Field collected;
- Databases: statistics (offices, Europe, national, local…), decision aid records (policy makers, businesses, research, consultant…);
- Documents (media, reports, cases studies, traffic studies etc.);
- Experiments (simulation);
- Discussions with representatives during workshops.

The data collected by evaluators themselves represent primary data and statistic data, collected by others, are secondary data (Dziekan, 2013).

There is a large variety of methods for collecting UFT primary data: observation, surveys and interviews: with freight transport company managers, with establishment managers (consignees/ shippers), with drivers, using on-board new technology (roadside camera data, satellite tracking, radio frequency identification (RFID) etc.).

2.1.3 Assessment methods

There is a wide range of different evaluation methods, with different traditions and preferences to be found among the European Member States. Assessment approaches of UFT projects or policies are classified according their approach and evaluation criteria.

Approach of evaluation:
- Survey based approach (Anderson, 2005);
- Simulation based approach: Systems dynamics is a simulation modelling approach for predicting the behaviour of complex systems;
- Intelligent agents model (Boussier, 2011; Teo, 2012);
- Meta-heuristic based approach;

Survey based approach is used in the most of the practical application of UFT projects, others relying on theoretical models.

To evaluate the indicators of the Table 1, it is necessary to use three types of primary data sources: commercial establishment, drivers and freight transport operators.
Commercial, Offices Establishment survey: to collect data about total goods vehicle trips to/from particular establishments, and variation by time, day and month. This survey can also be used to capture data about type of goods delivered/collected; quantity of deliveries; quality of deliveries (damage and delay); time taken to load/unload; and frequencies. This survey can be conducted by face-to-face, telephone or self-completion.

Freight operator survey: to collect data about the pattern of the companies’ goods vehicle activities in the urban area: total tonnes transported, total distance travel, number of vehicles. Allows opportunity to obtain data about the entire fleet rather than a single vehicle or round as in vehicle trip diary.

Driver survey: to collect data about the driver’s overall trip pattern, information about the loading/unloading/servicing activity in the street including time taken, loading/parking locations, number of stops. This survey is usually conducted by face-to-face at establishments receiving collections/deliveries, with driver intercepted after carrying out before they drive away.

Evaluation criteria
- Monetary assessment ((Haezendonck, 2007): Cost-benefit analysis (CBA), Cost effectiveness analysis (CEA), Economic-effects analysis (EEA);
- Multi-criteria assessment (MCA) (Macharis, 2012): provides a framework to evaluate different transport options with several quantitative and qualitative criteria and can be used when some impacts cannot be converted to a monetary basis; MCA is a well acknowledged technique for the assessment of sustainability at neighbourhood level, CBA is mainly used for infrastructure projects (where public expenses are expected), and policies (Beria, 2012).
- Qualitative Assessment (HEATCO Project, 2006): The effects are classified into one or several ranked categories (ordinal scale) based on well-defined standard criteria for each of the categories;
- Quantitative Measurements: (HEATCO Project, 2006): The effects are estimated in physical units or numbers (cardinal scale), but in contrast to the multi-criteria analysis (MCA) no specific weights are assigned to allow an aggregation of the effects to a single criterion.

2.2 Approach to measuring the energy efficiency and emissions

The specific and strategic objectives of TRAILBLAZER were to contribute to the EU 2020 targets on energy efficiency and renewable energy sources. The targets within the project duration concerned the reduction of greenhouse gas emissions and primary energy saving.

According to those targets, two major indicators were taken in consideration in this project: energy consumption and CO₂ emission.
McKinnon (McKinnon, 2009) makes a distinction between two approaches to measuring CO$_2$ emissions: input-based measures, output-based measures.

- **Input-based measures**: these are derived from estimates of the fuel / energy purchased by / supplied to companies in particular sectors. These are essentially ‘top-down’ measures.
- **Output-based measures**: these are derived from estimates of the actual amount of work done and the energy consumed per unit of output. The ‘output’ of freight transport operations is generally measured by tonne-kms and energy consumption by litres of fuel or kilowatt-hours of electricity used per tonne-km.

Input-based estimates do not accurately measure CO$_2$ emissions from freight transport. For this reason, the output-based measures were used for TRAILBLAZER.

The computation for emissions and energy consumption was realised according to the following rules.

### 2.2.1 GHG Emissions calculation

For each particular fuel type, emissions can be calculated using table 2 (emissions from quantity of fuel used), table 3 (emissions according to distance travelled for vans and light commercial vehicles) and table 4 (emissions from electricity used).

<table>
<thead>
<tr>
<th>Fuel used</th>
<th>Total units used</th>
<th>kg CO$_2$ eg per unit</th>
<th>Total kg CO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Petrol</td>
<td>litres</td>
<td>x 2.3</td>
<td></td>
</tr>
<tr>
<td>Diesel</td>
<td>litres</td>
<td>x 2.63</td>
<td></td>
</tr>
<tr>
<td>Natural Gas</td>
<td>kg</td>
<td>x 2.09</td>
<td></td>
</tr>
<tr>
<td>Liquid Petroleum Gas</td>
<td>litres</td>
<td>x 1.49</td>
<td></td>
</tr>
<tr>
<td>Heavy fuel oil (HFO)</td>
<td>litres</td>
<td>x 3.177</td>
<td></td>
</tr>
</tbody>
</table>

**TOTAL** (1)  
Sources: Defra 2010  
Notes: kgCO2eq - Kg CO2 equivalent

<table>
<thead>
<tr>
<th>Type of van</th>
<th>Total km travelled</th>
<th>Conversion factor</th>
<th>Total kg CO2 per km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Petrol (average) up to 3.5 t</td>
<td>x</td>
<td>0.24 (1)</td>
<td></td>
</tr>
<tr>
<td>Diesel (average) up to 3.5t</td>
<td>x</td>
<td>0.25 (1)</td>
<td></td>
</tr>
</tbody>
</table>

Sources: Defra 2010  
Conversion factors for electricity are different for each country. It depends on the sources of electricity e.g. nuclear, coal, water etc.
Table 4: Conversion factors for electricity use

<table>
<thead>
<tr>
<th>Energy equivalent conversion factor</th>
<th>Carbon equivalent</th>
<th>CO₂ equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity produced in %</td>
<td>goe/kWh</td>
<td>gCeq/kWh</td>
</tr>
<tr>
<td>in France 78%</td>
<td>223</td>
<td>23</td>
</tr>
<tr>
<td>in UK 16%</td>
<td>114</td>
<td>124</td>
</tr>
<tr>
<td>Germany 22%</td>
<td>124</td>
<td>141</td>
</tr>
<tr>
<td>Sweden 45%</td>
<td>164</td>
<td>12</td>
</tr>
<tr>
<td>Croatia 0%</td>
<td>86</td>
<td>93</td>
</tr>
<tr>
<td>Italy 0%</td>
<td>86</td>
<td>139</td>
</tr>
</tbody>
</table>

Notes:
- gCeq - Gram carbon equivalent
- kgCO₂eq - Kg CO₂ equivalent

2.2.2 Energy consumption

All energy consumption was converted into ‘grams of oil equivalent’ (goe) or tonnes of oil equivalent‘(toe) (Table 5). Grams of oil equivalent are a unit for measuring energy, and are the amount of energy that would be produced by burning one gram of crude oil. Conversion into grams of oil equivalent allows comparison of energy use between different energy sources.

Table 5: Standard conversion factor for energy

<table>
<thead>
<tr>
<th>Energy conversion factor</th>
<th>kWh</th>
<th>goe</th>
<th>Toe</th>
<th>GJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>kWh</td>
<td>1</td>
<td>85.96</td>
<td>85.96*10^6</td>
<td>0.0036</td>
</tr>
<tr>
<td>goe</td>
<td>11630*10^6</td>
<td>1</td>
<td>10^6</td>
<td>41.868*10^6</td>
</tr>
<tr>
<td>toe</td>
<td>11630</td>
<td>10^6</td>
<td>1</td>
<td>41.868</td>
</tr>
<tr>
<td>GJ</td>
<td>277.8</td>
<td>0.02388*10^6</td>
<td>0.02388</td>
<td>1</td>
</tr>
</tbody>
</table>

Notes: (1) Source: Carbon Trust. Energy and carbon conversions 2009

The standard conversion factor for energy was used to calculate the energy consumption per type of fuel used. Table 6 gives an example of the conversion factor used in United Kingdom.

Table 6: UK conversion factors for energy, fuel consumption and emissions

<table>
<thead>
<tr>
<th>Energy conversion factors</th>
<th>Fuels</th>
<th>litre</th>
<th>m³</th>
<th>= kg</th>
<th>= kWh</th>
<th>MJ/litre</th>
<th>= GJ</th>
<th>= goe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel</td>
<td>1</td>
<td>0.8312</td>
<td>10.551</td>
<td>38</td>
<td>0.0380</td>
<td>907</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Petrol</td>
<td>1</td>
<td>0.7385</td>
<td>9.477</td>
<td>34.1</td>
<td>0.0341</td>
<td>815</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3. Results

Within the Trailblazer project, Vercelli had implemented and developed the first delivery system in the city centre focused on access and parking management of vans. The new system of controlled access in the project area combined with the camera control reduced the number of vehicles in the area by about 19%.

The management of the delivery bays, the creation of new ones, and the reorganization of others improve the delivery process in the target zone. The results from fuel consumption and emission calculation show the positive impacts of the DSP measures on the environment. This resulted in energy saving and reduction of pollutant emissions by about 13%.

The impacts of the Trailblazer project on food consolidation were increased in Växjö by introducing the e-purchasing system which allows a better coordination of goods. The Municipality was able to decrease the number of deliveries by about 50% per week and as a result to reduce the number of kilometres travelled. Dry goods are now delivered only once a week and fresh food three to four times a week, whereas previously there were more than five deliveries each day. There is an optimised delivery plan with predetermined routes, so the units know in advance when to expect deliveries and can plan their work and resources, and also save a lot of staff time. The project has demonstrated 53% saving in fuel used to make Municipality deliveries and 87% saving of CO2 emissions. Those figures were amplified with the utilisation of green fuel and less polluting freight vehicles.

The evaluation in Zagreb has used two complementary data for the calculation of fuel consumption and CO2 emissions: observation data for a global picture of the freight traffic and questionnaire distributed to the principal actors of the freight activities. From the collected data, it was possible to demonstrate 30% improvement of goods traffic flows, 3.4% reduction in the CO2 emissions and 6% reduction in the fuel used which can be attributed to the DSP implementation.

In the context of Trailblazer project, Eskilstuna conducted feasibility for the consolidation of supplies and their co-ordinated study and presented the results to senior politicians.

The coordination of supplies in Eskilstuna assumed that the amount of released CO2 will decrease by 43% simply by reducing the number of deliveries. If the requirements in contracts placed on vehicles with Euro 5 will reduce CO2 by...
another 20%. Total reducing emissions will be 54%. With the introduction of biogas, the CO₂ emissions will reduce by 50%. Globally, the estimated reduction is about 69% in CO₂ emissions with the coordinated system. With the implementation of coordination system, the number of deliveries to the kitchens will be reduced to 2 deliveries per week. The reduction in fuel used consist of shorter distances overall, smaller vehicles with lower fuel consumption and shift to non-fossil fuels (gas).

The results concerning the annual savings in primary energy and greenhouse gases of the DSP implementation by the four European cities is summarized in the below table 7. The methodology and calculations behind these figures can be found in the Final Evaluation Report (Trailblazer, 2013).

Table 7: Common performance indicators

<table>
<thead>
<tr>
<th>Common Performance indicator</th>
<th>Planned target</th>
<th>Actual achievement</th>
<th>Comment on performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary energy savings (toe/year)</td>
<td>10% fuel saving 5,130.52</td>
<td>5,130.52</td>
<td>Target achieved overall: Eskilstuna - 50% (estimated); Växjö - 51%; Vercelli - 13%; Zagreb - 6%</td>
</tr>
<tr>
<td>Reduction GHG emissions (t CO₂e/year)</td>
<td>10% 100,779.81</td>
<td>100,779.81</td>
<td>Target achieved overall: Eskilstuna-69% (estimated); Växjö - 87%; Vercelli - 13%; Zagreb – 3.4%</td>
</tr>
</tbody>
</table>

4. Lessons learned and recommendations

4.1 Lessons learned
TRAILBLAZER experimentations confirmed many issues which have already been identified in other UFT implementations. The focus on DSPs and environmental impacts brought in some new aspects and the evaluation methodology for city logistics was comforted.

4.1.1 Environmental impacts
Undoubtedly city logistics improvements reduce GHG emissions. Evaluations in all TRAILBLAZER cities showed these impacts although they were quite different actions in the DSPs set up by the cities.
It was difficult to compare these actions and to determine the best ones for many reasons such as:
- the cities' context in general and more specifically regarding urban freight organisations as well as the types of areas in which the experimentations were conducted
- the relatively short demonstration time which did not allow to get enough data for such comparison

Although such actions are beneficial regarding environment, it remains quite difficult to forecast detailed quantified improvements and to associate reliable estimation to a specific type of action.
However, comparison of BAU (Business as usual) and actual data or even up-scaled ones, are consistent since they refer to a specific situation in a given city.

### 4.1.2 Evaluation process
Globally the difficulties in the evaluation identified in the section 2 were verified in the TRAILBLAZER project. Although evaluation teams prepared mitigation actions to overcome such problems, they had to face and to adapt to each site adequate response to the city context and its evaluation approach in.

- developing awareness and training of local actors
- convincing stakeholders, particularly private companies to share data
- optimising the resource and methodology allocated to evaluation tasks, especially for data collection

In the context of Trailblazer project, evaluation has been conducted differently in the four sites according to local context, experience and availability of data.

Växjö has a dedicated department for the evaluation of environmental impacts. For them the evaluation is an everyday task and their comments and experiences were very useful for the evaluation. Data collection was easy in Växjö where a specific contract was signed with freight operators. The data about the fuel used, kilometres travelled in the demonstration zone and tonnes transported has been sent to the local authorities monthly.

In Zagreb, the collaboration between the city of Zagreb and University allowed the involvement of the groups of students for the survey data and for collection of the observed traffic data in target area with less financial means. The observation data was useful for the project global picture of the measure.

The questionnaires completed face to face with the drivers and freight operators were more qualitative that those sent by e-mail (e.g. Vercelli and Zagreb).

In some cities, like Eskilstuna, evaluation took more time than forecasted because strategic approach developed in this city involved a large number of stakeholders with different interests. In the other cities, the learning process contributes to increase the participation of actors in the collection of data. In Zagreb the number of answers to the questionnaires for “after evaluation”, was 18% higher than in “before evaluation” for the same sample. In Municipality of Vercelli the learning process contributes to create a public group which participated to the identification and implementation of the useful measures for the city in order to reduce traffic.

### 4.2 Recommendations for transferability
By essence, TRAILBLAZER was a transferability project between some experienced cities and the 4 pathfinders' cities. Concerning this aspect, the findings may be synthetised along 5 themes:
4.2.1 Managerial position
For UFT improvements, political involvement must be different from the one set up for passengers transport. Although there are quite diverse organisations among the countries for passengers transport, city logistics require similar positioning from Local authorities or, at least a common basis for the principles of the organisation and cooperation with the stakeholders. Up to now, urban freight has been transported by private organisations in all cities, then similar methodologies, like DSPs, may be conducted in all cities; differences may happen from the sizes, the culture of cities but political position may be determined accordingly the various examples which have been illustrated in several cities.

4.2.2 Monitoring
Monitoring is essential for the management of such complex system as is city logistics and designed according to the political positioning. Evaluation is one part of this process which needs to be tuned to the local context. This adaptation is linked to the precision of the data which can be collected from the ground. This must be regarded as a continuous improvement process. Generally, at the beginning only basic data can be gathered on the flows, the behaviour of drivers or retailers and so on. Then an evolutive policy must be developed to accompany the development of solutions based on a larger number of collected data.

For instance basic indicators related to tonnes transported, total distance travelled and fuels used are relevant to estimate the GHG emissions from freight activities. According to the availability of the data, the GHG emissions might be analysed at different levels of precision:
- First level using data about the fuel used.
- Second level using data about distance travel and vehicles’ efficiency (e.g. litters/100km)
- Third level showing data on distance travelled and vehicle loading.

If primary data, collected at local level is not available, it is possible to use the statistic from national data, secondary data. The level of precision in this context is low, but this information can be useful for local authorities to start a continuous improvement cycle on this topics.

4.2.3 Economy
As the last part of many supply chains, city logistics is strongly connected to economy and must bring some profitability. This is sometimes difficult to achieve or even contradictory with cities strategies on integrated transport.
This is the reason why, among other impacts, environmental ones need to be taken into account. Evaluations like in TRAILBLAZER need to be completed with a costs-benefits analysis. This analysis can cover different perspectives: benefice and cost for society, financial viability for private and public operators. Such approaches bring new points of views on global economy and basis for discussions with stakeholders. New types of cooperation and sharing the costs may be determined through such holistic approach.

4.2.4 Information systems

As mentioned above, monitoring relies on the quality of data as well as of information systems.

Specific city logistics information systems must also be developed in order to facilitate the deliveries, to increase the awareness of drivers and freight operators, to optimise the flows. Software like routing systems exist, information on traffic flows is available in some cities, etc.

Considering the diversity of stakeholders; the main difficulty is the interoperability between the various software. Special attention must be paid in order to ensure the compatibility of data exchanges, the interpretation of information, the edition and transmission of data. Adequate information is the key point for sustainable success. Several levels of information might be installed, according to the resources and facilities of each stakeholders, they have to fit in a framework covering all information aspects of goods flows.

4.2.5 Deployment of solutions

Globally, the solutions for improving UFT need to be simple, clear although embedded in a larger framework in order to ensure the coherence with the mobility strategy of the city.

Strategies for the implementation of solutions are often balancing between two extremes: focusing on a small number of actions over the city or experimenting a large variety over a restricted area. Both approaches have their pro and cons and sometimes it is well advised to mix them. For instance optimising the organisation and utilisation of delivery bays can be expanded over the whole city although access control for deliveries or even UCC services can be set up for specific areas at the same time in the same city.

Restricted areas should be chosen for two purposes; either they are very specific (nature of flows, access,…) or they are representative of other parts of the city and can be considered as test zones for further upscaling. It is easier to experiment brand new actions in restricted areas where stakeholders can be well informed and play their participating roles.

5. Conclusions and perspectives

Many cities in emerging countries are facing new challenges for the integration of mobility resources as a keystone for strategic development. This is a real opportunity to encompass city logistics in such approach although it might appear as less
important at first glance. However, the share of freight transport in several bad effects in city life (congestion, environment, safety...) must be taken into account and new practices set up at the same time as passengers transport improvements. Among the impacts, it is quite important to consider that the majority of city logistics operators are professional; making them change their behavior towards city flows and driving practices will directly influence (and train) all users of mobility facilities, and particularly streets, parking areas, etc.

It is also important to keep accessibility of goods and merchandises in the city centers to citizens. They represent a strong element of the city centers life which brings liveliness, security and economic development in the heart or main social areas of a city.

As mentioned above, deployment of new comportments should be progressive, beginning with basic or fundamental actions like waste collecting or respect of parking or access control regulations.

The cities in Morocco, like the European cities are confronted with rapid urban growth, most often combined with expanding urbanization and high level of congestion, which is source of pollution.

In most Moroccan cities, there is a lack of effective institutions for monitoring and evaluating the impacts of the local municipality actions in urban freight transport. There’s lack of data and indicators for evaluation. For this reason, a special investigation approach on UFT has been launched in 2014 all over the country and more specifically in Casablanca. Like in many countries, freight flows grew quite empirically in cities according to the "mobility culture" and adding to the well known difficulties of traffic flows.

Many specificities must be considered, certainly leading to tuned and progressive solutions, among which

- The large number of very small retailers, located all over the city and requiring small but frequent deliveries. The frequency is often linked to the payment modes of the purchases which cannot allow larger ones. A specific attention should be paid to touristic areas (ex medinas) which concentrate particular goods flows
- The multitude of independent drivers, owning their own small vehicles working as middlemen between retailers and lorry drivers bringing goods in cities
- The lack of control on traffic regulations
- The difficulties to deliver the city centers supermarkets or large shops; in many cases they do not benefit of real delivery areas inside the buildings or nearby
- The wild development of wholesale areas, sprawling randomly over streets and places

Several "technical" solutions will be designed and developed for Casablanca in the framework of the study lead by AMDL (Agence Marocaine de Développement de la
Logistique). Regarding the discussions in this paper, the success of the future solutions will require:

- The implementation of a strong evaluation team able to build an evolutionary reference book for this process, beginning with only few data available then enlarging them as the process grows
- The awareness, training of the various stakeholders, especially those belonging to small organisations who represent a very important vector for changing the behaviors for all traffic users in the city.

6. References


Breuil, D. & Blackledge, D., 2009. ImprovingMobility in Medium Size Cities Lessons from the CIVITAS-SUCCESS project, CIVITAS publication.


A SYSTEM DYNAMICS APPROACH TO UNDERSTANDING TRAFFIC LAW COMPLIANCE PROBLEM IN COMMERCIAL MOTORCYCLE OPERATION

ITS, University of Leeds

In Nigeria, commercial motorcycle operation is facing a serious challenge with respect to regulation. Policies and other interventions to improve the operation of this mode, in particular with respect to safety, have not been successful mainly due to poor enforcement. For the system to improve, behavioural changes are required from the drivers with regards to adherence to law. This paper uses system dynamics to identify factors that affect drivers’ compliance to law and how these factors can be swayed to improve compliance, and thus safety. A causal loop diagram is developed from interview data obtained from a survey conducted with stakeholders in Nigeria and formalised into a quantitative stock and flow model using secondary data obtained from multiple sources. Results from model simulation suggest that the harsh operating condition drivers are subjected to due to their “illegal” operating status contributes to their compliance difficulty. It also found that under a corrupt transport system such as in Nigeria reliance on an enforcement agency alone to improve compliance may not achieve any substantial improvement. This paper concludes by providing some policy recommendations on how compliance can be improved in commercial motorcycle operation. Improving safety enforcement would protect vulnerable road users and provide co-benefits to reduce other externalities of transport, e.g., through stricter adherence to speed limits. These recommendations might also be useful for enforcing emission regulations in future.

1.0 INTRODUCTION

Motorcycle safety is an issue the world over. It is however worse in developing countries. For example, motorcyclists’ fatality accounts for about 15% share of total traffic fatality in the United State (1). In India and China, the share of total traffic fatality for motorcycles is about 20%; this value is five times higher than their share of total trips. Thus, they are described as the “most dangerous way of getting around” in these countries (2). Similarly, they were described as “the most hazardous mode in Taiwan, Malaysia and Vietnam” (3).

The situation in Nigeria is not different. Motorcycle transport is responsible for one in five road traffic accident victims in the country (4) but accounts for as much as 35% fatality (5). Commercial motorcycles are always blamed for this problem (6, 7). As a result, a number of attempts have been made to combat commercial motorcycle safety problem. Unfortunately, most of these attempts have been generally unsuccessful (8, 6), so its safety problem has remained unresolved. This has led to continuous study on various aspects of motorcycle operation including the
characteristics of the drivers in general, the characteristics of drivers involved in accidents, and even factors that pre-dispose drivers to accident. But how these characteristics emerge and what their dynamic pattern is has not been as well researched. So it has been difficult to successfully intervene in the factors that pre-dispose the drivers. This paper provides another perspective for understanding possible reasons for this safety problem by exploring the dynamics of the operation of this mode. Factors and processes influencing commercial motorcycle safety problem and their interactions are approached from a systems perspective. This means identifying processes and interactions that lead to the problem. These interactions and processes are modelled through the development of a system dynamics model. The work is part of a broader PhD research project and what is emphasised in the following sections is a portion of the model – driver characteristics sub-model. The results from this sub-model show that simply removing the causal factors for the system problems is not enough to restore the system.

The following section provides a basis for addressing the behaviour of drivers as an important component of safety improvement exercise. This is followed by a brief introduction to system dynamics in section 3. Section 4 presents the model while section 5 discusses the result of policy tests.

2.0 ROAD SAFETY AND THE HUMAN FACTOR

The three broad factors of accident causation are the human, road environment, and the vehicle. Of all these three, human factor is known to be the most significant contributor to accident causation (9, 10, 11). Specifically, Davey et al (9) noted that the link between, for example, aggressive driving violations and increased risk of crashes has been growing of late. This has, however, been found in some developing countries much earlier (12). To deal with this human factor, several studies are being conducted to identify what constitute human factor and how its negative effect can be reduced in the driving task. McKenna, (13) identified some earlier approaches including accident proneness, biorhythm, differential accident involvement, etc., many of which have failed to provide reliable or useful information about the human factor causation. West et al., (11) identified two other more recent approaches to dealing with human error: studying of accident report to determine causation; and evaluation of driver “performance” to find out features which may be risky in certain circumstances. This second approach is reflected in the concept of driving skills and driving style (driver performance and behaviour respectively) as the two main components of human factor in road safety (10). The basis for this is the expectation that it should be possible to improve understanding about human causes of accidents by investigating the variations in driver performance and behaviour and judging what may be related to accident rates (11). Ozkan et al. noted that driving style is influenced by motives, attitudes and personality traits while driving skills are related to information processing and motor skills: skills concerns the ability the driver has to control the car; style reflects the habitual modes of operating the car on the road.
The variation in these characteristics between drivers has therefore become an important study object.

2.1 Driver Behaviour

The study of individual difference in accident involvement assumes that different degrees of accident involvement are in part a product of differences in driving style or driving skills as opposed to chance factors (11). But both style and skills are empirically related to each other and interact together to influence crash risk. While it is not clear the extent to which accident liability results from defects in skill or style or some interaction between them, earlier studies focused on improving drivers’ performance with little or no attention given to style. But as skills models of drivers’ performance were not effective (14), findings led to a view that driving style may be more important than skills for an average driver (11). This led to a switch to more concentration in driving style (driver behaviour) rather than skills (driver performance). Driver behaviour which reflects driving habit is now in use to estimate the amount of risk a driver accommodates as he uses the roadway.

The interest of the current study is to understand the motivations for the pattern of drivers’ behaviour in commercial motorcycle operation and to identify what might be influenced to improve this behavioural pattern, as well as explore how such intervention would perform. In this paper, the use of a system dynamics model is presented as a method to understand commercial motorcycle driver behaviour and determine what factors might be influenced to reduce deviant driving in the operation of commercial motorcycles. The next section provides some information about system dynamics and its use. This is followed by the development of a system dynamics model in section 3. Section 4 discussed the result of the model while section 5 wraps up with a brief summary.

3.0 SYSTEM DYNAMICS METHOD AS AN ALTERNATIVE TOOL

System dynamics (SD) is a computer based modelling approach for analysing and solving complex and dynamic problems. SD is an approach based on system theory and extends cause-and-effect relationships to consider possible feedback effects. The problems addressed by SD are based on the premise that the structure of a system generates its behaviour (17). A system is a structure that maintains its existence and functions as a whole through interaction of its components. In this way, a model based on SD organises information by linking the components of the system with one another, and linking the past to the present to show how the present conditions arose. SD is also a useful method in exploring possible scenarios to solve complex real world problems, especially those that involve human behaviour.

The choice of system dynamics method in this research is based on the principle of behavioural adaptation which shows that driver behaviour is in a dynamic state and is
influenced by several factors, all of which interact in a complex manner over time. SD capability to deal with this type of problem is demonstrated in its use in behavioural study in many fields and some of these include (18 and 19).

4.0 SD MODEL DEVELOPMENT

The model described in this section considers the pressures that mobilises commercial motorcycle drivers to engage in deviant behaviours. First, the structure of the interacting factors generating the pressure is described. This is followed by the model development.

Before presenting the model it is necessary to clarify the adopted approach. The formulation and the implementation of the model were borne out of pre-modelling engagement with relevant stakeholders in the commercial motorcycle operation in Nigeria. These stakeholders provided the basic information from which the conceptualisation of the system and the formalisation of the model were developed. There was, however no reliable data. Due to the lack of solid data, the calibration of the model was focused on dynamic patterns of observed trends described by the stakeholders. Due to these limitations, the resulting model should be seen as a tool for learning by exploring possible futures by scenario analysis, instead of a solidly calibrated model to predict the implications of certain policies. In this section, driver means a commercial motorcycle driver while trade refers to the commercial motorcycle trade.

4.1 Model Structure and Characteristics

Information obtained from the stakeholders was coded and used to generate a causal network (not included in paper). This network is a summary of the operation of commercial motorcycle as understood by the stakeholders. A reflection upon this network identified the following concepts, amidst others, about the system:

1. The trade is lucrative and so more and more people are joining as drivers; but this rapid growth is causing increasing competition in the trade
2. Expensive motorcycle acquisition options make joining the trade easy but generates a repayment pressure; this pressure influences drivers’ behaviour

The causal network indicated that drivers’ population growth is supported by the awareness that drivers perceive the trade as lucrative. There is the indication that individuals with no means of livelihood can join the trade and thrive. Also drivers make above the national minimum wage from the trade and this is confirmed in the literature (20, 21). In addition, unlike most other informal trades, commercial motorcycle trade does not require long apprenticeship or training. This is the reason why people from various other trades switch job to commercial motorcycle trade on full time or part time basis.
Furthermore, it also emerged that the availability of motorcycle hire purchase and motorcycle rent options for prospective drivers make joining the trade a lot easier for many who cannot afford the cost of a motorcycle (22). These options are relatively expensive. Nevertheless people take them based on the awareness that commercial motorcycle trade is lucrative and drivers actually become owners after a relatively short time of about a year. This structure thus shows that increase in the number of motorcycles on hire purchase and rent is an important influencing factor in the determination of the number of commercial motorcycle drivers.

But this increasing number of drivers results in competition for picking passengers which affects drivers’ income. Malstein’s (7) study supported this effect of growing population when he found that drivers were willing to pick passengers for lesser amount than they would have otherwise taken due to rising competition. This has an implication on how drivers work. For example, to make a desired target amount, drivers might have to work more than they would otherwise do. Arosanyin et al. (23) found that drivers’ average working period was as high as 13 hours a day (with half of drivers on expensive repayment options – motorcycle rent).

In addition, drivers who join the trade through these expensive routes (motorcycle hire purchase and motorcycle rent) need to make payments for the cost of the motorcycle and raise enough for their livelihood. The stakeholders all agreed that this is another reason why some drivers work more and are more pre-occupied with what they want to make (when compared with others who own their motorcycles). Since more work is done to earn more money, drivers are pushed to work more (thereby increasing their average daily working time) in other to realise a desired target. This push, termed earning pressure, results from the desire to meet up with a hypothetical target income set by drivers as well as the increasing competition for passengers. This pressure is a major motivation influencing driver aberrant behaviour in the trade. Unfortunately, the current system of enforcement is not able to match the problem. Notwithstanding, as drivers reach their desired target income, the perception that commercial motorcycle trade is lucrative is maintained – all at the cost of excessive work and high risk behaviour. So the population of drivers keep increasing, howbeit, under intensely increasing earning pressure. This description is shown using a causal loop diagram in the figure below.
4.2 Model Description

The description in section 4.1 is summarised in figure 1 above. Four feedback loops are identified to describe the system interaction. These interactions are developed into mathematical equations and presented in this section. However, a few assumptions are made. First drivers are categorised into three groups based on their driving experience, earning capacity and target income. The first group are new drivers who are less than a year in the trade. Many drivers in this group join the trade through expensive motorcycle acquisition means and are under pressure to pay back within a short time. Yet they have less capacity to earn than the experienced drivers. The literature supports this, showing that experienced drivers earn more than new drivers (20, 21). The second group are those who have just graduated from the process of learning the trade; this group does not have any repayment to make. But they have become used to working under pressure and set high target income. This second group have an average experience of four years in the system. The third group are the more experienced and relaxed drivers who work rather smartly than under pressure. The sum of the three groups of drivers makes the total drivers. These three groups are identified for the purpose of generating a representative driver which is an average for all drivers. Thus, aside these three distinctions, all other
characteristics in the model are that of the average of all the drivers rather than treating each group differently.

The first equation is for the growing number of drivers and is given by:

$$ND_t = (1 - EIS_t) * (1 + EAO_t) * GR * TD_t * \left(1 - \frac{TD_t}{CC_t}\right)$$  \hspace{1cm} (1)

This is the estimated number of drivers joining the trade on a weekly basis. This is treated as a logistic function to make up for new drivers joining and leaving as well as to fit the growth pattern indicated by stakeholders. ND stands for new drivers, EIS stands for effect of income shortfall, EAO stands for the effect of alternative ownership options, GR stands for growth rate, TD stands for total drivers, and CC stands for carrying capacity. This equation shows that the number of new drivers (ND) joining the trade decreases with decreasing drivers earning relative to their target (denoted as effect of income shortfall (EIS)). It increases with increasing availability of options for acquisition of motorcycle (i.e., effect of alternative ownership options (EAO)). This parameter, EAO, also takes care of the expensive hire purchase and rent options. The growth rate is a constant chosen to fit the model to data as nearly as possible while the total driver is the sum of all stocks of the three drivers’ groups in the model. By developing this equation in this manner, it is able to account for the awareness of the trade’s high job returns. The unit is driver/Week.

Competition for passengers is treated as an effect on the total income that a driver earns. It is taken as a function of driver population’s density. Its maximum effect is however set to a third of the drivers’ population density. It is given by:

$$ECI_t = MEC * DPD_t$$  \hspace{1cm} (2)

EC is effect of competition on income, MEC is maximum effect of competition, and DPD is drivers’ population density. The value for MEC is taken as 30%. It is arbitrarily assumed that the maximum level of competition should not require more than a third of a driver’s income. Values from the literature have been found to be as much as about 20% (7).

Similarly, drivers are assumed to set a hypothetical target income which they desire to make to become satisfied in a typical day. This target income is treated in this model as that for a representative driver in the system (an average of all drivers). It is given by:

$$TI_t = \left(\frac{(NED_t + ED_t) * DCL + (1 - SOD) * AWC_t * AD_t}{TD_t}\right)$$  \hspace{1cm} (3)

TI is target income. NED, ED and AD are the three groups of drivers in the model. NED is New Entrant Drivers, ED Established Driver, and AD is Ambivalent Drivers. DCL is driver’s capacity less repayments, SOD is self-owned drivers’ repayment factor, AWC is average work capacity, and TD is total drivers. Target income (TI) is the average expected income a representative driver wants to make in the trade on a
typical day of the week. The new entrant drivers (NED) are those in the trade within their first year. Due to the repayment they have to make, their target is set at the minimum for all drivers, i.e. the value of DCL. The established drivers (ED) are mature drivers who have been in the trade for five years and above. The model conceptualisation shows that this group is more relaxed and don’t have high targets. Yet they have high earning capacity. Their target in this equation is also set at the minimum too (i.e., to DCL) since you are not under pressure. The driver's capacity less repayments (DCL) is the minimum capacity in the system - what is left to a driver after paying for the daily instalment cost of the motorcycle. It is therefore the average value of income of drivers less all repayments. This amount is taken as the real income that goes into the drivers’ pocket. It is also about the estimated income a prospective driver looks forward to making. The self-owned drivers’ repayment factor (SOD) is the average cost of acquiring a new motorcycle, i.e., the amount a driver saves toward replacing his motorcycle to avoid expensive acquisition options. Its value is decided based on the average life of motorcycles in use for this trade as shown in the literature. The average work capacity (AWC) is the average income if there are no repayments for the cost of motorcycles, i.e., it is the income of a driver who is not making repayments. The ambivalent drivers (AD) are those in their second to fourth year; they share the characteristics of the other two groups in the they have the same earning capacity like the established drivers (ED) but they share similar work pressure like the new entrant drivers (NED). Because of their higher working pressure, higher earning capacity and lower repayment, they set higher target income than the other two groups. This equation presents target income (TI) as the average expectation for all the driver groups. But it also shows that the ambivalent drivers (AD) group has higher target than those in the other two groups as described earlier in this section. The units is NGN/(Week*day*driver).

The model shows that the difference between target income and drivers’ real income is the shortfall that motivates drivers’ behaviour in the system. The assumption is that the pressure under which drivers work lasts long enough to get them used to it. As a result, once a driver has been subjected to pressure as a new entrant driver (NED), he carries this pressure on for years until maturity, taken in this model as about four years. The period under which this happens is the time covered in the group of ambivalent drivers (AD). This shortfall is represented by the following equation.

\[ ES_t = \int_0^t (SD_t - LE_t) \, ds \]  

ES is effect of shortfall, SD is shortfall deficit, LE is loss of effect. Though this is intended to show a pressure, it is presented in monetary value so that effect of shortfall (ES) is the monetary equivalence of the pressure a representative driver is experiencing at a time. The shortfall deficit (SD) is the difference between target income and total income that a representative driver earns. The loss of effect (LE) is used to capture the fact that this pressure diminishes over time until the driver becomes mature. The unit is NGN/(day*driver).
The pressure effect of the shortfall described above is represented by *earning pressure*. The value of this pressure is the ratio of driver’s perceived shortfall to the average capacity of the driver. The driver feels this pressure by comparing what he wants to make to what capacity he has to work. So earning pressure is given by

\[ EP_t = \left( \frac{TAE_t}{DCL_t} \right) \]  

\( EP \) is earning pressure, \( TAE \) is target additional earning, and \( DCL \) is driver's capacity less repayments. The earning pressure measures the ratio of the pressure represented by *Effect of Shortfall* (ES) to target additional earning (TAE). Target additional earning (TAE) is the value of effect of shortfall (ES) at the time the pressure is being considered. The unit of this pressure is dimensionless.

As previously mentioned, the model shows that it is this pressure that influences the behaviour of the drivers and causes high risk behaviour (aberrant behaviour) noticed amidst the drivers. This behaviour is formalised and represented by the equation:

\[ TTV_t = IT(0) + \int_0^t (TG_t - TL_t)ds; IT(0) = 0.45 \]  

TTV is *tendency to violate*, IT is initial tendency, TG is tendency gain, and TL tendency loss. *Tendency to violate* is a measure of a representative driver’s attitude towards high risk behaviour. Its measurement it formalised to range between zero and one. Model conceptualisation shows that these high risk behavioural actions are all punishable by law and similar thing was noted by Abane (12). The initial tendency (IT) is an arbitrary value given to *tendency to violate* (TTV) at the start of the simulation. It is used to show that the private motorcycle owners who initiated the trade were previously violating too since the system was not previously violation-free. Tendency gain is a measure of the effect of sanction on drivers while tendency loss is a measure of the benefit from this high risk behaviour. The relationship in this behavioural measurement follows the theory of deterrence (23, 24). The unit of *tendency to violate* is dimensionless.

Finally, the effect of enforcement operation is added to the equation by include the capacity of enforcement officers. It is this capacity that determined the probability of arrest for unlawful behaviour as well as the cost of violation such that the deterrence effect of sanction is created. Denoted by *enforcement coverage*, this effect of enforcement operation is given by the following:

\[ EC_t = ES_t' * ATM_{j,t} \]  

EC is *enforcement coverage*, ES is enforcement size, and ATM is attention to mode. *Enforcement coverage* represents the ability within the enforcement system to deal with the traffic. *Enforcement coverage* is used to measure the level of the physical presence enforcement officers create to drivers. It is a function of both the population of enforcement officers (known as enforcement size in this model) and the level of attention enforcement operation is committing to commercial motorcycle mode.
(attention to mode). Attention to mode is a measure of the concentration committed by officers to dealing with commercial motorcycle problems relative to their share in traffic.

5.0 MODEL RESULT AND DISCUSSION

5.1 Calibration and Validation of Model
As earlier noted, the challenge being addressed here is that of availability of reliable quantitative data for a rigorous quantitative analysis. Since such data is not available, two parameters described by stakeholders were used as a guide for model calibration: tendency to violate and the total number of drivers (not included due to space limitation). In addition to these a number of other validation steps were conducted as suggested by Sterman (17): the initial conceptual model was used to conduct boundary adequacy test, using respondents familiar with the mode’s operation; all model parameters have real life meanings. The dimensional consistency test was also conducted. Similarly, different integration methods and time-steps were used to test model sensitivity and to check for strange model behaviour.

5.2 Scenario Testing
This paper goes a step further here to check the effect of some policy intervention on the system described in section 4. As previously noted, two major factors contributes to the pressure within the system: expensive repayments and competition. An attempt is therefore made to check if removing these influences would change the behaviour of the drivers. In addition, an attempt is made to check what the effect of increasing sanction would be on the behaviour of the drivers. In all, these three policy measures are tested for and the result is discussed below.

5.3 Result and Discussion
The model is developed for a period of 15 years (780 weeks) and scenario testing extends this period by additional five years, making it 1040 weeks in all. The outcome of the simulation is now discussed with graphical illustrations.
What is first shown in figure 2 is baseline model result to compare the patterns of changes in three selected parameters of the system: Effect of Shortfall (in blue colour and labelled 1); Tendency to violate (red and labelled 2); and enforcement coverage (green and labelled 3). As previously described, the effect of shortfall represents the cumulative effect of working under pressure in monetary terms for each driver. This pressure translates into risk-taking behaviour and is measured by a driver’s tendency to violate. The term enforcement coverage represents the capacity of enforcement officers under the various scenarios. In relative term, the left-hand graph in figure 2 is used to describe the current situation and the likely trend over the next five years. It shows that effect of shortfall keeps rising and approaches almost 300 units (about a quarter of a driver’s income). But tendency to violate peaks and falls slightly to 0.8 as enforcement coverage increases (a measuring index of 0 to 1 is used). Enforcement coverage’s increase is steady as it rises to about 15 units (about 15% of human resources of the police traffic unit).

In the right-hand graph of figure 2, a different scenario is shown. Supposing the system characteristics were the same as in the left-hand graph but there were no expensive motorcycle acquisition options, what the system would look like is shown in figure 2 (right). Relative to figure 2 (left), the effect of shortfall delays over a long time before it starts to rise and stops at about 220 units (compared to 300 in the other graph). Tendency to violate improves and falls to about 0.2 units (compared to 0.8 in the other case) after a small rise in enforcement coverage at about week 260. Similarly, the enforcement coverage required in the system is lower at 12 units compared with 15 units in the left hand graph scenario.
work pressure, i.e., the making stringent registration requirements for drivers. This leads to more fall in the drivers' income is achieved by reducing the effect of competition to near zero, say by policy: removal of expensive repayment and securing drivers' income. Securing multiple policy measures. In this case, two measures are combined together in the policy does not change their behaviour. This may be partly due to the fact that behaviour does not change easily especially when there are no deterrence measures attached to the policy. The second graph in figure 3, the right-hand graph, tests multiple policy measures. In this case, two measures are combined together in the policy: removal of expensive repayment and securing drivers’ income. Securing drivers’ income is achieved by reducing the effect of competition to near zero, say by making stringent registration requirements for drivers. This leads to more fall in the work pressure, i.e., the effect of shortfall. But these two measures combined do not bring any significant change to tendency to violate either. These findings may not be a “common sense” without the help of a model. The use of a model to test these policies therefore helps to see what is not easily obvious.

Figure 3 shows the behaviour of the three elements for two different scenarios. In the left-hand graph of figure 3, a policy instrument to stop expensive repayment option at week 780 (after 15 years of commercial motorcycle operation) is adopted. As can be seen from the graph, this policy leads to a reduction in the effect of shortfall, meaning a fall in the pressure a driver works under. But this did not result in any significant reduction in the tendency of the driver to violate. The implication of this is that all the gain of removing this pressure is internalised by drivers such that the policy does not change their behaviour. This may be partly due to the fact that behaviour does not change easily especially when there are no deterrence measures attached to the policy. The second graph in figure 3, the right-hand graph, tests multiple policy measures. In this case, two measures are combined together in the policy: removal of expensive repayment and securing drivers’ income. Securing drivers’ income is achieved by reducing the effect of competition to near zero, say by making stringent registration requirements for drivers. This leads to more fall in the work pressure, i.e., the effect of shortfall. But these two measures combined do not bring any significant change to tendency to violate either. These findings may not be a “common sense” without the help of a model. The use of a model to test these policies therefore helps to see what is not easily obvious.

The last test conducted is the effect of improved sanction on the behaviour of drivers. This measure is shown to have the most significant impact on the behaviour of

**FIGURE 3 Policy scenarios on repayment and secure income.**

**FIGURE 4 Policy on improved sanction.**
drivers by lowering tendency to violate from about 0.8 unit to 0.6 unit. This thus reinforces similar studies on driver behaviours (e.g., 18) that show that improvement in enforcement is very important to deterring aberrant behaviour amidst drivers. In addition, the graph shows that this improvement is achieved without necessarily reducing drivers’ work pressure. Moreover, it is achieved by less enforcement coverage of about 13 units (which is less than 15 units and 16 units in the two scenarios in figure 3).

However, the challenge with many poor developing countries is how to improve the rule of law and to make sanction more effective. This cannot happen simply by increasing enforcement coverage. An alternative method of implementing sanction that is more effective than increasing the number of traffic police officers should be considered. For example, drivers’ unions are known to be very powerful in coordinating their members (25). Using them as internal guard for the drivers and offering incentives for doing well might be a better alternative to increasing the number of traffic police officers.

CONCLUSION

This paper reports an exploratory model of drivers’ behaviour using system dynamics. While the entire model could not be included due to space, the complex dynamics of interactions within the operation of commercial motorcycle has been pointed out. The scenarios tested show that some policy measures would not work, at least in the short run even when they look sensible on face value. This capability of system dynamics to conduct exploratory analysis despite limited data is noteworthy. It is therefore recommended for policy makers in developing countries, especially where there are no sufficient quantitative data.

One important pointer from this analysis is the need to improve enforcement operations. However, many developing countries have problem with corruption which make enforcement operations ineffective. Anbarci et al., (26) stressed this and noted that some countries have completely removed all officers in their enforcement agencies and replaced them. There is however no guarantee that such drastic step would work. More research will be required to assist policy makers in dealing with the problem of corruption with a view to improving traffic safety. A suggestion raised in this study is to use the drivers’ union as a guard for the drivers. How this would perform is not certain yet either.

Finally, this model is exploratory in its current form. More calibration is necessary to improve the quality of the outcome generated by the model. This can be by expert judgement, Delphi method or even through a combination of quantitative and qualitative data collection methods. This will be the future direction of the study.
REFERENCES


8. Ayodele, S. The Menace of motorcycle as a paratransit mode in Lagos metropolis, *Journal of Estate Surveying Research, Department of estate Management, Yaba College of Technology* December, 2010, pp.64-79


22. Olubomehin, O.O. The development and impact of commercial motorcycles as a means of commercial transportation in Nigeria, Research on humanities and social sciences Vol 2 No 6, 2012


MOTOTAXIS OU CLANDOS ENTRE ADAPTATION CITOYENNE ET REFUS POLITIQUE AU SEIN DE LA VILLE DE N’DJAMENA.

Hassane MAHAMAT HEMCHI¹

Résumé :

L’utilisation du transport artisanal est une pratique courante dans la plupart des villes africaines. N’Djamena fait partie de ces villes qui essaient de répondre à la demande incessante de sa population dans les transports urbains. Son taux d’accroissement démographique annuel estimé à plus de 5% pose de réels problèmes à tous les acteurs de la gestion urbaine (colloque national, 2013). Bien qu’il suscite de nombreuses critiques de la part de la population, des propriétaires des autres modes de transports (taxis et minibus), et des autorités publiques et privées, voilà près d’une décennie que le “mototaxi”, appelé clando (appellation locale) s’impose tant bien que mal, pour répondre à la demande des déplacements quotidiens à travers les différents quartiers de la ville.

Aujourd’hui, les mototaxis sont devenus comme un moyen de transport à part entière. L’objectif de cette communication est d’exposer, dans un premier temps, l’importance de ce système de transport dans le quotidien des n’djamenois, puis, de montrer les avantages et les inconvénients que génèrent cette pratique entre acceptation citoyenne et refus non-dit des autorités de la place. Enfin, se posera la question de la continuité de cette pratique dans une ville capitale qui n’a pas de transport en commun public ou privé de qualité ? Pour répondre à cela, nous nous appuyons sur des données d’enquêtes ménages de mobilité urbaine et entretiens effectués auprès de la population et les acteurs dans le cadre des travaux d’une thèse en cours.

Mots clés : N’djamena, mobilité urbaine, mototaxis, clando, transport urbain.

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INTRODUCTION :

L’usage des mototaxis dans les villes africaines est devenu une pratique courante (Diaz Olvera, 2007 ; Godard, 2008 ; Sahabana, 2011). L’acceptation de ce mode de transport dans la plupart des villes y compris certaines capitales est l’un des signes du manque ou d’insuffisance du transport en commun public/privé de qualité et surtout de l’hégémonie qu’impose le transport artisanal.

Aujourd’hui, la transformation de l’usage de motos en moyens de transport populaire - motos-taxis - date de moins d’une décennie au sein de la capitale tchadienne (2005). Pourtant, dans certains pays d’Afrique cette pratique date des années 70 (Oyesiku, 2001). N’Djamena n’est pas l’épicentre du phénomène au Tchad comme pour certaines villes-capitales d’Afrique : Lomé et Cotonou (Tublu, 2010). Les mototaxis étaient en service depuis plus d’une décennie dans certaines villes du Tchad à l’exemple de Kélo, Moundou et Pala. Mototaxi ou clandos est une appellation locale de la pratique, elle tente de répondre à la demande de la population tant bien que mal, pour une ville qui ne dispose pas de transport collectif public/privé pouvant répondre aux aspirations de la population. Sinon, ne serait-ce que des minibus et des taxis urbains appartenant à des particuliers et gérer par ces derniers en accord avec les syndicats concernés (Mahamat Hemchi, 2012). L’absence d’une compagnie publique ou privée de gestion des transports urbains a entrainé une dynamisation du transport artisanal. Néanmoins, sur le terrain, il existe deux modes de transport urbain reconnu officiellement par les autorités, qui sont les minibus de 16 à 25 places et les taxis urbains de 4 à 6 places. Le troisième qui s’impose ces dernières années n’est autre que les mototaxis face à l’attitude des autorités qui oscillent entre acceptation à défaut de solutions curatives et éradication d’une activité à risque, incontrôlable et non-conforme à l’image d’une ville capitale vitrine d’Afrique Centrale (Sahabana, 2011).

La capitale tchadienne est confrontée à des réalités très complexes et dans tous les secteurs urbains ; avec absence de stratégie de transport urbain. Bien qu’il ait été élaboré un Plan des Transports et de Circulation en 2012 (PTC), ce dernier n’arrive pas à être adapté sur le terrain. C’est dans ce contexte que l’idée de ce travail a pris origine.

Ainsi, dans un premier temps nous expliquerons l’importance et l’influence des mototaxis dans le quotidien de la population ndjamenoise, avec un aperçu sur le processus évolutif de cette pratique au sein de la ville. Dans un second temps, nous montrerons les avantages et les inconvénients socioéconomiques générés par les mototaxis entre acceptation citoyenne et refus non-dit des autorités de la place. Enfin, dans la dernière partie de ce travail, nous démontrerons quel avenir doit-on prédire à cette pratique dans une ville capitale qui vit au rythme d’un urbanisme d’un autre âge prôné par le slogan de “N’Djamena vitrine d’Afrique Centrale” ? Pour cela, nous allons nous baser sur des données d’enquêtes-ménages de mobilité urbaine et entretiens effectués sur le terrain (N’Djamena, du février à avril 2013) dans le cadre des travaux d’une thèse en cours. Ainsi de même certains travaux de recherches publiés dans ce secteur et certains documents de planification recueillis au niveau de la ville de N’Djamena.
1. L’évolution inespérée de la pratique des mototaxis à N’Djamena :

L’origine du service des mototaxis dans les villes d’Afrique date des années 70, d’abord au Nigeria et sur le reste du continent à partir des années 80 (au Niger et au Cameroun). Elle impose ses marques à partir des années 90 dans des villes capitales comme Lomé (Togo) et Cotonou (Bénin), suite à des mouvements sociopolitiques causés par des grèves générales du secteur des transports urbains dans ces villes (Diaz Olvera, alii., 2007 ; Tublu, 2010). Ainsi, cette pratique apparaît comme une activité génératrice de revenu et une préoccupation des jeunes sans emplois. Dans la capitale tchadienne, les premiers mototaxis sont apparus vers le milieu des années 2000. Elle n’assurait que le relai aux autres modes de transport urbains de la place (minibus et taxis urbains) au niveau des terminus pour acheminer les clients vers les quartiers périphériques non-accessibles par les transports urbains : à l’exemple des carrefours de Diguel, Goudji, Chagoua, Démbé, Farcha, …. Le centre-ville était épargné, les autorités interdisaient cette pratique. Même s’il est difficile de faire la différence entre les mototaxis dans l’ensemble des motos en circulation. Faute de signe évident, ils n’ont pas d’étiquette, ni de symbole illustrant que la moto en circulation est un clando. Aux yeux des autorités les clando sont ceux qui sont stationnés aux différents carrefours de la première voie de coulennement. Ainsi, il a fallu attendre 2010 pour que certains clients prennent ce mode de transport depuis leurs maisons des quartiers périphériques jusqu’au centre-ville pour ne pas vivre le calvaire d’attente des moyens ordinaires du transport urbain, de ses arrêts spontanés et de sa qualité médiocre (Mahamat Hemchi, 2012). Avec le temps, cette pratique a conquis toute la ville comme une toile d’araignée. Aujourd’hui, on peut trouver une mototax à n’importe quel endroit de la ville, même devant la présidence au niveau de la place de la nation. Cette conquête du centre-ville par les mototaxis a été en partie favorisée par les autorités à la suite des premières élections municipales qu’a connue la ville de N’Djamena en 2012. La population s’est bien adaptée à cette nouvelle pratique, moins chère que les taxis et minibus, et accessible à tout âge et en tout lieu, disponible sur toutes les voies de circulation. Et surtout, avec leur précipitation les clients arrivent à destination souhaitée en un temps record. C’est ainsi que cette pratique a imprimé ses marques dans peu de temps au niveau de la capitale tchadienne dans des conditions controversées entre tolérance et scepticisme des autorités.

Tableau 1 : Les appellations des mototaxis dans certains pays d’Afrique

<table>
<thead>
<tr>
<th>Pays</th>
<th>Appellation locale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benin</td>
<td>Zémidjan (prends-moi vite)</td>
</tr>
<tr>
<td>Cameroun</td>
<td>Bendskin (penche-toi pour mieux t’accrocher au véhicule)</td>
</tr>
<tr>
<td>Tchad</td>
<td>Clando (dérivé du clandestin, une adaptation locale du terme)</td>
</tr>
<tr>
<td>Niger</td>
<td>Kabu-kabu</td>
</tr>
<tr>
<td>Togo</td>
<td>Oléya</td>
</tr>
</tbody>
</table>

Sources diverses
1.1. Les points saillants de l’évolution des mototaxis de N’Djamena:

Il a fallu attendre 2011 pour voir la création du Syndicat National de Transport Hayine (SNTH), une initiative émanée par les conducteurs des mototaxis. Le nom du syndicat est aussi porteur de sens, mais passe inaperçu par les autorités en charge de la régulation. C’est-à-dire, le mot Hayine est dérivé de l’arabe local, hayine signifie « facile », et encore en d’autre terme le sens figuré donné à ce mot par les conducteurs voudrait dire ”moins cher“, comme ce dernier se négocie à partir de 100FCFA et 150FCFA². Ensuite, il a été créé le Syndicat National des Moto Taxis (SNMT) pour donner une certaine légitimité à cette pratique à travers tout le Tchad. Après la création de ces deux structures, le phénomène prend de l’ampleur. Le SNTH implanté dans le 7ème en dehors de la première voie de contournement (dans son territoire de prédilection) connaissait un véritable succès auprès de la population. Le SNTH récences ses membres à des centaines dès les premiers mois de sa création, face à l’évolution exponentielle de la pratique. Ils espèrent pouvoir résoudre les problèmes de transports urbains de toute la population des quartiers périphériques de N’Djamena. Ce nouveau système de transport urbain (mototaxi) se structure par la mise en place de règlement et des exigences vis-à-vis des conducteurs, auprès des usagers et surtout réclame une reconnaissance auprès de l’État. En 2012, le SNTH a estimé à plus de 11 000 mototaxis en circulation pour une population estimée à 1 150 091 habitants au sein de la ville de N’Djamena. Au sommet de son succès, le syndicat n’arrive plus à cadrer le nombre de ses adhérents et les multiples problèmes qui découlent de sa gestion. Certains particuliers font leurs propres gilets à l’image du SNTH sans se déclarer et se donnent à cette pratique. Ainsi, le SNTH et le SNMT finissent par être victimes de leur propre succès, n’arrivent plus à gérer le problème à l’échelle de toute la ville, faute de moyens matériels, humains et financiers.

Par ailleurs, après la proclamation des résultats de la première élection municipale qu’a connue la ville. Le phénomène prend une autre dimension par la création de nouveaux syndicats à travers les différents arrondissements, lorsque les nouveaux maires ont pris fonction dans ces différents arrondissements. À l’exemple du Groupement des Clandomans de la Commune du 6ème Arrondissement (GCCA), est le résultat de regroupement de certains anciens cadres du SNTH et le SNMT en janvier 2013.

En effet, après les élections municipales qu’a connues le Tchad en 2012, tous les 10 arrondissements de N’Djamena sont érigés en communes urbaines. Face à cette nouvelle situation, les différents maires tentent de normaliser la pratique de motototaxi au niveau des différentes communes respectives, pour des raisons financières. C’est dans ces conditions que chaque arrondissement a pu créer son propre syndicat de mototaxi à l’exemple du GCCA dans le 6ème arrondissement, puis, l’Association des Clandomans de la Commune de 5ème Arrondissement (ACC) dans 5ème arrondissement. Et aussi, l’Association des Motos Taxis de la Commune du 1er Arrondissement (AMTCA) dans le 1er arrondissement,… Si bien que le SNTH et le SNMT sont tous en activité, mais beaucoup plus fragilisés par la défection de

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Aujourd’hui, 1€=656FCFA
c certains de leurs membres-fondateurs. Les nouveaux syndicats créés par les différents Maires à travers les arrondissements instaurent une nouvelle politique de gestion de la pratique en structurant cette dernière, par la mise en place des règlements internes, avec des cartes d’adhésion, des taxes journalières et surtout le port de gilet obligatoire pour chaque conducteur de mototaxis au sein de la ville de N’Djamena. Aussi, sur les gilets, l’on peut lire le numéro d’adhésion, l’effigie du syndicat et la couleur choisie par le syndicat. Parfois même le nom ou numéro du carrefour où le conducteur a pour gare ou point de départ. Dans cette nouvelle logique de gestion, certains syndicats disposaient de deux sièges ; un dans la commune, bien connu par ses adhérents et l’autre dans le siège communal de l’arrondissement. Enfin, face à l’absence de ressources financières au niveau des nouvelles communes, l’attitude oscille entre tolérance et méfiance vis-à-vis de la reconnaissance voulue par les différents syndicats.

1.2. Le processus d’évolution et d’adaptation des mototaxis au sein de la ville de N’Djamena

Figure 1 : Processus d’évolution des mototaxis dans la ville de N’Djamena

Réalisation : Mahamat-Hemchi, Hassane, CNRS UMR ADESS 5185
En 2013, les mototaxis sont estimées à 22 000 au sein de la ville de N’Djamena par la police nationale et à plus 15 000 mototaxis par les services de transports de la mairie centrale. Et enfin, le ministère des infrastructures et des transports estime en moyenne annuelle l’immatriculation de plus de 15 000 motos au niveau de la ville de N’Djamena (voir Tableau 2). Les motos représentent 59% des autres moyens de transports urbains de la ville de N’Djamena. Par ailleurs, en plus des chiffres connus par les différentes institutions de la ville, il y a pas mal de mototaxis en circulation n’ayant pas de papiers et ils représentent 30% sur l’ensemble des conducteurs enquêtés, selon l’enquête ménage de mobilité urbaine. A cela s’ajoute les 18% des clandestins qui déclarent entraine de circuler avec des faux papiers au sein de la ville de N’Djamena. Il faut mentionner que certains particuliers rendent occasionnellement leurs motos personnelles comme mototaxis. Du coup, le nombre exact des mototaxis au sein de la ville de N’djamena reste et restera indéterminé. Aujourd’hui, cette pratique a été interdite par le ministère de l’intérieur, suite à un arrêté ministériel depuis mai 2013 sur les ondes de la radio et télévision nationale. Mais dans la ville, la pratique des mototaxis se fait comme d’habitude dans tous les endroits de la ville, demeurant cette fois-ci méconnaissable et dissimulée aux motos personnelles.

Tableau 2 : Immatriculation annuelle des motos au sein de la ville de N’Djamena :

<table>
<thead>
<tr>
<th>Années</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nombre de motos</td>
<td>14306</td>
<td>18054</td>
<td>17105</td>
<td>11642*</td>
</tr>
</tbody>
</table>

*Ce nombre d’immatriculation de motos s’étale sur la période du 03/01/2011 au 31/06/2011, ce qui veut dire que cet effectif n’est pas pour une année.

2. L’adaptation des mototaxis au contexte socio- économique de la ville :

La ville de N’djamena à l’instar de nombreuses villes africaines et du monde entier, la problématique du transport devient préoccupante et un défi majeur pour les autorités en charge de la gestion du secteur. L’aspect la plus préoccupante est l’augmentation des accidents en milieu urbain. Aujourd’hui, le parc immatriculé du pays en entier s’élève à 193 000 véhicules dont 59% de motos en 2011. En moyenne 15 000 nouvelles motos se font immatriculer chaque année et 9 000 nouveaux véhicules au niveau de la ville de N’djamena. Le niveau de la demande quotidienne en transport est estimé à 500 000 déplacements motorisés en 2011 (Mairie de N’Djamena, 2013). A cela s’ajoute la croissance des prix du transport dans l’ordre de 6,6% par ans. La part de la consommation moyenne en transport d’un ménage par jour est de 630FCFA selon l’INSEEED (Institut National de la Statistique, des Etudes Economiques et Démographiques du Tchad), soit une moyenne de 19 000 FCFA/mois (29 euros). Par ailleurs, la ville de N’Djamena, évolue à un taux moyen annuel de plus de 5% par an, la population actuelle (2013) est estimée à 1 207 596.

3 Source : la Direction Générale de la Brigade de la Circulation Routière (BCR).
d’habitants. N’Djamena demeure le centre urbain le plus important du pays et principal pôle d’attraction. Elle concentre presque 45% de la population urbaine (Harre, Moriconi- Ebrard, et Gazel, 2010) et 8,6% de la population totale du Tchad (Ngaressem, 2013). Cette croissance démographique s’est accompagnée par une extension spatiale considérable qui fait, qu’aujourd’hui, la ville de N’Djamena s’étale sur plus de 20 000 ha. Ainsi, la nature de la croissance urbaine - étalement urbain incontrôlé et incontrôlable - est symptomatique de cette ville marquée par une pauvreté extrême. Les capacités limitées d’interventions publiques des différents arrondissements eu-égar aux besoins croissants de la ville de N’Djamena en équipements et infrastructures de base. C’est dans cette gestion aléatoire que le système a favorisé le développement d’une offre privée majoritairement artisanale et gérée par des particuliers a pu s’imposer pour répondre à la demande croissante de la population. La motorisation individuelle est encore réservée à une minorité, le taux moyen annuel d’immatriculation des voitures personnelles est dans l’ordre 1300 véhicules sur la période de 2006 à 2010 (Mahamat Hemchi, 2012). La voiture particulière est considérée comme un luxe (Guezere, 2008). Aujourd’hui la pérennisation des différentes pratiques de transport artisanal sont des réponses issues des crises multiformes qui frappent la ville de N’Djamena et c’est dans ce contexte que la mototaxi apparaît comme une réponse à la conjonction d’une triple pénurie : de véhicules privés, d’infrastructures et de transport en commun (Diaz Olvera, ali., 2007). De même, l’émergence des mototaxis a enfin été facilitée par le vide dans les réglementations locales des transports publics. Les mototaxis se reconnaissent à travers leurs gilets de couleur différentes selon les arrondissements jusqu’au mai 2013. On y trouve facilement les mototaxis au niveau des gares routières, les marchés et certains équipements publics de fortes fréquentations comme les banques, les hôpitaux, les sièges des opérateurs téléphoniques, .... Aujourd’hui, la mototaxi est interdite de circuler en ville par les autorités, mais dans la pratique elle s’exerce de manière informelle. Ils sont aux mêmes endroits et ils pratiquent les mêmes manières, si ce n’est que le port de gilet qui a été interdit. La plupart des accidents qui se créent en ville sont attribués aux mototaxis à 94% selon les conducteurs des minibus, et à 92% selon les conducteurs de taxis urbains d’après le résultat de nos enquêtes de mobilité urbaine. Le taxi-cours au sein de la ville de N’Djamena vaut au minimum 2000FCFA ; ainsi, le taxi-cours n’est pas fonction du kilométrage à parcourir, ainsi pour la desserte de certains quartiers le conducteur peut demander plus que les 2000 FCFA fixé par les autorités, ceci est dû à la praticabilité des voies et aussi en fonction des saisons de l’année dans la ville de N’Djamena. Par contre, les prix d’usage de la mototaxi se négocient et pour la plupart des distances l’on ne dépense pas au-delà de 500FCFA, ce qui fait le ¼ du prix normal d’un taxi-cours. Cela prouve très bien les déclarations des clandomans enquêtés sur la liberté de circuler en ville à 85% selon l’enquête. Même si, les conducteurs de taxis urbains déclarent à 82% libres de circuler en ville, ces derniers, empruntent les grands axes connus (souvent les voies bitumées) et sauf à la demande de client (taxi-cours), ils quittent les trajets bien connus par la population.
2.1. Système de gestion des mototaxis au sein de la ville de N’Djamena :

Figure 2 : système de fonctionnement des mototaxis

Réalisation : Mahamat-Hemchi, Hassane, CNRS UMR ADESS 5185

Les raisons du succès de la pratique des mototaxis sont basées sur sa disponibilité, l’accessibilité de ses tarifs par rapport aux autres modes de transport (Guezere, 2008). Même si, le phénomène des mototaxis se trouve à la marge de la réglementation avec, absence de qualification de conduite et ayant une part importante dans les accidents qui surviennent en ville. La mototaxi a introduit une nouvelle forme de mobilité sur demande et accessible par toutes les couches sociales de la ville. C’est au client de donner sa destination, en fonction de la distance à parcourir lui sera proposé un prix, ce dernier peut être négocié et renégocié. C’est dans cette flexibilité des parcours et du prix que ce moyen de transport donne la possibilité au client de se faire conduire jusqu’à son domicile. Même si, le risque que l’on en court demeure élevé (accident, poussière, chaleur, …). Enfin, les mototaxis desservent aussi les quartiers difficilement accessibles où il y a un manque considérable de voies bitumées, et absence de transport en commun public/privé et aussi des zones inondables en saison de pluie « quel que soit l’état des routes, les conducteurs de mototaxis trouvent l’ingéniosité de les pratiquer » disait Tublu Komi (2010).
2.2. Processus d’acquisition des mototaxis au sein de N’Djamena :

L’acquisition de la mototaxis se fait de plusieurs voies au sein de la ville de N’Djamena. D’abord, pour certains jeunes ce sont leurs parents ou un des membres de la famille achètent la moto et mettent à la disposition du jeune sans emploi pour le faire travailler, ils représentent 10% selon l’enquête ménage de mobilité urbaine. Ensuite, certains jeunes se procurent leurs propres motos, d’abord en commençant comme conducteur de mototaxi, et puis avec leurs économies s’achètèrent leurs motos. De même, certains jeunes investissent toute leur économie en achetant une moto, pour exercer la pratique de la mototaxi en ville ; Ce qui explique les 36% des mototaxis en circulation appartiennent aux conducteurs. Par ailleurs, certains particuliers mettent leurs motos personnelles à l’usage de mototaxi à un moment de la journée ou certains jours de la semaine, juste pour avoir de l’argent de l’essence (Diaz Olvera, ali, 2007), ou pour se dépanner les jours sans travail. Le plus souvent, ce sont des ouvriers travaillant dans la menuiserie, la maçonnerie, la plomberie se livrent à cette pratique lorsque les chantiers sont en arrêts en attendant la reprise des travaux. Enfin, pour la majorité des cas le bailleur peut être de la famille ou non, mais la seule garantie qui lie le conducteur et propriétaire est l’entente sur parole en présence de témoignes ou non. Ainsi dans cette entente de confiance mutuelle, le conducteur doit assurer un taux journalier convenu mutuellement à son bailleur. Le conducteur a l’obligation de rapporter le montant attendu à la fin de la journée ou en fin de semaine selon les affinités d’ententes et toutes les autres charges afférentes à la moto comme : l’essence, taxes syndicales et entretiens sont à la charge du conducteur (Sahabana, 2011). Selon l’enquête ménage de mobilité urbaine, les chauffeurs de mototaxis représentent 24% des mototaxis en circulation au sein de la ville de N’Djamena.

La durée de vie moyenne d’une moto étant d’environ quatre ans dans certaines villes d’Afrique comme Douala, Lomé et Cotonou (Diaz Olvera, ali, 2007 ; Sahabana, 2011). À N’Djamena la durée de vie d’une mototaxi dépend de l’entretien et l’attention que porte chaque conducteur à son engin. La plupart de ceux qui ont leur propre moto changent avec de nouvelles motos après six mois de travail de mototaxi, en ajoutant une somme qui avoisine entre 25000 à 100 000fcfa. Ce qui explique le fort taux de mototaxis sans papiers qui est à 48%, repartie avec 30% sans-papiers et 18% avec des faux papiers selon l’enquête ménage de mobilité urbaine et entretiens. Aujourd’hui certains commerçants de la place se sont spécialisés dans le commerce des motos, puis d’autre dans les pièces à motos. Enfin, ce qui a entraîné la prolifération des ateliers de réparations dans la plupart des rues à travers la ville de N’Djamena.
Tableau 3 : le parc des mototaxis dans certaines villes africaines

<table>
<thead>
<tr>
<th>Villes</th>
<th>Population</th>
<th>Nombre des mototaxis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotonou - 2000</td>
<td>1 000 000</td>
<td>60 000 (Godard, 2008)</td>
</tr>
<tr>
<td>Douala - 2004</td>
<td>2 000 000</td>
<td>22 000 (Sitross, 2004 ; Godard, 2008)</td>
</tr>
<tr>
<td>Lomé - 2008</td>
<td>-</td>
<td>40 000 (Tublu, 2010)</td>
</tr>
<tr>
<td>N’Djamena - 2013</td>
<td>1 207 596</td>
<td>22 000 (Mahamat Hemchi, 2013)</td>
</tr>
</tbody>
</table>

Sources diverses

« La précarité des emplois est le propre du transport artisanal, celle des matos-taxis est pire en tous points », disait Maidadi Sahabana. Cette citation donne une idée sur le quotidien des transports urbains de la ville de N’Djamena, surtout celui qui est assuré par les mototaxis.

3. Quel avenir doit-on prédire à la pratique de mototaxi pour une ville capitale comme N’Djamena ?


Par ailleurs, l’absence ou l’insuffisance des documents d’urbanisme sur la ville de N’Djamena n’entraîne pas seulement un problème de maîtrise de la gestion quotidienne de la ville, mais hypothèse aussi l’avenir que doit hériter la ville, de ses problèmes qui sont résolus aujourd’hui de manière sectorielle. "Les solutions d’urgence –font les problèmes de demain" disait François Ascher (2004). L’absence d’un document de planification stratégique élaboré par tous les acteurs connu et accepté fait un défaut pour la capitale tchadienne. Il y a aujourd’hui, une politique de gestion sectorielle qui entraîne une « faible implication des différents acteurs dans leur conception explique en partie la faible concrétisation de ces stratégies sur le terrain » (Mairie de N’Djamena, 2013). De même, le Plan des Transports et de Circulation (PTC) de la ville de N’Djamena n’arrive pas à donner les effets escomptés sur le terrain. Ainsi, le Schéma Directeur d’Aménagement Urbain (SDAU) de la ville de N’Djamena élaboré en 2012 et non approuvé par faute d’incompatibilité aux réalités du territoire explique très bien l’absence de coordination entre les différentes entités de la gestion urbaine à l’échelle de toute la ville. Il existe toujours un décalage entre le contenu et l’application des décrets ou arrêtés régulant le secteur des transports en milieu urbain.
La pratique de mototaxi s’est développée à N’Djamena dans une situation de dominance du transport artisanal, stimulée par l’insuffisance de l’organisation du transport urbain et surtout, par l’absence et la précarité d’emploi au sein de la ville de N’Djamena. L’activité de mototaxi est pénible, les conducteurs sont exposés aux conditions climatiques de chaleur accablante de 45°C sous l’ombre, et même sous la pluie en saison pluvieuse. Ils sont aussi soumis à des agresseurs qui les amènent dans des endroits isolés de la ville ou sur des friches urbaines en pleine nuit et enfin, le racket dont ils sont victimes de la part de la police. Même si, toutes ces contraintes font le quotidien du secteur des mototaxis, ses adeptes ne sont pas prêts à abandonner leur activité. Pour exercer cette activité en ville, aucune condition de base n’est exigée au départ, il suffit d’avoir une moto peu importe ; immatriculée ou non. Ensuite, la pratique ne nécessite pas de protection physique ni aussi, la détection d’un permis de conduire en ville. Enfin, les accidents sont quotidiens au niveau de N’Djamena, ils sont attribués aux motos en général et aux mototaxis en particulier d’après l’enquête ménage de mobilité urbaine. Aujourd’hui, l’usage des mototaxis au sein de N’Djamena, "l’on ne peut plus les négliger. Ils accompagnent le développement et la vie quotidienne, permettent la mobilité des populations vers les centres économiques et sont, de ce fait, source de production de richesses" Assogba Güezere (2008). C’est pourquoi, les mototaxis constituent et constitueront encore pendant longtemps au Togo, au Tchad, au Benin, au Cameroun,… un mode de transport décisif pour les déplacements. Il est donc très important d’organiser, au mieux, ce nouveau mode de transport urbain dans les grandes villes, de manière à rendre moins vulnérables les populations usagères et les jeunes conducteurs qui n’ont que cette pratique comme métier. Par une mise en place d’une politique de réorganisation et de rationalisation du métier des mototaxis. C’est dans cette optique que l’on doit, pouvoir remédier les insuffisances juridiques et surtout résoudre les difficultés d’application des documents de planification urbaine. Certes, il est difficile d’interdire le phénomène dans un contexte de manque d’infrastructures viaires et d’insuffisance aux offres de transport urbain, mais il est temps de les cadrer et surveiller. Régulariser cette pratique à l’échelle de toute la ville de N’Djamena est une aberration, mais donner de l’importance à cette dernière dans l’accès aux zones périphériques semble être raisonnable comme solution dans l’immédiat. Afin, d’assurer une complémentarité intermodale entre les taxis urbains et les minibus actuels.

Enfin, au regard de la forte implication des mototaxis dans les accidents et du comportement irresponsable des jeunes conducteurs, il est urgent de mettre en place des mesures de sécurité, épaulée par des formations, informations et sensibilisations. On devient conducteur de mototaxi à défaut de mieux, lorsqu’on a perdu son travail ou bien parce qu’à la sortie des études aucune autre opportunité ne se présente. Pour certains, cette pratique demeure la seule manière de financer ses études. En somme, en attendant mieux, c’est un métier qui permet aux chômeurs et aux analphabètes de gagner leur vie de citadins.
Conclusion :

La voirie urbaine de la ville de N’Djamena connait aujourd’hui une évolution remarquable sur le linéaire bitumé qui n’était que 60 km en 2000 sur l’ensemble de la ville est arrivé à 150 km de longueur en 2012. Si on compare à la superficie de la ville qui atteint les 20000 ha, cette évolution linéaire reste insuffisante. Par ailleurs, la ville connaît aussi des manquements importants : comme l’absence de trottoirs, des signalisations, des passages à niveau pour les piétons sur les grands axes et enfin l’absence des arrêts réglementés du transport urbain qu’assurent les minibus et les taxis. Sans oublier la prolifération des mototaxis à travers toute la ville de N’Djamena. « Le taxi-moto peut paraître le comble de l’inefficacité du transport public de masse puisque les ratios classiques de productivité sont au plus bas comparés aux modes de transport collectif de type autobus : un seul passager par véhicule (parfois davantage… jusqu’à 3 ou 4 personnes), un passager pour un chauffeur… » Xavier Godard. Mais ils deviennent supportables et s’adaptent à la demande de la population dans des milieux où le chômage et la pauvreté sont présents de façon structurelle comme la ville de N’Djamena. Même si le niveau de rémunération est faible, cette pratique demeure une activité rentable pour ses adeptes. Face à une pratique acceptée aujourd’hui par la population et certains Maires des différentes communes de la ville fut un temps, ensuite interdite depuis mai 2013 par les hautes autorités, l’abolition de la pratique des mototaxis au sein de N’Djamena n’est pas pour demain. Car, aujourd’hui la politique se mêle ; certains partis politiques financent ou assurent en dotation journalière (essence ou une somme forfaitaire) pour accueillir leurs chefs de partie au niveau de l’aéroport international Hassan Djamous (Raymond Fahttah, 2014) ou sur certaines places publiques lors des manifestations.
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Bibliographie :


Mahamat Hemchi Hassane, 2012, Système des transports urbains de la ville de N'Djamena (Tchad) : Mobilité urbaine entre théorie et pratiques- IATU, Mémoire de master 2e année, 72p.


Sahabana Maidadi, 2011, Les motos-taxis à Douala et leur perception par les pouvoirs publics : entre tolérance d’un secteur pourvoyeur d’emplois et de transport et volonté d’éradiquer une activité incontrôlable, Laboratoire d’Economie des Transports, ENTPE – Université Lyon 2 – CNRS.

MISE EN ŒUVRE D’UN MODE DE TRANSPORT URBAIN PERFORMANT ET DURABLE AUTOUR DU MOTO-TAXI À BOUAKE
(CÔTE D’IVOIRE)
Traoré Porna-Idriss¹

RESUMÉ

Depuis la crise militaro socio-politique de 2002, la majorité des infrastructures de la ville de Bouaké ont été détruites ou dégradées notamment celles du transport. Cette crise a entraîné le ralentissement de l’activité économique, entraînant un chômage de masse. Cette situation a engendré l’avènement d’un nouveau mode de transport urbain qui s’effectue à moto. Celui-ci se révèle comme un secteur pourvoyeur d’emplois et surtout de refuges pour les ex-combattants qui espèrent par cette activité se réinsérer socialement. Ce mode de transport s’implante dans le paysage urbain de Bouaké comme le seul alternatif, assurant le déplacement quasi généralisé de la population sur un territoire de plus en plus étalé et éclaté. Cependant, ce mode de transport génère d’importantes externalités négatives (une mobilité quasi généralisée, un étalement de la ville, une pollution environnementale, une violence criminelle de plus en plus préoccupante, un délétère du lien social etc.), faute d’une politique urbaine de transport performant et durable autour de ce mode de transport à Bouaké.

I. INTRODUCTION

1.1. Contexte et nature du phénomène étudié
Depuis la crise militaro socio-politique de 2002, la majorité des infrastructures de la ville de Bouaké ont été détruites ou dégradées notamment celles du transport. Cette crise a entraîné le ralentissement de l’activité économique. En effet, de nombreuses industries ont été fermées telles que la TRITURAF², GONFREVILLE³, entraînant un chômage de masse. En dépit d’une relance de l’activité économique, le chômage persiste. Cette situation a engendré l’avènement d’un nouveau mode de transport urbain qui s’effectue à moto.

1.2. Cadre d’étude
Située au centre de la Côte d’Ivoire⁴, Bouaké est la seconde ville du pays avec une superficie de 72 km² pour une population de 695 000 habitants⁵. Elle est située à 350 km de la capitale économique Abidjan. Elle se trouve au carrefour des grands axes routiers et ferroviaires et à la lisière de deux zones à économies complémentaires, le Nord et le Sud, faisant de cette ville un lieu privilégié d’échanges.

¹ Université Félix Houphouët-Boigny de Cocody à Abidjan (Côte d’Ivoire), traore.pornaidriss@yahoo.fr, 13 BP Abidjan 2338 Abidjan 13
² Usine d’égrenage du coton
³ Usine de textile
⁴ Voir carte de la ville de Bouaké
⁵ Selon les estimations de l’Institut Nationale de la Statistique de Côte d’Ivoire (INS) en 2012
1.3. Importance du phénomène

Ce mode de transport va se révéler comme un secteur pourvoyeur d’emplois et de refuges surtout pour les ex-combattants qui espèrent par cette activité se réinsérer socialement. Ce mode de transport va s’implanter dans le paysage urbain de Bouaké comme le seul alternatif, assurant le déplacement quasi généralisé de la population sur un territoire de plus en plus étalé et éclaté. De 2002 jusqu’en 2006, début du redéploiement de l’administration, Bouaké a été une zone où régnait un désordre consubstantiel à la crise. Cette situation a favorisé une entrée importante de motos provenant des pays frontaliers. En outre, le moto-taxi a pallié à l’absence de taxis communaux dans la première moitié de la décennie 2000 pour assurer le service minimum et a fini par s’installer durablement dans les habitudes des habitants. Ainsi contrairement aux taxis traditionnels, la moto coûte moins chère (320000 – 400000€ f CFA), consomme moins d’essence. Le mauvais état des routes est aussi l’une des principales causes du dynamisme de ce mode de transport. Certains quartiers de la ville sont enclavés et inaccessibles par les véhicules. Alors le seul moyen efficace et pratique pour se déplacer est le transport par moto.

1.4. Problématique

Dès son accession à l’indépendance en 1960, la Côte d’Ivoire a mis en œuvre une politique de transport public. Elle a mis en place un cadre institutionnel et infrastructurel permettant une meilleure mobilité des personnes et des biens. La mise en place des structures de régulation du transport telle que l’AGEROUTE7, la SONATT8, la SICTA9, le fond d’entretien routier en sont une illustration. Toutes les grandes villes du pays ont bénéficié de cette politique, dont Bouaké. Seconde ville de la Côte d’Ivoire, Bouaké doit son dynamisme économique à sa situation de carrefour entre le nord et le sud du pays. Le rayonnement économique de cette ville est dû essentiellement à l’essor de son secteur industriel et tertiaire. Cependant, la crise militaro-politique de 2002 a affecté les fondements de la ville, ce qui s’est traduit, entre autre, par l’exode de la population, le ralentissement de l’activité économique, l’arrêt des échanges avec la capitale économique, le tout entraînant de facto le déclin de cette ville. Cette crise a engendré un dysfonctionnement du système de transport classique. Les taxis-ville et les minibus communément appelés « gbakas » qui assuraient l’essentiel des déplacements devenant quasiment inexistants. Dans ce contexte, va naître et se développer un type de transport nouveau : le moto-taxi. Aujourd’hui, malgré un retour à la normalité, le phénomène de mototaxi ne semble pas faiblir et continue de s’implanter dans le paysage urbain de Bouaké. Cependant ce nouveau mode de transport urbain est sujet à d’énormes critiques. S’il parait évident que les taxis-motos résolvent un certain nombre de problèmes dont le déplacement des biens et des personnes, l’emploi et surtout la réinsertion des ex-combattants ; ce mode de transport génère d’importantes externalités négatives (une mobilité quasi généralisée, un étalement de la ville, une pollution environnementale et sonore, une violence criminelle de plus en plus...
préoccupante, une occupation anarchique de l’espace urbain etc.). Face à cette situation, les pouvoirs publics et les ONG locales tentent de remédier à ces problèmes. Des séances de sensibilisations et d’informations sont faites pour réglementer ce secteur. En outre, des aides en matériels roulant neuf et des casques de protection sont octroyés aux acteurs de ce secteur. En dépit de ces efforts consentis, force est de constater une montée en puissance de l’anarchie dans ce mode de transport urbain. De ces constats, se dégage une question centrale. Comment intégrer le moto-taxi dans le transport urbain à Bouaké comme un mode de transport performant et durable ?

1.5. Analyse pertinente des résultats d'autres auteurs


On remarque que la plupart des recherches traitant ce sujet se sont appesanties sur la dimension socio-économique, sur l’impact environnemental du moto-taxi sur le paysage urbain, mais également et en terme de sécurité. Le présent travail prend un

11 Terme pour désigner les chauffeurs des motos-taxis
tout autre intérêt dans une approche systémique pour mieux comprendre la complexité de ce nouveau mode de transport urbain à Bouaké.

1.6. Annonce des objectifs scientifiques
Cette étude vise à mettre en œuvre un système de transport urbain performant et durable autour du moto-taxi. De façon spécifique, il s’agit de :
- analyser le contexte du moto-taxi dans le transport urbain à Bouaké ;
- évaluer les externalités liées au moto-taxi à Bouaké ;
- déterminer le défi que pose le moto-taxi pour une politique de transport urbain durable.

1.7. Méthodologie
Pour mener cette étude, nous avons mobilisé de la documentation, de l’observation directe, des enquêtes de terrains et des interviews. La mobilité est un objet complexe dont la nature et la dynamique résultent de l’interaction de multiples facteurs d’ordre naturels et humains. Pour faire face à la complexité de l’objet d’étude ; dans le cadre de ce travail, qui vise la mise en œuvre d’un système de transport urbain performant et durable autour des motos taxis, nous privilégierons l’approche systémique. Cette approche s’appuie sur « une approche globale des problèmes ou des systèmes que l’on étudie et se concentre sur le jeu des interactions entre leurs éléments » (Rosnay, 1975). C’est donc une approche qui met l’accent sur les interactions qui peuvent permettre de faire évoluer le système de transport urbain. Le modèle éco-systémique permet une meilleure compréhension des déterminants qui fondent le fonctionnement du système de transport urbain.

Figure1 : Modèle éco systémique de la mobilité

Le modèle éco systémique de la mobilité met en interaction quatre sous-systèmes ; ce sont les sous-systèmes : spatial, social, politique de transport urbain et la mobilité. L’approche éco systémique de mobilité a pour objet de planifier, de gérer et de valoriser la mobilité en tenant compte de la multiplicité des aspirations et des besoins sociaux actuels, cela sans remettre en cause les avantages que les générations futures doivent tirer de l’ensemble des biens issus de l’écosystème urbain. Cette démarche intègre les dimensions économiques, sociales et environnementales. La question de la mobilité se situe donc à l’interface des rapports entre espace, société et politique.
de transport urbain. Elle est dès lors, l’expression d’une interaction entre les faits spatiaux, sociétaux et politiques, et constitue de ce fait, le fruit de la conjugaison du spatial, du social et du politique.

Carte 1 : Situation de Bouaké en Côte d’Ivoire

Source : INS¹², 2000

¹² Institut National de la statistique de Côte d’Ivoire
II. DYNAMISME DU MOTO TAXI A BOUAKE

1.1. Le manque d’emploi
La crise socio-politique de 2002 a entraîné le ralentissement des activités économiques. En dépit d’une relance de l’activité économique, le chômage de masse persiste. Par conséquent, les jeunes s’orientent vers ce mode de transport générateur de revenus.

1.2. La facilité d’acquisition des motos
Jusqu’au redéploiement de l’administration en 2006, Bouaké a été une zone où régnait un désordre institutionnel. Cette situation a favorisé l’entrée massive de motos provenant des pays frontaliers. En outre, les motos-taxis ont profité de l’absence de taxis communaux dans la première moitié de la décennie 2000, pour s’installer dans les habitudes des habitants. Ainsi, contrairement aux taxis traditionnels, la moto coûte moins cher (320 000 à 400 000 f CFA) et consomme moins d’essence.

1.3. Le mauvais état des routes
Le mauvais état des routes est l’une des principales causes du dynamisme de ce secteur. En effet, à causes des effets de la crise socio-politique, les investissements dans le secteur des infrastructures de transports ont été arrêtés. Cette situation a eu pour corollaire, la dégradation du réseau viaire et l’inaccessibilité des quartiers par les
véhicules à quatre roues. Et donc, le seul moyen pour accéder à ces quartiers est le transport par motos-taxis.

2. L’organisation des motos taxis

L’organisation des motos-taxis est de type « losangique ». On a le Syndicat de Motos Taxis de Bouaké (SMTB), les chefs de sections, les chefs de gares de chaque section, les conducteurs de motos taxis.

Organigramme 1 : Acteurs du moto-taxi

Tableau 1 : Répartition des conducteurs des motos-taxis selon l’âge.

<table>
<thead>
<tr>
<th>Classe d’âge</th>
<th>Effectifs</th>
<th>Pourcentage(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>[5 - 15]</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>[15 - 25]</td>
<td>54</td>
<td>54</td>
</tr>
</tbody>
</table>

L'organisation des motos-taxis est de type « losangique ». On a le Syndicat de Motos Taxis de Bouaké (SMTB), les chefs de sections, les chefs de gares de chaque section, les conducteurs de motos-taxis.

Organigramme 1 : Acteurs du moto-taxi


L'activité des motos-taxis est dirigée par le syndicat de motos taxis de Bouaké. Ce syndicat a mis en place un système d'organisation informel. La ville de Bouaké est subdivisée en quatre secteurs qui sont gérés de manière autonome tout en rendant compte au syndicat. Les différents chefs de sections doivent veiller à la bonne gestion des différentes gares qui composent leurs secteurs. Chaque gare, souvent de fortune est rattachée à un chef de section. Au bas de cette structure « losangique », on trouve les conducteurs de motos-taxis. Le service technique de la mairie de Bouaké, chargé du transport, a recensé en 2014, 1762 conducteurs. Ces conducteurs effectuent deux modes de déplacements : le mode en rotation qui est le plus courant et le mode linéaire pour les déplacement dans les zones en périphéries. Une enquête réalisée sur les motos taxis nous donne les résultats ci-dessous.

Tableau 1 : Répartition des conducteurs des motos-taxis selon l'âge.

<table>
<thead>
<tr>
<th>Classe d'âge</th>
<th>Effectifs</th>
<th>Pourcentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>[5 - 15]</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>[15 - 25]</td>
<td>54</td>
<td>54</td>
</tr>
<tr>
<td>[25 - 35]</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>[35 - 45]</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>[45 - 55]</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>55 et plus</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

Source : Nos enquêtes, janvier 2014.

Les conducteurs des motos-taxis à Bouaké sont en majorité jeunes entre 15 et 35 ans (84%).

Tableau 2 : Répartition des conducteurs de motos-taxis selon le niveau d’instruction

<table>
<thead>
<tr>
<th>Niveau d’instruction</th>
<th>Effectifs</th>
<th>Pourcentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primaire</td>
<td>27</td>
<td>27</td>
</tr>
<tr>
<td>Collège</td>
<td>28</td>
<td>28</td>
</tr>
<tr>
<td>Lycée</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>Analphabète</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Supérieur</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

Source : Nos enquêtes, janvier 2014.

Les conducteurs des motos-taxi ont en majorité le niveau secondaire (44%).

Tableau 3 : Nombre d’année de service des conducteurs de motos-taxis

<table>
<thead>
<tr>
<th>Nombre d’année (ans)</th>
<th>Effectifs</th>
<th>Pourcentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>[0 - 2]</td>
<td>51</td>
<td>51</td>
</tr>
<tr>
<td>[2 - 6]</td>
<td>34</td>
<td>34</td>
</tr>
<tr>
<td>6 et plus</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

Source : Nos enquêtes, janvier 2014.

Plus de 25% des conducteurs des motos-taxis ont plus de 4 années d’activité.

**II. EXTERNALITES LIEES AU MOTO-TAXI A BOUAKE**

Les motos-taxis génèrent d’importantes externalités négatives, en termes d’accidents de la circulation, de violences criminelles, de dégradations de l’espace urbain, de pollution environnementale et paysagère.

1. Une approche contextuelle des accidents des motos-taxis.

Le mauvais état du réseau viaire de la ville et à l’intérieur des quartiers intra-urbains et périphériques est l’une des principales causes des accidents. La préfecture de police de Bouaké a enregistré au mois de Juin 2014 soixante-douze cas...
d’accidents de la route dont vingt-deux causés par les motos-taxis. Des investigations menées au CHU nous ont relevé de blessés graves.


<table>
<thead>
<tr>
<th>Age (ans)</th>
<th>Chirurgie</th>
<th>Traumatologie</th>
<th>Urgence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moins de 15</td>
<td>5</td>
<td>15</td>
<td>135</td>
</tr>
<tr>
<td>(16 ; 30)</td>
<td>5</td>
<td>25</td>
<td>423</td>
</tr>
<tr>
<td>(31 ; 41)</td>
<td>7</td>
<td>23</td>
<td>440</td>
</tr>
<tr>
<td>(46 ; 60)</td>
<td>1</td>
<td>21</td>
<td>157</td>
</tr>
<tr>
<td>60 et plus</td>
<td>1</td>
<td>19</td>
<td>55</td>
</tr>
<tr>
<td>TOTAL</td>
<td>19</td>
<td>103</td>
<td>1210</td>
</tr>
</tbody>
</table>

Source : Service statistique du CHU, 2009

Ces chiffres montrent la brutalité et l’intensité des chocs issus des accidents causés par les motos-taxis.

2. Les violences criminelles

Ce nouveau mode de transport est source de violences criminelles, dont les auteurs sont des conducteurs des motos-taxis. Le service de Police de la ville enregistre pour la seule année 2014, 52 cas de viol, des agressions physiques à l’arme blanche.

3. La dégradation du cadre urbain

On assiste à la prolifération des gares de motos-taxis aux abords des lieux publics (marché, école, ronds-points etc.), à l’occupation anarchique des trottoirs et réseaux d’assainissement. L’implantation des gares à proximité des lieux d’habitation gêne la tranquillité des habitants.

Photo 1 : Moto-taxi et passager sans port de casque.

Source : Traoré Porna Idriss, 2004
III. RESULTATS

1. Bilans

Aujourd’hui, face aux nombreux débats sur ce mode de transport à Bouaké, un bilan doit être établi pour mieux évaluer son impact réel sur le plan socio-économique, urbain, environnemental, voire politique.

1.1. Bilan socio-économique

Pour les acteurs, le métier du moto-taxi est une activité lucrative. En outre, pour la population, ce nouveau mode de transport est plus économique et très efficace, car les prix des trajets sont discutables quelque soit le lieu de destination. Toutefois, il faut noter que les motos-taxis sont des concurrents déloyaux pour les autres moyens de transport que sont les auto-taxis et les « gbakas »13. De plus, les motos-taxis ne payent pas régulièrement les taxes communales, ce qui impacte fortement l’économie locale. Cependant, cette activité contribue à réduire le taux de chômage et permet l’insertion sociale des ex-combattants.

1.2. Bilan environnemental et paysagère

Les gares de fortunes se créent de façon anarchique, entrainant une dégradation du paysage urbain. Les motos-taxis génèrent également des nuisances sonores qui impactent la santé de la population.

2. Défis

2.1. Elaboration de lois statuant la réglementation des motos taxis.

Contrairement aux autres pays Africains, la Cote d’Ivoire ne dispose pas de loi réglementant ce secteur de transport urbain. Or si rien n’est fait, le désordre risque de s’installer durablement, rompant ainsi l’équilibre social déjà fragilisé par la crise.

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13 Termé pour désigner le transport urbain populaire autour de l’automobile
2.2. Allègement du coût du permis de conduire
92% des moto-taximen qui exercent ce transport n’ont pas de permis moto. Les conducteurs expliquent cette situation par le coût élevé du permis.

2.3. L’octroi des cartes professionnelles aux acteurs des motos-taxis
Afin de mieux contrôler l’activité et la rendre professionnelle, il est nécessaire d’octroyer des cartes professionnelles aux acteurs.

2.4. La sensibilisation comme un moyen de réorganisation de l’activité des motos-taxis
Pendant longtemps, les moto-taximen ont agis comme des hors la loi par le non-respect des feux tricolores et des limitations des vitesses et le port de casque.

2.5. L’uniformisation des couleurs des motos et une tenue appropriée pour les chauffeurs
Devant la multitude de motos qui roulent dans la ville, les autorités communales ont exigé des conducteurs de motos-taxis le port d’une tenue singulières. Cependant cette innovation n’est pas suivie car trop distinctive par les forces de l’ordre qui pourraient les verbaliser pour défaut de permis.

CONCLUSION
Depuis 2002, le moto-taxi est devenu un nouveau mode de transport à Bouaké et semble s’implanter durablement dans le paysage urbain de Bouaké. Ce mode de transport est en train de devenir le seul alternatif, assurant le déplacement quasi généralisé de la population et des biens sur un territoire de plus en plus étalé et éclaté. Même si ce mode de transport génère d’importantes externalités négatives, il ne faut pas sous-estimer son impact réel sur le plan socio-économique, urbain, voire politique. Cette Activité est Génératrice de Revenus pour les populations pauvres, et permet en partie de résorber les inégalités sociales. Dans un contexte de retour à la normalité, suite à deux décennies de crise militaro-socio-économique, cette activité doit être étudiée pour son intégration dans le système de transport urbain à Bouaké. Son intégration devra prendre en compte l’évolution future de la ville par la réduction des externalités négatives. Un Plan de Déplacement Urbain des Motos-Taxis devra être élaboré en mettant l’accent sur un système de transport multimodal/périphérique. Le moto-taxi peut être un mode de transport peu consommateur d’espace et devenir durable et très écologique.

BIBLIOGRAPHIE

PLANNING TWO WHEELS IN LOMÉ FOR A SUSTAINABLE URBAN MOBILITY VISION FOR 2030

Assogba Guezere

1 The University of Kara-Togo

Abstract

The urban transport in Lome is characterized by a low level of equipment in the individual cars and by the inefficiency of public transport. The main part of urban displacements is organized around the double use of the motorbikes, namely the private motor bike and the taxi-motor bike whose role is incontestable in Togo’s urban development. In this communication, I want to talk about the future of these taxi-motor bikes which, in spite of their significant role, involve negative externalities prejudicial with the sustainable urban development. Lome will have 3 millions inhabitants in 2030 against 1.5 million currently.

There is a vast project of economic development called “Togo, vision 2030” where all the economic branches of activities are concerned. A capital city as Lome which wants to be modern and which will have to be the engine of this program of emergence of Togo in 2030 cannot continue by making function its system of urban transport in an artisanal way. This is why I seize the occasion of CODATU 2015 to propose the need for planning the two wheels and for developing public transport for a sustainable urban mobility in Lome in 2030.
CHALLENGES AND OPPORTUNITIES FOR MOTORIZED TWO-WHEELERS IN ASIAN CITIES

Rebecca Heywood\(^1\) and Madhav Pai\(^2\)

Abstract

Rising incomes and aspirations for increased personal mobility, coupled with a lack of extensive and reliable public transport, have contributed to rapid growth in the use of motorized two-wheelers in cities across the developing world. Two-wheelers fill a gap in urban mobility and are increasingly used by urban residents looking for convenient, safe and comfortable modes of transport. However, their growing presence—and the associated trade-offs between positive and negative externalities—is too often ignored by urban transport initiatives in developing cities.

Using surveys, stakeholder interviews and on-the-ground observations, this paper aims to improve understanding of the demographics and motivations of two-wheeler users in urban India, reflect on current and future challenges associated with two-wheeler use and provide guidance for urban transport policies that incorporate and recognize the presence and needs of motorized two-wheelers.

A 2012 survey conducted in Pune, India, where two-wheelers make up over 75% of registered vehicles, found that existing users see them as an attainable, flexible and affordable alternative to unreliable, overcrowded and unsafe public transport, particularly for trips in the 2-10km range. The Pune case suggests that affordability and convenience are two key factors that influence two-wheeler use in Indian cities, but that many users aspire to car ownership. Two-wheelers are often seen as a midterm mobility solution, and their long-term use can lead to a lifelong preference for private motorized transport.

Experience from India offers guidance for future transport policies across Asian cities where two-wheelers are a ubiquitous urban transport mode. Managing two-wheeler use for sustainable transportation requires not only attention towards improving emissions technologies and road design and engineering standards, but also an in-depth understanding of the needs and aspirations of existing (and future) users.

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1. Introduction

Motorized two-wheelers are an increasingly common mode of transportation for the growing middle-class in India and across the developing world. Two-wheelers cater to the needs of low- and middle-income residents and are filling the gaps left by inefficient, poorly integrated and often non-existent urban transport systems (PCFV, 2010). The reality is that many developing cities lack substantial and efficient public transport systems, and as incomes rise, captive users of public transport and people limited by their lack of mobility aspire to use private modes of transportation to solve their mobility needs. While two-wheelers enable improved accessibility to economic, educational and recreational opportunities for urban residents across the socio-economic spectrum, they are also responsible for externalities including air pollution, traffic congestion and road accidents.

This paper seeks to explore the opportunities and challenges for two-wheeler use, and their potential future role within urban transport in India and beyond. A case study of Pune, India suggests that affordability and convenience are two key factors that influence two-wheeler use in Indian cities, but that two-wheeler use can lead to a lifelong preference for private motorized transport. Rising levels of motorization associated with rising incomes, and in turn growing aspirations for motorization, point to a need to provide alternative and attractive modes of transport to reduce the negative externalities associated with private motorized transport. In turn, however, it is also necessary to recognize that a certain level of private motorization may always be necessary, at least in the near term, and that two-wheelers can serve as a substitute for automobiles. Exploring the role and opportunities for two-wheelers, as well as challenges faced by cities in mitigating their negative impacts, can help work towards long-term sustainability in developing cities.

The paper is structured as follows: section 2 presents existing literature on two-wheelers in Asia; section 3 presents a case study of Pune, India; section 4 discusses opportunities and challenges for two-wheelers in Asia, and section 5 presents the final conclusions of the research.

2. Literature Review

The use of motorized two-wheelers as a primary mode of transport is a phenomenon unique to Asia. Nearly 80% of the 300 million two-wheelers worldwide are in Asia, as are 90% of two-wheeler sales (PCFV, 2010). In India, more than 70% of motorized vehicles are two-wheelers, while in Vietnam this is over 97% (MoUD & WSA, 2008; Kamakate & Gordon, 2009). While motorization and vehicle ownership in developed countries is slowing, motorization in developing countries is increasing as a very rapid rate, much of it due to increases in two-wheeler ownership as shown in Figure 1.
1. Introduction

Motorized two-wheelers are an increasingly common mode of transportation for the growing middle-class in India and across the developing world. Two-wheelers cater to the needs of low- and middle-income residents and are filling the gaps left by inefficient, poorly integrated and often non-existent urban transport systems (PCFV, 2010). The reality is that many developing cities lack substantial and efficient public transport systems, and as incomes rise, captive users of public transport and people limited by their lack of mobility aspire to use private modes of transportation to solve their mobility needs. While two-wheelers enable improved accessibility to economic, educational and recreational opportunities for urban residents across the socio-economic spectrum, they are also responsible for externalities including air pollution, traffic congestion and road accidents.

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![Figure 1: Two and Three Wheelers in Asia](image)

2.1 Growing motorization

Motorization, the number of motor vehicles per thousand inhabitants, continues to be one of the most important factors in urban development and transportation. It is closely connected with urbanization, economic and income growth, and government policies and investments (Zegras & Chen, 2010). Gross Domestic Product (GDP) grew quickly in Asia between 1989 and 2002 and contributed to the increase in two-wheeler and automobile ownership among the growing middle class. Only 23% of households in India own a two-wheeler (Munjal, 2009), but the mode share of MTW is growing at 12% per year. Increases in private transport ownership are associated with higher levels of congestion, longer travel times, and a greater loss in worker productivity.

Current data from across Asia indicates that car ownership only rises significantly after GDP per capita exceeds US $8,000 per year (Mohan et al., 2009). In India, the GDP per capita is currently only US $1,700 annually, indicating that there is likely to be continued growth in two-wheeler ownership before significant rises in automobile ownership. There is evidence, however, that in India, two-wheeler ownership and monthly household income levels are not correlated (Pai, 2009), and wealthier households still show a preference for two-wheeler use for shorter trips.

In many developing cities, a high modal share of public transport comes from captive users³ (Archaya, 2005), but does not indicate a high quality transportation system. Rising incomes provide users with more choice in meeting their mobility needs, and in cities lacking sufficient public and non-motorized transport infrastructure, can

³ 'Captive' users are those who use a mode because their mobility options are limited, often due to a lack of access to alternative modes or a lack of affordability of alternative modes.
often lead to increases in private motorization. On the other hand, cities with widespread and efficient public transport systems, as well as growing traffic congestion, may be able to entice motorized vehicle users, particularly two-wheeler users, to switch modes. A study conducted in Malaysia suggests that if a bus and motorcycle were to travel the same distance at the same speed, 62% of people would use the bus while only 38% would choose to use a motorcycle (Ibrahim et al., 2006).

National policy on the automobile and two-wheeler industries also relate closely to motorization rates, however. In India, the national government has created policies to make India an attractive business destination for global automotive companies (Pai et al., 2014). Opening the market to foreign manufacturers has decreased the price point, and increased the range of models available for sale (Banerjee et al., 2010). The national government has projected an increase in the share of the automotive industry to the nation’s economy from 5% to 10% by 2016.

### 2.2 Effects of air pollution and road safety

A large body of research exists on the relationships between emissions and road safety, two of the major public health concerns associated with two-wheeler usage, and two-wheelers (Meszler, 2007; Cherry, 2007; Schwela, Zali & Schwela 1997; Iyer, 2012; WHO, 2006). Growth in the automotive industry may have some positive economic benefits, but a study by Patankar & Trivedi found that the total economic cost of air pollution exposure in India is estimated to be 4523 billion Indian Rupees ($113 million) for every 50-µg/m³ increase, a substantial societal burden.

The transportation sector is a significant contributor to global air pollution. A 1998 study found that in Delhi, the transportation sector contributes nearly 70% of air pollution (IGES, 2007). Two-stroke engines, which have particularly poor emission performance, are prevalent in two-wheeler fleets across Asia due to their durability, easy maintenance and low-cost, but emit substantial quantities of hydrocarbons, carbon monoxide and particulate matter (PM). Poor maintenance, misuse of lubricants and poor quality gasoline also worsen the emission performance of two-wheelers (Kojima, Brandon & Shah 2000). In Hanoi, motorcyclists were found to have the highest exposure to particulate matter of all road users, and more than twice that of bus riders (PCFV, 2010).

Historically there have been few innovations in emissions control for small motorcycles due to their scarcity in developed markets. Recent changes in India have led to manufacturers increasing fuel efficiency and reducing emissions from two-stroke engines in two- and three-wheelers through changes in manufacturing policies, aftermarket additions and the introduction of compressed natural gas, but these are not yet widely adopted outside of India. Adaptation of aftermarket technologies for smaller engine sizes can still be difficult (Meszler, 2007).

A number of countries have begun to mandate higher emissions standards for new vehicles and changes in fuel standards, though the age of the existing fleet and non-
compliance with new standards prove a challenge for Asian cities (IGSE, 2007). Previous studies in the field have also emphasized the need for improving inspection and maintenance systems for all vehicles (ADB, 2003; Kojima, Brandon & Shah, 2002; Gorham, 2002), which requires significant improvement in enforcement mechanisms.

In addition to air pollution concerns, road safety is one of the most important public health issues related to two-wheelers. As seen in Figure 2, two-wheelers account for more than half of road fatalities in some places (PCFV, 2010). Addressing the needs of vulnerable road users has become a focus of the World Health Organization, particularly the use of helmets and improving trauma care. Helmet use has been shown to reduce the risk of motorcycle injuries by 69 percent and motorcycle fatalities by 42 percent (Pervin et al., 2009). WHO data shows that nearly a quarter of victims of road traffic collisions admitted to hospitals sustained a traumatic brain injury.

![Figure 2: Road User Deaths](image)

### 2.3 Demographics and Motivations

There is little literature available addressing questions regarding the demographics and motivations of two-wheeler users. A 2010 study, summarized in Table 1, found that the key factors influencing two-wheeler ownership in Asia were the low-cost availability and financing opportunities, good fuel economy, high levels of traffic congestion and competitive trip lengths, while weather and vulnerability were deterring factors (PCFV, 2010).
Table 1. Factors influencing motorcycle ownership in Asian cities

<table>
<thead>
<tr>
<th>Factors</th>
<th>Description</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost and Financing</td>
<td>Low cost and availability through easy financing terms, sometimes at zero interest rates</td>
<td>+++</td>
</tr>
<tr>
<td>Fuel Economy</td>
<td>Consumes less fuel and has better mileage compared to other modes</td>
<td>+++</td>
</tr>
<tr>
<td>Congestion</td>
<td>Highly-congested areas suit 2-wheelers</td>
<td>+++</td>
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<tr>
<td>Trip Length</td>
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<td>+++</td>
</tr>
<tr>
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<td>++</td>
</tr>
<tr>
<td>Technology and Innovations</td>
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<td>++</td>
</tr>
<tr>
<td>Parking</td>
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<td>++</td>
</tr>
<tr>
<td>Maneuverability</td>
<td>High maneuverability in traffic congested areas and narrow streets</td>
<td>++</td>
</tr>
<tr>
<td>State of public transport and NMT</td>
<td>Low levels of services and adequate facilities for public transportation and non-motorized transportation</td>
<td>++</td>
</tr>
<tr>
<td>Regulations and enforcement</td>
<td>Poor and/or lack of regulations and insufficient enforcement</td>
<td>+</td>
</tr>
<tr>
<td>Occupancy</td>
<td>Lower occupancy</td>
<td>-</td>
</tr>
<tr>
<td>Weather</td>
<td>Exposure to sun and rain</td>
<td>- - -</td>
</tr>
<tr>
<td>Vulnerability</td>
<td>Prone to collisions with other transport modes and other accidents</td>
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</tr>
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</table>

Source: PCFV, 2010

In India, mid-sized cities have the highest modal share of two-wheelers, including Pune, Ahmedabad, Chennai and Hyderabad, with populations ranging from 3.76 million in Pune to 6.56 million in Chennai, shown in Figure 3. Large metro areas across Asia generally have better developed public transport networks, while small and medium sized cities have few transport options, leading more people to shift from non-motorized and public transport to two-wheelers when they are financially capable.
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Figure 3: Modal Split of Various Indian Cities

2.4 Lack of relevant road and traffic engineering standards for motorized two-wheelers

Two-wheelers are often blamed for causing congestion in urban areas, but there is ambiguity in the data regarding their congestion impacts. While there is emerging research about the adaptation of the passenger car unit (PCU) metric used to assess traffic flows for developing countries (Metkari, Budhkar & Maurya, 2012; Arkatkar, 2011; Chandra & Sinha, 2001), in practice the application of PCUs rarely takes into account urban heterogeneous traffic conditions or weak lane discipline common in most developing cities. Other factors that affect the congestion impact of two-wheelers include lane discipline, lane demarcation, traffic signal timing, as well as assumptions that are made about load factors of different vehicle types.

3. Insights from the case of Pune, India

The city of Pune is located in the state of Maharashtra, about 150km southeast of Mumbai. The population of the Municipal Corporation area was about three million in 2011 with a working population of 34% (PMC, 2013). It is both a major industrial and educational hub, boasting a strong automotive sector and a student population of over half a million, leading to a median age of only 24 years, compared to nearly 27 countrywide. It is the sixth largest metropolitan economy in India, and one of the fastest growing. It is a relatively wealthy city with the seventh highest family income and second highest per capita income (PMC, 2006).

While large Indian cities have higher public transport mode shares and lower two-wheeler mode shares, the converse is true of small and mid-sized cities, such as Pune. Little literature and data is available on transport trends in Tier II and III cities.
in India\textsuperscript{4}. Pune was chosen as a case study because it is typical of mid-sized Tier II cities with a high, and growing, two-wheeler mode share.

The key objective of the study is to better understand the role of motorized two-wheelers in urban mobility and the challenges associated with the sector in Indian cities. Focus areas were identified based on gaps in current literature and include:

- Factors influencing motorbike ownership
- Demographics of two-wheeler users
- Motivations for two-wheeler use over other modes
- Role of two-wheeler use in influencing future automobile ownership
- Key issues and challenges for cities with high-levels of two-wheeler use
- Potential role of two-wheelers in sustainable urban mobility in India

3.1 Traffic and Transport Characteristics

Pune was once known at the ‘cycle city of India’, but has become a city of two-wheelers. There are few provisions for cyclists or pedestrians in Pune, and more than 40\% of roads lack sidewalks. Public transport provision is poor, and ridership has been decreasing as passengers turn to rickshaws or private transport to meet their needs (PMC, 2006). Ridership on public transport has decreased nearly 20 percent since 2010-11, despite a target for 3 percent annual growth set out in the city’s Comprehensive Mobility Plan (Parisar, 2013). Two-wheelers also accounted for 20 percent of fatal and serious accidents in Pune, while trucks accounted for 24 percent and cars accounted for 14 percent (PMC & WSA, 2008).

Between 1981 and 2002, motorcycle ownership in Pune increased 16-fold, while automobile ownership increased 7-fold (Reddy & Balachandra, 2010). Although Pune has one of the highest levels of automobile ownership among similar cities in India at more than 450 vehicles per 1000 persons, two-wheelers still make up over 70\% of motorized vehicles in the city. Recent studies have shown that many two-wheeler users in Pune also own a private automobile, but choose not to use it for daily travel needs. Private motorized vehicles have been gaining mode share in Pune since 2005 (Pai et al., 2014).

3.2 Case Study Methodology

The goal of the study was to better understand the role of motorized two-wheelers in providing urban mobility, and to gather quantitative information regarding the demographics, characteristics and motivations of two-wheeler users in mid-sized cities. The first step of the study was a literature review on the role of motorized

\textsuperscript{4}The Indian government classifies cities based on population. Tier I: \textgreater 4 million (Bangalore, Chennai, Delhi, Hyderabad, Kolkata, Mumbai), Tier II: 1-4 million (e.g. Ahmadabad, Chandigarh, Jaipur, Pune); Tier III: \textless 1 million (e.g. Indore, Trichy, Rajkot, Trivandrum)
two-wheelers in urban transport in India, and across Asia, with a goal of identifying gaps in available literature.

A two-wheeler user survey was then designed to address these gaps and survey data from Pune, as well as stakeholder interviews and first-person observations contributed to an in-depth understanding of the role of two-wheelers. The survey was designed as an intercept survey of one thousand two-wheeler users, conducted over the course of three months. To reach a diverse population, surveyors fluent in local languages spoke with users at a variety of locations, times and days of the week. The survey consisted of seven parts: household information, user information, two-wheeler use information, safety, alternative transport modes, user opinions about transport in Pune and observer field notes.

About 72 percent of survey respondents were male and 28 percent were female. Respondents were also asked about the travel habits of members of their households, providing important information about the correlation of household economic and demographic characteristics with mode choice data, and ensuring the inclusion of travel habits of populations with low two-wheeler use. Based on the household information provided, the percentage of males and females represented in the dataset is 51 percent and 49 percent, respectively.

### 3.3 Demographics of Two-Wheeler Ownership and Use in Pune

Table 2 shows the household statistics of survey respondents in Pune, all of whom were two-wheeler owners. The average ownership was 1.5 two-wheelers per household, and the distribution was in line with the stated household income. Like in many Indian cities, the majority of households in Pune have several generations living in the home. The average household size found in the survey is smaller than that of the city overall, 4.56 persons per household in Pune City in 2001 (Sridhar & Bandyopadhyay, 2007). The high number of student two-wheeler users and survey respondents may have skewed the metric due to single person households living in dormitory or other student residences.

The average income of car-owning households in Pune is more than Rs 68,000 per month, while the average monthly income of all respondents is between Rs. 25,000 and 50,000. Just under a third of respondents own a car, while 2/3 of those who do not currently own a car indicated that they would be interested in purchasing one in the future.

---

5 An ‘intercept’ survey is an in-person, one-on-one, impromptu survey done on location. The questionnaire is administered to a sample of ‘intercepted’ respondents as they pass by the interviewer.
Table 2: Household Statistics of Survey Respondents

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>Maximum</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household Size</td>
<td>3.7 persons</td>
<td>8 persons</td>
<td>1 person</td>
</tr>
<tr>
<td>Number of adults</td>
<td>3.0 adults</td>
<td>8 adults</td>
<td>1 adult</td>
</tr>
<tr>
<td>Number of children</td>
<td>0.6 children</td>
<td>3 children</td>
<td>0 children</td>
</tr>
<tr>
<td>Monthly household income (% of respondents)</td>
<td>Rs. 25,000 to 50,000 [US $ 404-809] (33% of sample)</td>
<td>More than Rs. 100,000 [US $1,617] (12% of sample)</td>
<td>Less than Rs 10,000 [US $162] (5% of sample)</td>
</tr>
<tr>
<td>Number of motorized vehicles</td>
<td>1.9</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>Number of motorized two-wheelers</td>
<td>1.5</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Number of cars</td>
<td>0.4</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>Number of bicycles</td>
<td>0.4</td>
<td>3</td>
<td>0</td>
</tr>
</tbody>
</table>

Source: Pai et al. 2014

There were clear trends that emerged among survey respondents. The majority of two-wheeler and car owners were male, while the majority of passengers were female. Women are historically not the primary purchasers of two-wheelers, though manufacturers have started marketing some vehicles, generally scooters, specifically to women (iTrans, 2009).

Figure 4: Overall Transport Mode Split by Gender from Pune Survey

Source: Pune Survey, 2012
Some further trends include:

- The majority of two-wheeler and automobile passengers, as well as public transportation users, are female
- The majority of car and two-wheeler drivers are male, though females between the age of 18-30 make up a significant portion
- Two-wheelers were the primary mode of transport for 55 percent of total respondents; 19 percent used cars as primary transport and 15 percent public transport
- Car ownership for men increases dramatically after age 30 while car (passenger) as a primary mode increases for women after age 30
- After age 50, there is a significant decline in the percentage of both men and women using two-wheelers with a general shift for both genders to being car passengers and public transportation users
- 38 percent of respondents with children also own an automobile
- Half of households that owned a car indicated that it served as the primary mode of transport, while half relied on two-wheelers

While one can legally drive a two-wheeler from age 16, the average age for men to begin riding a two-wheeler was 20 years old, while for women it was 21.5 years old. The dramatic shift away from two-wheeler use after age 50 may indicate concerns about safety and comfort associated with the mode, or slow adoption of new technologies among older adults.

### 3.4 Motivations for Two-Wheeler Ownership and Use

Surveyed riders were asked about the nature of the trips they make with two-wheelers. While males primarily use them to travel to work, women are more likely to use two-wheelers for education or recreational and shopping trips.

Roughly 45 percent of surveyed respondents, both male and female, stated that they use a two-wheeler more than 14 times per week, while 33 percent use it 10-14 times per week. These high usage numbers indicate that it is likely being used daily. Many users supplement two-wheeler usage with other modes. 31 percent saying they used a car on occasion, 25 percent use city buses and 16 percent use auto-rickshaws. 72 percent responded that they walk occasionally or often throughout the week. Additionally, 26 percent of males, and 30 percent of females, also use a two-wheeler in conjunction with another mode during a single trip. Of these, 43 percent used bus, 31 percent auto–rickshaws and 20 percent walked.

Prior to two-wheeler use, the majority of respondents, 67%, said they used public transportation, while 14% cycled. The large shift away from public transport indicates that it is unsuitable for meeting the travel needs of a large portion of the public. Table 3 shows the mode choice prior to two-wheeler use by gender.
Table 3. Mode choice prior to MTW use by gender

<table>
<thead>
<tr>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public Transportation</td>
<td>Public Transportation</td>
</tr>
<tr>
<td>70.8%</td>
<td>59.2%</td>
</tr>
<tr>
<td>Bicycle</td>
<td>Car (passenger)</td>
</tr>
<tr>
<td>14.3%</td>
<td>13.6%</td>
</tr>
<tr>
<td>Car (passenger)</td>
<td>Bicycle</td>
</tr>
<tr>
<td>5.6%</td>
<td>6.8%</td>
</tr>
<tr>
<td>Other</td>
<td>Other</td>
</tr>
<tr>
<td>2.5%</td>
<td>6.4%</td>
</tr>
<tr>
<td>Walking</td>
<td>Two-wheeler (passenger)</td>
</tr>
<tr>
<td>2.1%</td>
<td>4.3%</td>
</tr>
<tr>
<td>Two-wheeler (passenger)</td>
<td>Walking</td>
</tr>
<tr>
<td>1.8%</td>
<td>3%</td>
</tr>
<tr>
<td>Car (driver)</td>
<td>School Bus/Van/Auto</td>
</tr>
<tr>
<td>1.6%</td>
<td>2.1%</td>
</tr>
<tr>
<td>School Bus/Van/Auto</td>
<td>Car (driver)</td>
</tr>
<tr>
<td>1.3%</td>
<td>0.4%</td>
</tr>
</tbody>
</table>

Source: Pune Survey, 2012

In Pune, comfort, convenience and enjoyment were the top three reasons both men and women use two-wheelers. They were indicated to play an important role in family mobility, and seen as leading towards auto ownership for most families. Further reasons provided for users to begin riding two-wheelers are seen in Table 4.

Table 4. Reasons for beginning to ride two-wheelers

<table>
<thead>
<tr>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>More comfortable</td>
<td>More comfortable</td>
</tr>
<tr>
<td>Enjoy riding</td>
<td>Convenience and flexibility</td>
</tr>
<tr>
<td>Convenience and flexibility</td>
<td>Enjoy riding</td>
</tr>
<tr>
<td>Faster than other modes</td>
<td>Faster than other modes</td>
</tr>
<tr>
<td>Low cost</td>
<td>Low Cost</td>
</tr>
<tr>
<td>Public transport not available/inconvenient</td>
<td>Public transport not available/inconvenient</td>
</tr>
<tr>
<td>Longer commute</td>
<td>Safer than other modes</td>
</tr>
<tr>
<td>Higher status/ cool</td>
<td>Higher status/cool</td>
</tr>
<tr>
<td>Easier to park</td>
<td>Easier to park</td>
</tr>
</tbody>
</table>

Source: Pune Survey, 2012

The Pune survey also asked for what would make respondents switch from their current modes of transportation to public transportation, cycling and walking. While
20% of respondents said they would not use public transportation, the remaining 80% gave a variety of scenarios in which they would use public transportation, shown in Table 5. The top response is that if service was reliable and regular, many would be willing to switch.

Table 5. Top scenarios for switching modes

<table>
<thead>
<tr>
<th>Switch to Public Transportation</th>
<th>Switch to Cycling</th>
<th>Switch to Walking</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Reliable/regular</td>
<td>Small distance</td>
<td>Small distance</td>
</tr>
<tr>
<td>2. Less crowd</td>
<td>Recreation/exercise</td>
<td>Exercise</td>
</tr>
<tr>
<td>3. More frequent</td>
<td>Cycle track</td>
<td>Won’t walk</td>
</tr>
<tr>
<td>4. Clean/neat</td>
<td>Compulsory/Law</td>
<td>Better footpath</td>
</tr>
<tr>
<td>5. Better buses</td>
<td>Greater cycle use</td>
<td>Last option</td>
</tr>
<tr>
<td>6. Safer (women)</td>
<td>Very high petrol price</td>
<td>Very high petrol price</td>
</tr>
<tr>
<td>7. Conductor/driver behaviour</td>
<td>Last option</td>
<td></td>
</tr>
<tr>
<td>8. Reserved seats</td>
<td>Can’t ride cycle</td>
<td></td>
</tr>
<tr>
<td>9. AC</td>
<td>Old age</td>
<td></td>
</tr>
<tr>
<td>10. Door to door service</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Reservation for women/ senior citizens</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Information system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. Metro/tram</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. More convenient</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Pune Survey, 2012

While motorization in Pune is still relatively low, there is a high level of desire for automobile ownership in the city. The primary impetus for a future car purchase would be a higher income, cited by 90% of respondents, followed by marriage. This is corroborated by current car owners who indicated higher income and family concerns as the reason for their purchase. Respondents also indicated, however, that they are concerned about worsening congestion in Pune and that they feel that the traffic is very dangerous because of lack of enforcement of road rules.

Two issues of concern for both two-wheeler and car users are the price of petrol and the price and availability of parking. Respondents indicated that the price of petrol was a more important factor in their travel decisions than the price of parking, though 52 percent do not currently pay for parking and very few pay more than Rs. 5 (US $0.07). The median price point for petrol that would cause respondents to switch to alternative (non-private) modes is Rs. 170/L (US$ 2.78/L).

3.5 Road Safety and Two-wheelers
About 13 percent of riders, both male and female, report having been involved in an accident while riding. 49 percent of these accidents resulted in a visit to the doctor, while 13 percent required a trip to the hospital. 69 percent required the rider to take time off of work or school. Shown in Table 6, nearly half of the accidents involved a collision with another two-wheeler, while 22 percent involved the individual falling off the bike. 22 percent involved a collision with another type of vehicle.

<table>
<thead>
<tr>
<th>Table 6. Accident type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Collision with two-wheeler</td>
</tr>
<tr>
<td>2. Fell off bike</td>
</tr>
<tr>
<td>3. Collision with bus</td>
</tr>
<tr>
<td>4. Collision with automobile</td>
</tr>
<tr>
<td>5. Collision with pedestrian</td>
</tr>
<tr>
<td>6. Collision with three-wheeler</td>
</tr>
<tr>
<td>7. Collision with goods carrier</td>
</tr>
<tr>
<td>8. Other</td>
</tr>
</tbody>
</table>

Source: Pune Survey, 2012

While less than half of all respondents indicated that they always wear a helmet, of those who had been in an accident, 43 percent never wear helmets, while only 30 percent always wear a helmet.

4. Opportunities and Challenges for Two-wheelers

This section discusses the challenges associated with the current high two-wheeler mode share in developing cities, as well as the opportunities for an alternative role for two-wheelers in sustainable transportation. The rapid growth of two-wheelers in Pune is indicative of trends across the region, and provides a clear example of the impact of poor non-motorized and public transport provision. Rapid growth causes challenges affecting economic competitiveness and equity, but many users indicate a willingness to switch back to public transportation or non-motorized transport if adequate service and facilities were provided. While existing mode shares of two-wheelers may be unsustainable, that does not preclude an alternative role for the mode.

4.1 Opportunities for Two-Wheelers in Sustainable Transportation

Often unaddressed in discussions regarding two-wheelers is the opportunity for two-wheelers to be used as a tool for building more sustainable transport systems. While the current modal share of two-wheelers in many Asian cities is likely unsustainable moving forward, there are opportunities to view the mode as a substitute for private automobiles. Regardless of the robustness of the public and non-motorized transport
facilities, there will likely always be people who want or need to drive either due to a love of the mode, or because of unusual travel patterns. Two-wheelers must also be considered as a separate and unique mode of transportation, rather than considered together with cars or non-motorized modes. They have unique characteristics and fill a void in the transportation spectrum. They have a smaller footprint than cars, both physically and environmentally, particularly when they are electric powered. With proper facilities and regulations, two-wheelers have the opportunity to supplement public transportation, in particular, and can help address the first/last mile problem.

The city of Taipei, Taiwan has maintained a high two-wheeler mode share for daily and commuting trips despite high automobile ownership rates by investing in two-wheeler specific infrastructure and traffic management policies. Road safety and congestion improved after the implementation of policies such as two-stage left turns, two-wheeler boxes, two-wheeler lanes and helmet laws (Chang, 2012).

4.2 Challenges for Two-Wheelers

Despite the opportunities that two-wheelers can provide in urban transport, there are significant challenges ahead. It was indicated that many two-wheeler riders have shifted from public transportation use. Low public transport ridership in turn means lower investment in the sector, and creates a vicious cycle that can lead to even high levels of two-wheeler use. The data from Pune indicates that over time, two-wheeler use may lead to a lifetime preference for private motorization.

4.2.1 Emissions and Air Pollution

The lack of relevant and applicable standards for two-wheeler emissions means that two-wheelers are significant contributors to air pollution across Asia. Despite significant advances in vehicle emission control technology in the past several decades, these changes have not been applied to two-wheelers globally and in some cases, two-wheelers can be more polluting than much larger vehicles.

However, it is possible to implement and enforce new regulations in order to address these concerns, important given the growing usage of two-wheelers and the potential for negative health effects not just on riders, but for all residents in cities. These new regulations and programs can include:

- Tighter emissions regulations for new and in-use vehicles
- Emissions inspection programs
- Stricter fuel standards
- National level awareness of air quality management
- Mobile inspection stations
- Public Awareness Campaign
- Health Impacts Assessment

4.2.2 Road Safety
Road safety is one of the most important public health issues in today’s world. Just as many emissions technologies and standards are not designed for high levels of two-wheeler use, many road design guidelines also do not take two-wheelers into account. Addressing major road safety concerns requires action from at least three areas: education, enforcement and engineering.

Enforcing licensure laws and ensuring access to drivers’ education can help to significantly reduce the number of accidents. Poor driver education for two-wheeler users can later lead to poor driver behaviour for automobiles, which in many places cause a disproportionate number of accidents compared to their mode share. In Vietnam driver behaviour and human error is deemed to be a major contributing factor to road traffic accidents, leading to over 97% of accidents (73% caused by motorcyclist error, 24% by automobile driver error including buses and trucks) (Hung & Huyen, 2011).

Mandating and enforcing helmet usage has also been shown to have significant road safety effects. Vietnam implemented a mandatory helmet law in 2007 and compliance has been maintained at 90% and above in major urban areas among adults, though use among children is still low, closer to 30 percent compliance (WHO, 2006), showing the importance of proper sanctions for responsible adults. The National Transportation Safety Committee reported that 1,557 lives were saved in 2008, the first year of implementation, as compared to 2007 (Passmore, 2012). Helmet laws have also led to reductions in motorcycle related deaths by up to 30 percent in Malaysia and the United States (WHO, 2004).

Beyond education and enforcement, attention to the unique context of developing cities, including narrow streets and inadequate infrastructure, and high mode shares for pedestrians and two-wheelers, can help address the issues from a design perspective. Taipei, Taiwan, the city with the highest two-wheeler density in the world even despite high levels of automobile ownership, has taken steps to design streets with motorcycle-specific traffic management policies. These include two-stage left turns for two-wheelers, specific waiting zones in front of cars to take into account their faster acceleration from a stop, and separated motorcycle lanes on some major roads (Chang, 2012).

4.2.3 Congestion and Restrictions on Two-Wheelers

Severe traffic congestion has led to some cities banning two-wheelers outright because they are seen as major contributors to the problem. The city of Guangzhou, China banned motorized two-wheelers within the city limits officially in 2007 after beginning with a gradual ban in the early 1990s. Many former two-wheeler users, however, shifted to private automobiles because the public transport network did not have adequate capacity to accommodate the new potential users. In the end, congestion in the city increased, and also led to new unregulated paratransit services (Pai et al., 2014). In Pune in 2009, the Traffic Department considered banning vehicle traffic in core areas of the city, and plans were discussed including higher
parking charges, congestion charges, and more widespread bans on two-wheelers (Pai et al., 2014).

There is also ambiguity about the congestion impacts of two-wheelers. In planning, two-wheelers are often considered to be equivalent to automobiles in Passenger Car Unit equivalent tables (PCUs), which is not the case. Recent reports conclude that bicycles and two-wheelers are the most efficient users of road space, after buses and pedestrians (ITDP, 2009). Instead of bans on two-wheelers, traffic management strategies and measures to mitigate congestion should also be focused on private, single-occupancy automobiles, and taxis, which often cruise while empty looking for a fare.

### 4.2.4 Parking and Public Space

Parking is a contentious issue in urban areas given the limited space available. Often considered to be private use of a public space, drivers are often loathe to pay for parking. In developing cities, particularly for two-wheelers, parking charges can be thought to be an undue hardship on vulnerable and low-income users, as was the case in Pune, India, leading to a repeal of parking fees. In reality, however, many two-wheeler users in Pune also own an automobile, and would be able to pay parking fees and other costs associated with the externalities of its use.

Implementing and enforcing parking fees, particularly in congested areas or important public spaces, can help force users to pay for the full cost of their use and the impact on the wider society. Low or non-existent parking fees encourage higher levels of two-wheeler use. Parking problems and road congestion have led to the Pune Municipal Corporation to study trends more closely in order to frame policy and find solutions to the city’s traffic and parking problems. While in some cities, two-wheeler users may be a more vulnerable population, the study in Pune makes it clear that this is not the case in all cities.

### 4.2.5 Aspirations and Societal Pressure

A major challenge in addressing not only two-wheeler usage, but sustainable transport as a whole, is the aspiration towards private automobile ownership. In places where automobile ownership is a status symbol, or even a prerequisite to marriage, private motorization is not just an issue of mobility. In these contexts, providing alternative modes of transport is not enough; other awareness and educational programs may need to be undertaken to shift societal perceptions and norms.

In terms of existing two-wheeler motorization, care must be taken that high mode shares do not engender a lifetime preference for private motorization. Many people have only recently shifted modes, so attention must be taken to improve public transportation and non-motorized transport facilities, and to work with the public to promote them.
4.2.6 Lack of Alternative Modes

Cities lacking substantial public transport face a challenge in developing a safe, efficient, clean and comprehensive system quickly before private motorization becomes the norm. Challenges in building robust and attractive public transportation and non-motorized transport networks are not only technical, but also lay in relationship building, legitimacy and politics.

5. Conclusion

It is clear that while two-wheelers play an important role in many people’s livelihoods around the world, there are significant challenges in making them part of sustainable transportation networks. Like other transport systems in the developing world, two-wheelers have gained a foothold because of a lack of attractive alternatives, including a comprehensive and formal public transport system, or provisions for non-motorized transport. The use of two-wheelers represents freedom, mobility and a growing economic power, but the rapid growth in usage has led to concerns including air pollution, congestion and traffic accidents.

Many of these same problems stem from a lack of policies and regulations for two-wheelers that recognize the unique and distinct needs of developing cities. Moving forward, the high mode share of two-wheelers, particularly in Asian cities, must be addressed, but present safety concerns must also be mitigated. The widespread usage makes it compulsory to comprehensively and immediately address safety concerns not only by user-directed tactics such as compulsory helmet use, but also by designing roads, vehicles and policies that make cities safer for two-wheeler users. Given the significant differences in usage patterns, and safety requirements, it is vital that two-wheelers be considered separately from private automobiles when designing policies and urban transport systems. Understanding the needs and aspirations of current two-wheeler users will also contribute to building stronger and more sustainable mass transport systems.

The use of two-wheelers in developing Asian cities stands apart from that of developed cities, where they are primarily a recreational vehicle and cater to a niche market. In the developing world, two-wheelers have the opportunity to be a substitute for private automobiles for individuals or businesses requiring ultimate flexibility in their travel. They can complement quality mass transport systems by providing flexibility in first and last mile transport. They take up significantly less road space than traditional automobiles, meaning that more space could be transferred back for the public good. With the appropriate attention and investment, emissions controls can be implemented as they have for automobiles. With careful attention to building appropriate policies and programs, and enforcing them, the rapid growth of private motorization can be addressed, and two-wheelers can become complementary component of a quality sustainable transportation network that relies on a backbone of public and non-motorized transportation.
6. References


Pai, M. 2009. 12 Indian Cities: Transport Indicators. Clean Air Initiative. , Prepared for EMBARQ as part of the SUMA Project.


STRATEGIES FOR INTEGRATED URBAN AND TRANSPORT DEVELOPMENT IN MOTORCYCLE DEPENDENT CITIES – A CASE STUDY IN HO CHI MINH CITY, VIETNAM

MSc. Nguyen Thi Cam Van¹, Dr. Vu Anh Tuan²

Abstract

In developing Asian countries, urban transport systems are currently being dominated by motorcycle mode, which is causing problems of traffic congestions, accidents, and pollution. The use of motorcycles may have contributed to increased urban sprawls and challenge the development of new public transport systems. To solve the problems, it is required to improve the integration between urban and transport development through formulating and implementing long-term strategies. This study aims to understand the urban and transport development processes, review the implemented strategies, and formulate a specific concept for integrating urban and transport development in such so-called motorcycle dependent cities. It also examines the possibility of applying the developed concept to Ho Chi Minh City, a typical motorcycle dependent city. Strategies for a better integration are discussed.

Keywords: Motorcycle Dependent Cities, Urban Transport, Integrated Urban and Transport Development, Integration Strategies.

1. Introduction

Many developing Asian cities are facing urban transport problems, and their socioeconomic and environmental impacts are critical (Barter, 1999). Urban transport problems are generally caused by rapid population growth, overcrowded urban cores, inadequate road networks, high private transport modes usage and ownership, spatial mismatches between housing and jobs, deteriorating environmental conditions, and economic losses from extreme traffic congestion (Cervero, 2013). In many South and Southeast Asian cities, since the urban form is mostly unwell structured and highly dense, motorcycle appears to be the most effective and popular mode of transport. The term “Motorcycle Dependent Cities” (MDCs) is being used to describe the specific situation of high motorcycle ownership and intensive use (Khuat, 2006).

The high density and mixed land-use urban structure presents both challenges and opportunities to transport development in the cities. High traffic volume and limited

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road spaces make most Asian cities extremely vulnerable to traffic and its problems such as noise, emissions, and other vehicle impacts. However, the dense urban areas can support a potentially strong role for public transport, walking and non-motorized transport, presenting opportunities for long-term transport development (Barter and Kenworthy, 1997).

Clearly, urban and transport development has been mutually influenced each other. Transport planning is a basic and crucial element in urban planning. Transport systems are developed to enable urban developments. On the one hand, if transport development cannot support urban development and unmeet increased travel demand, problems of traffic congestion, accident and pollution will occur, thereby slowing down urban developments. On the other hand, urban development is a driving force for transport development. The requirement to speed up urban development calls for increased investment in transport system.

In recent years, there has been much interest among urban and transport planners in integrating urban transport development and land-use planning. This is very much driven by sustainability concerns. Planning for sustainable development calls for an integration of land-use and transport to create a compact city which limits automobile use and encourages walking, cycling, and public transport (Ong et al., 2009). In every city, it is necessary to understand the relations between urban and transport development and find out strategies to enhance and support those relations. Such strategies have to focus on overcoming challenges and exploiting opportunities in order to address urban and transport problems for a sustainable integration between the two.

Over years, transport studies in Asian cities did achieve meaningful results in generalizing urban transport characteristics and its impacts on urban and socioeconomic development. Also, there are recommendations for efficient urban transport development and management drawn from the studies. However, there are a limited number of studies on the urban and transport development process in MDCs. Therefore, this study aims to understand the urban and transport development process and implemented strategies in selected MDCs. It helps to formulate strategies for effectively integrating urban and transport development in those cities.

The paper consists four parts. The second part presents the methodology for doing the study and necessary data for fulfilling the study objectives. In the third part, the integration concept and strategies are formulated based on case studies in several MDCs. The fourth part introduces an initial analysis of the application of the concept and strategies to Ho Chi Minh City (HCMC) with a focus on the corridor of Urban Mass Rapid Transit (UMRT) Line 1. The last part concludes and recommends policy direction.
2. Methodology and data

This study is based on an empirical approach. Firstly, through literature review, the term “integrated urban and transport development” is defined. Ways of the integration are also explained. Then, an attempt is made to analyze urban and transport development process and implemented strategies in a number of MDCs. The case studies include Taipei, Jakarta, Bangkok and HCMC. Some indicators showing trends of urban and transport development are analyzed. Lessons from these cities are useful references to identify potentially effective strategies for integrated urban and transport development in MDCs. Next, a concept for the integration is formulated specifically for MDCs. Finally, the considered strategies are examined for the case of HCMC with a focus on a typical UMRT corridor to see how they may have impacts on developing the areas.

In this study, analytical parts follow the mainstreams of how the integration between urban and transport development is defined, what strategies have been applied to realize the integration in the context of selected MDCs? The following sections present definitions of the integration and strategies to achieve it.

2.1. Definitions of integrated urban and transport development

Transport is one contributor to the effective running of businesses, industries and communities. Integrated planning is an approach that seeks to pull together all the contributing elements to increase the effectiveness of delivered solutions. Integration allows individual activities to be coordinated to achieve the best solutions to meet the ongoing needs of people and communities, and to achieve value for money. Decisions about transport systems, the form of urban development and how land is used all impact each other. Integrated urban and transport planning – an approach that takes account of and connects all these considerations – helps ensure that transport network development and land use development are coordinated. It ensures the most efficient use of public funds and avoids creating unintended impacts (New Zealand Transport Agency, 2011).

There are several definitions of the integrated urban and transport development. For example, Tornberg (2011) defined that the integrated approach is referred to the extent to which publicly mandated efforts to influence the spatial structures of society, and urban areas in particular, are characterized by considerations of the inter-linkages between the perspectives of those responsible for urban and transportation development. According to Kidd (2007), integrated urban and transport development refers to the horizontal “joining up” of different public policy domains and their associated actors within a given territorial area”, it may also apply to other dimensions, such as the vertical relationship between territorial units, e.g. local and national administrative levels, or the organizational relationship between different parts of a strategy-making process in different initiatives or programs.
In short, integrated urban and transport development is a development process that takes into account of and coordinate all planning of transport networks, the forms of urban development and land allocation to archive sustainable urban development. The integration is planned and implemented on four levels. These include: (1) Integration between policy instruments involving different modes; (2) Integration between policy instruments involving infrastructure provision, management, information and pricing; (3) Integration between transport measures and land-use planning measures; and (4) Integration with other policy areas such as health and education (May et al., 2006).

2.2. Strategies for the integration

Strategies for integrated urban and transport development can be grouped into 6 bundles as follows (May et al., 2006).

(1) Land-use planning and control include zoning, land allocation, density requirement, height control, etc.,

(2) Infrastructure provision includes constructing new roads, road improvements, parking supply, park and ride facilities, etc.,

(3) Public transport and non-motorized transport promotion includes constructing new MRT, LRT, BRT, new stations, bus route restructuring, bus dedicated lane, driver route guidance and information, passenger information, pedestrian streets, etc.,

(4) Traffic management and regulations include traffic control, one-way streets, truck management, on-street parking control, parking management, car sharing, etc.,

(5) Attitudinal change includes public awareness and education,

(6) Pricing and taxation include parking charges, road pricing, fuel price, environmental taxes, etc.

3. Concept of integrated urban and transport development for MDCs

Every city has its own development process, which is affected by the city’s socioeconomic characteristics, urbanization process, and infrastructure development. However, this study analyses the development processes and characteristics of selected MDCs with an intention to seek for similarities and differences. Understanding of these may help to develop a good concept of integrated urban and transport development for MDCs. Studied cities include Taipei, Bangkok, Jakarta, and HCMC, where motorcycles commonly dominate transport system of these cities.
3.1. Overview of urban and transport development trends

Table 1 shows key urban development indicators in the studied MDCs over the past 20 years. The trends and characteristics are summarized as follow.

Table 1 – Key indicators of urban and transport development

<table>
<thead>
<tr>
<th>Indicators</th>
<th>City</th>
<th>1990</th>
<th>2000</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRP per capita (2005 US$, PPP)</td>
<td>Taipei</td>
<td>13,243</td>
<td>25,822</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Jakarta</td>
<td>1,837</td>
<td>5,197</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bangkok</td>
<td>6,322</td>
<td>7,184</td>
<td>8,419</td>
</tr>
<tr>
<td></td>
<td>HCMC</td>
<td>1,365</td>
<td>2,800</td>
<td></td>
</tr>
<tr>
<td>Area (ha)</td>
<td>Taipei</td>
<td>27,200</td>
<td>27,200</td>
<td>27,200</td>
</tr>
<tr>
<td></td>
<td>Jakarta</td>
<td>658,000</td>
<td>658,000</td>
<td>658,000</td>
</tr>
<tr>
<td></td>
<td>Bangkok</td>
<td>156,870</td>
<td>156,870</td>
<td>156,870</td>
</tr>
<tr>
<td></td>
<td>HCMC</td>
<td>209,370</td>
<td>209,370</td>
<td>209,370</td>
</tr>
<tr>
<td>Population (inhabitants)</td>
<td>Taipei</td>
<td>2,711,000</td>
<td>2,550,000</td>
<td>2,600,000</td>
</tr>
<tr>
<td></td>
<td>Jakarta</td>
<td>17,000,000</td>
<td>21,500,000</td>
<td>27,939,000</td>
</tr>
<tr>
<td></td>
<td>Bangkok</td>
<td>5,882,400</td>
<td>6,355,100</td>
<td>8,081,000</td>
</tr>
<tr>
<td></td>
<td>HCMC</td>
<td>3,924,000</td>
<td>5,034,058</td>
<td>7,396,500</td>
</tr>
<tr>
<td>Population density (inhabitants/ha)</td>
<td>Taipei</td>
<td>100</td>
<td>94</td>
<td>96</td>
</tr>
<tr>
<td></td>
<td>Jakarta</td>
<td>26</td>
<td>33</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>Bangkok</td>
<td>37</td>
<td>41</td>
<td>52</td>
</tr>
<tr>
<td></td>
<td>HCMC</td>
<td>19</td>
<td>24</td>
<td>35</td>
</tr>
<tr>
<td>Road density (m/ha)</td>
<td>Taipei</td>
<td>53.30</td>
<td>56.70</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Jakarta</td>
<td>98.30</td>
<td>96.50</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bangkok</td>
<td>24.30</td>
<td>26.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td>HCMC</td>
<td></td>
<td>21.35</td>
<td></td>
</tr>
<tr>
<td>Road length/population (m/1,000 inhabitants)</td>
<td>Taipei</td>
<td>545.60</td>
<td>587.80</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Jakarta</td>
<td>756.90</td>
<td>659.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bangkok</td>
<td>686.50</td>
<td>717.60</td>
<td></td>
</tr>
<tr>
<td></td>
<td>HCMC</td>
<td></td>
<td>604.32</td>
<td></td>
</tr>
<tr>
<td>No. of buses/population (bus/million inhabitants)</td>
<td>Taipei</td>
<td>1038.00</td>
<td>1549.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Jakarta</td>
<td>1405.30</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bangkok</td>
<td>1477.10</td>
<td>1193.50</td>
<td></td>
</tr>
<tr>
<td></td>
<td>HCMC</td>
<td></td>
<td>403.97</td>
<td></td>
</tr>
<tr>
<td>Private cars (veh./1,000 inhabitants)</td>
<td>Taipei</td>
<td>143</td>
<td>211</td>
<td>220</td>
</tr>
<tr>
<td></td>
<td>Jakarta</td>
<td>60</td>
<td>240</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bangkok</td>
<td>110</td>
<td>350</td>
<td></td>
</tr>
<tr>
<td></td>
<td>HCMC</td>
<td>26</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Motorcycle (veh./1,000 inhabitants)</td>
<td>Taipei</td>
<td>220</td>
<td>362</td>
<td>400</td>
</tr>
<tr>
<td></td>
<td>Jakarta</td>
<td>100</td>
<td>700</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bangkok</td>
<td>120</td>
<td>400</td>
<td></td>
</tr>
<tr>
<td></td>
<td>HCMC</td>
<td>312</td>
<td>624</td>
<td></td>
</tr>
</tbody>
</table>

Sources: Rujopakarn, 2003; Huang et al., 2009; Chen and Lai, 2011; Asri and Hidayat, 2005; Susilo et al., 2007.

Urbanization and population growth

Urbanization is one of the most significant issues facing the Asia – Pacific region (Kenworthy and Laube, 2000). Over the past two decades, the MDCs experienced rapid population increases except Taipei. Among these cities, HCMC has the highest
population growth. Its population nearly doubled over the period. Accompanying population increase is the rapid growth in GRP per capita, for examples, it tripled in Jakarta and doubled in Taipei and HCMC. The fast urbanization and high economic growth have increased urban travel demand.

Road network

Road infrastructure has slightly increased in terms of road density and road length per 1,000 inhabitants. In Taipei, road density increased from 53.3 m/ha in 1990 to 56.7 m/ha in 2010. In Bangkok, the figure also slightly increased from 24.3 m/ha (1990) to 26 m/ha (2010). In Jakarta, road density and road length per population, however, decreased during the last two decades. However, HCMC experienced a significant increase in road density and road length per population due to continuous investment in the sector. During a period of 2000-2010, road density and road length per population increased by 3.5 times and 2.4 time, respectively. However, since the population of HCMC increased more rapidly, road length per 1,000 inhabitants during the period (2000-2010) increased only 2.4 times. Despite the improvement, road supply levels seem to be much lower than that of the developed cities, and hence the road systems in the MDCs are very vulnerable to the growth in private vehicle ownership and use.

Public transport

During the past 20 years, the public transport systems have been investing to increase capacity and quality of the service. Among the four cases, Taipei, Jakarta and Bangkok already introduced bus, BRT, and MRT systems. HCMC is now constructing the first UMRT line and doing a feasibility study for the first BRT line.

In Taipei, the number of buses had increased from 1,038 bus/million inhabitants in 1990 to 1,549 bus/million inhabitants in 2010. The first MRT line came into operation along with a grid-type bus-lane network in 1996. Since then, the length of Taipei’s MRT network expanded from 10.5 km to 74.4 km with six lines in 2007 (Chen and Lai, 2011).

In Jakarta, the figure is 1,405 bus per million inhabitants. Besides conventional buses, Jakarta also has a BRT network with the first route (12.9 km) began operating in the beginning of 2004. Since then, the government of Jakarta city has continued constructing other BRT lines. Currently, there are 13 lines (200 km) in operation and 3 lines under plan. In addition, the city started a construction of the first MRT in October 2013 (Rukmana, 2014).

In Bangkok, the number of buses per million inhabitants decreased from 1,477 (1990) to 1,193 (2010) due to the removal of some bus routes and the population growth. The city opened the first BRT line in 2010 with a length of 16 km. Bangkok operated the first MRT line since 1999 and the city has 3 MRT lines (72 km) by 2010. The city is still continueing expanding the MRT network to serve the demand.
In HCMC, there are currently 403 buses per million inhabitants. This figure is very low as compared to that of the other cities. Bus system meets about 7% of the total travel demand in the city. The city is planning the first BRT and constructing the first MRT line. The planned MRT network includes 8 lines crossing whole city and is expected to be completed in 2020 (HCMC Transport Master Plan, 2013).

**Private motorcycle and car ownership**

Urban population and economic growths have contributed to increasing demand for passenger and freight transport. As a result, most of the MDCs have experienced an increasing trend of motorization. HCMC and Jakarta have the highest motorcycle ownership rates, more than 600 and 700 motorcycles/1,000 inhabitants, respectively. Although Bangkok has a lower motorcycle ownership rate (400 motorcycles/1,000 inhabitants) but has the highest private car ownership rate among the four cities. The development of elevated highways and expressways to relieve road traffic congestions seem to encourage the growth of private cars.

**Urban form**

Taipei’s urban form has changed over time. The city used to be a harbor town. During 1895-1945, it was planned to have the grid urban form and became centralization. During 1945-1985, the city became decentralization. From 1985 to 1995, Taipei experienced a mutation of urban sprawl. After the rapid economy growth for twenty years, the real estate business became popular and the urban development was driven by the opportunistic private developers. At that time, a dyke along the river embankment was constructed to prevent flooding in Taipei area. An expressway was also constructed on top of the dyke. The extension of highway, along with the embankment expressway, tended to transform the city to automobile oriented. In 1985, SOGO Pacific department store was opened. The area was called as ‘East District’ which showed the location difference to the old city centre. For a period of 1995-2009, a ‘Dual-core city structure’ was proposed for the city centrality. Hsinyi District, located on the east of the East District, was proposed by the government to be a new CBD. The metro reinforces the connection between the old city centre, East District and Hsinyi district (Huang et al., 2009).

In Jakarta, it has seen a rapid growth of suburban areas in Jakarta during early 1990s with the increasing of large-scale housing projects for moderate and high-income families (Leaf, 1994). The new towns were still heavily dependent on the central city and the development of large-scale housing projects intensified the daily interaction between the fringe areas and the central city of Jakarta. This worsened the traffic problems in metropolitan Jakarta (Firman, 1999). The periphery of Jakarta is also made up of specialized zones of commercial and industrial enterprises. In the peripheries of the megacity of Jakarta, agricultural areas and forests were massively converted into industrial estates, large-scale subdivisions and new towns (Firman, 1999; Silver, 2007).
Bangkok was a city developed along the riverbanks of the Chao Phraya river. During 1900-1960, urbanization happened without proper planning regulation unceasingly accompanied road construction, resulting in the ribbon development. In the Land-Use Plan 1999, the city targeted to improve mobility and accessibility with a moratorium on new road construction, develop transit zones and centers, expand central business district, and create new metropolitan sub-centers. Clearly, the city has been transforming into a policentric urban struture to solve the transport problems and contribute to sustainable development (Rujopakarn, 2003).

HCMC also developed from a city along Saigon riverbank. When the French came (1860-1945), the city was well planned in a grid form with specific areas for administrative, commercial, residential purposes. When the American came and overtook the French (1954-1975), there was a huge immigrants from rural areas to the city due to the military purpose. The city received huge investment to build luxury hotels, high-rise buildings, mordern factories, etc., and the road network was constructed widely (Nguyen, 2010). After the independence in 1975, the city started to recover after the war, economic development was the priority of the city. When Doi Moi (the economic reform in Vietnam since 1986) was implemented and had strong effects on socioeconomic development, the housing development industry emerged in response to the housing demand. New housing estates built mostly in the peripheries where vacant green lands are available (Waibel, 2006). The city has been sprawled while infrastructure system has not been constructed adequately.

In conclusion, the MDCs have shared similarities in terms of rapid population growth, high urbanization, and heavy dependence on motorcycle. Despite of the fact that car ownership and use are increasing rapidly, motorcycle ownership and use still remain dominant in urban transport system. It associated problems (e.g., congestion, accidents, and pollution) are threatening sustainable development of the cities in the long term. Although each city has implemented its own strategies to develop urban facilities and urban mass transit systems, the problems are still worsening and thus require more aggressive and long-term solutions.

### 3.2. Review of implemented strategies

The present situation and issues of urban transport in the MDCs are, of course, the result of the policy-making and strategy implementation. By reviewing implemented strategies and perceived results, it is good to learn from the experiences and determine potential strategies for integrating urban and transport developments in the MDCs. Table 2 summarizes the strategies under 6 categories.

<table>
<thead>
<tr>
<th>Strategy bundle</th>
<th>Strategy</th>
<th>Jakarta</th>
<th>HCMC</th>
<th>Singapore</th>
<th>Taipei</th>
<th>Bangkok</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Increased tax and registration fee on private vehicles</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>II</td>
<td>Encourage people to use more public transport</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>III</td>
<td>Awareness building for private vehicle users</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>IV</td>
<td>Attitudinal change</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>V</td>
<td>Traffic management and regulations</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>VI</td>
<td>Creating walking streets/zones</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>VII</td>
<td>Transit friendly intermodal system</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>VIII</td>
<td>Free feeder bus systems</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>IX</td>
<td>Exclusive bus lanes</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>X</td>
<td>Van transit system</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>XI</td>
<td>Using community vehicles</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>XII</td>
<td>Integrated fare system</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>XIII</td>
<td>Constructing new MRT/LRT/BRT</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>XIV</td>
<td>Public transport and non-motorized transport promotion</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>XV</td>
<td>Organizing head-start waiting zones for motorcycles</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>XVI</td>
<td>Organizing motorcycle exclusive lanes</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>XVII</td>
<td>Providing park and ride/ bike and ride facilities</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>XVIII</td>
<td>Transit oriented development (TOD)</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

Table 2 – Urban and Transport Management and Development in MDCs
3.2. Review of implemented strategies

The present situation and issues of urban transport in the MDCs are, of course, the result of the policy-making and strategy implementation. By reviewing implemented strategies and perceived results, it is good to learn from the experiences and determine potential strategies for integrating urban and transport developments in the MDCs. Table 2 summarizes the strategies under 6 categories.

Table 2 – Urban and transport management and development strategies in MDCs

<table>
<thead>
<tr>
<th>Strategy bundle</th>
<th>Taipei</th>
<th>Jakarta</th>
<th>Bangkok</th>
<th>HCMC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>I  Land-use planning and control</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Changing the urban form from monocentric to polycentric structure while remaining the mixed land-use pattern</td>
<td>x</td>
<td></td>
<td></td>
<td>plan</td>
</tr>
<tr>
<td>2 Transit oriented development (TOD)</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td><strong>II  Infrastructure provision</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Constructing new highways</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>2 Improving existing highways</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>3 Supplying parking places to meet the demand</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>4 Providing park and ride/ bike and ride facilities</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 Organizing motorcycle exclusive lanes</td>
<td>x</td>
<td></td>
<td></td>
<td>plan</td>
</tr>
<tr>
<td>6 Organizing head-start waiting zones for motorcycles</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 Organizing bicycle exclusive lanes</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td><strong>III  Public transport and non-motorized transport promotion</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Constructing new MRT/LRT/BRT</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>Under construction</td>
</tr>
<tr>
<td>2 Improving public transport services</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>3 Providing information on public transport service</td>
<td>x</td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>4 Integrated fare system</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>5 Using community vehicles</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 Van transit system</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 Exclusive bus lanes</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 Free feeder bus systems</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>9 Transit friendly intermodal system</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 Creating walking streets/zones</td>
<td></td>
<td></td>
<td></td>
<td>x plan</td>
</tr>
<tr>
<td><strong>IV  Traffic management and regulations</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Controlling on-street and sidewalk parking</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Controlling &amp; limiting new private vehicle registration</td>
<td>2003-2005</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Controlling and limiting private vehicle usage</td>
<td>plan</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 Prohibiting motorcycle rides on highways</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>5 Limiting/prohibiting private vehicle use in city centre/some main streets</td>
<td>plan</td>
<td></td>
<td></td>
<td>x plan</td>
</tr>
<tr>
<td>6 Managing motorcycle taxi service</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>7 Helmet wearing</td>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>8 Emission/fuel standard/tax</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>plan</td>
</tr>
<tr>
<td>9 Vehicle inspection and maintenance system</td>
<td>x</td>
<td>x</td>
<td></td>
<td>plan</td>
</tr>
<tr>
<td>10 Shift from two- to four-stroke motorcycles</td>
<td>x</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td><strong>V  Attitudinal change</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Awareness building for private vehicle users</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>2 Encourage people to use more public transport</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td><strong>VI  Pricing and taxation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Increased tax and registration fee on private vehicles</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>2 Increased parking fees</td>
<td>x</td>
<td>x</td>
<td></td>
<td>plan</td>
</tr>
<tr>
<td>3 Congestion charge in the city centre</td>
<td></td>
<td></td>
<td></td>
<td>plan</td>
</tr>
</tbody>
</table>

The implementation of strategies in each city has significantly contributed to the development of the city’s transport system. To improve efficiency of mass transit systems, particularly railways, Taipei, Jakarta and Bangkok have been planning and controlling land-uses around railway stations to help promote the TOD concept. But, the new highways have contributed to faster suburbanization and urban sprawls, which in turn negatively affect mass transit ridership. In HCMC, it has planned to transform the city to the polycentric form by developing UMRT corridors and TOD model around the stations. To integrate with private vehicles and further support the...
development of mass transit system, these cities have provided Park-and-Ride facilities at transit stations. Taipei has invested in bus system with exclusive bus lanes and free feeder bus systems to enhance the efficiency and attractiveness of the overall transit system. In Bangkok, there is a van transit system, which is very effective in commuting passengers from suburban areas to the city center. This might be a good strategy to learn and apply in other cities given the fact that MRT system is still limited and bus system is overcrowded. In addition, the cities have also implemented strategies to control the use of private modes to support public transport development and enhance traffic safety. It is worthwhile noting that limiting new private vehicle registration might be failed, for example, Hanoi City implemented this policy from 2003 to 2005, but it was in conflict with the ownership right of the people and thus was abolished.

For a sustainable long-term development, it is very important to integrate land-use planning and control, public transport development, and private transport control to create synergic effects. To achieve the integrated urban and transport development, a bundle of strategies need to be formulated comprehensively to harmonize, minimize and avoid conflicts between the strategies. For example, providing parking spaces in crowded city centre are necessary to meet the demand. However, this policy somehow encourages private motorization. Therefore, strategies should be carefully studied and formulated to avoid conflicting goals and promote synergy.

3.3. A Proposed concept of integration for MDCs

The analysis above is a solid foundation for the formulation of a concept of integrated urban and transport development for HCMC, a typical MDC. A new concept can be explained below, and the future transport system and the role of each transport mode are properly defined.

Urban form of the MDCs should be transformed from monocentric to polycentric structure while remaining the mixed land-use pattern. The urban transport network need to be hierarchical with MRT lines connecting the city centre to satellite cities. MRT systems include rail-based MRT, LRT, and BRT, play the role of trunk lines along the main corridors and strongly supported by bus system, motorcycle (including motorcycle taxi), taxi, and bicycle as feeder modes. Along each of the MRT corridor, motorcycle use has to be prohibited in order to support the converting of the motorcycle to feeder mode. Parking facilities at the stations should be well developed. Walking conditions need to be improved to enhance accessibility to public transport. Integrated urban and transport development can be achieved only when policies for promoting mass transit and non-motorized transport and controlling motorcycle use are implemented at the same time (Vu, 2012). It is important to note that by implementing the integrated strategies for each of the transport corridor, the integration can be achieved for the whole network.
4. The Application for HCMC UMRT Line 1

The city plans a rail-based UMRT network of 8 lines with a total length of 172 km (HCMC Transport Master Plan, 2013). By applying such a concept of integration and implementing strategies for land-use planning/control and mobility management along the UMRT corridor, it is expected to encourage further modals shift from motorcycle and car to public transport, thus contributing to mitigating the transport problems. This part overviews the corridor and examines the possibilities of the application to the corridor.

4.1. Overview of the UMRT Line 1

The UMRT Line 1 is the first line under construction in HCMC, construction started in 2012 and expected to be operational in 2018. Total length of the line is 19.7 km, including 2.6 km underground and 17.1 km elevated, and 14 stations. The project is being funded by Japanese ODA loan with a total cost of nearly US$ 2.5 billion (MAUR, 2007).
4.2. Urban developments along the UMRT corridor

HCMC planned to develop four satellite cities in the east, west, south and north while remaining city centre as the core with high density (HCMC Construction Master Plan, 2010). The city is planned in polycentric urban form with MRT lines and highways connecting the existing centre to the satellite cities (Figure 3).
The Construction Master Plan indicates the basic development direction of the planned area, including the basic land-use concept, urban structure and location of major infrastructures. In order to control urban development around the stations, there is a need to develop an effective zoning plan that incorporates the TOD concept. Figure 4 shows such a future plan for UMRT Line 1.

4.3. Integrating UMRT Line 1 with other transport modes and land-uses

UMRT Line 1 covers various urban land-uses from the CBD to suburban areas, and thus is expected to bring a lot of opportunities for urban development along the corridor. Different land-uses at station areas require an adequate development approach to fit the appropriate socioeconomic activities and for peoples’ mobility, while the line is expected to encourage the development and formation of the “UMRT Corridor” in an integrated manner. The formation of urban transport nodes in conjunction with station area development is illustrated in Figure 5.
The plan also considers urban and transport development aspects of specific areas along the corridors simultaneously to ensure the integration (Table 3).

Table 3 – Urban and transport development of the UMRT Line 1 corridor

<table>
<thead>
<tr>
<th>Area</th>
<th>Urban Development Aspect</th>
<th>Urban Transport Aspect</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBD Area</td>
<td>- Promote station area development such as the Ba Son shipyard or Tan Cang port area</td>
<td>- Provide adequate feeder bus services by the rerouting of existing bus routes</td>
</tr>
<tr>
<td>District 2 Area</td>
<td>- Promote the Sports City Development</td>
<td>- Promote seamless transfers at Tan Cang station to buses</td>
</tr>
<tr>
<td>Thu Duc and District 9 Area</td>
<td>- Promote and lead station area development by using the concept of TOD</td>
<td>- Provide adequate feeder bus services</td>
</tr>
<tr>
<td></td>
<td>- Provide organized urban lands ahead of urbanization to prevent sprawl</td>
<td>- Rerouting of existing bus routes on the overlapping section with the UMRT Line 1</td>
</tr>
<tr>
<td>University and High-Tech Park Area</td>
<td>- Promote the master plan of national university and High-Tech Park</td>
<td>- Develop station plazas</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Provide parking facilities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Promote the seamless transfer at Rach Chiec Station to BRT 1</td>
</tr>
<tr>
<td>Suoi Tien Terminal Area</td>
<td>- Promote and lead station area development by using the concept of TOD</td>
<td>- Promote the seamless transfer at Suoi Tien Terminal Station to BRT/buses</td>
</tr>
</tbody>
</table>

Source: SAPI, 2014

4.4. Mobility management along the corridor to support the integration

To support the realization of the integration concept along the UMRT Line 1 corridor, it is vital to manage mobility needs along the corridor. Mobility management strategies focus on organizing feeder services and intermodal transfer facilities in the station plazas and controlling and managing motorcycle use along the corridor.

Organizing feeder services

To expand the ridership catchment area of UMRT Line 1 and improve its service quality, it is vital to provide feeder services. To do so, the road network along the corridor has to be improved and structured hierarchically to accommodate the planned feeder services.

Understanding the preferable access modes to the station is helpful for organizing feeder services. A stated preference (SP) survey on access mode choice is conducted under the SAPI study and the results are illustrated in Figure 6. People who are living and/or working along the corridor may choose different access modes depending on the access distance. Walking is mostly chosen within a distance of 800 m or shorter. Bicycle is also used, but with a limited number due to the fact that riding bicycle is currently perceived dangerous. Motorcycle and bus would be preferable modes for a distance beyond 800 m. Because bus and motorcycle seem to be competitive, it is important to carefully consider the local road network conditions to coordinate the supplies of these two services. Clearly, feeder bus service must be prioritized in areas...
where local roads are in good conditions for bus operation. Motorcycles can be used as an effective feeder mode in areas where the roads are still poor. Intermodal facilities, including bus and taxi bays in front of railway station and Park-and-Ride facilities, have to be well organized and integrated with urban developments around each of the stations.

![Figure 6 – Stated access mode choice to UMRT stations (N=3,691) (SAPI, 2014)](image)

**Controlling and managing motorcycle use along the corridor**

The SP survey shows that despite of the introduction of UMRT and feeder bus services, a large percentage of the commuters may still use motorcycle for daily commuting. Two scenarios are tested under the survey. In the first scenario, it is assumed that the respondents walk to the final destination. Having compared travel time and travel cost of the asked trip as given in seven alternatives, each respondent chooses his/her most preferable alternative. Figure 7 shows that 50.3% of the respondents might consider shifting to the MRT and still 49.7% might still use their current mode (10.5% keep going by bus and 39.2% still using motorcycle/car). In the second scenario, it is assumed that the respondents use the planned feeder bus to go to the final destination. As shown in Figure 8, there would be still 41.9% the respondents choosing “Motorcycle/car”, followed by “Motorcycle-MRT-Feeder bus” (19.6%) and “Feeder Bus-MRT-Feeder Bus” (18.7%). The share of “Conventional Bus” is 10.4%. “Xe om-MRT-Feeder Bus” is the least option (0.4%).

Therefore, it is necessary to control and manage the use of motorcycle along the corridor to encourage further modal shifts to public transport. Furthermore, for safety reason, motorcycle use on the Hanoi Highway would need to be banned completely or partially controlled. In addition, it is equally important to limit the usage of private vehicles to access to the city centre or CBD area. Strategies may includes: (1) increasing parking fees on motorcycle and car in the city centre, (2) issuing emission/fuel standard for motorcycle, and (3) organizing walking streets in the city centre.
The feeder services (i.e., bicycle, motorcycle, motorcycle taxi, taxi and bus) will surely bring a greater accessibility to the UMRT stations. The SP survey showed that the development of seamless transfer facilities and good connections with bus services at the railway stations is likely to increase the ridership by nearly 20% and fare revenue by more than 5% in 2020 (SAPI, 2014). The planned station area developments would play as a catalyst and provide opportunities for integration with urban activities surrounding the stations, thus contributing to the realization of the TOD concept.
5. Conclusions

This paper has reviewed the urban and transport development process in a number of selected MDCs. Based on the trends and implemented strategies, the paper suggests a specific concept of integrating urban development and transport development for the MDCs. Under the concept, MRT systems shall play a dispensable role in the integrated development. New towns and urban developments should be placed in proximity to the planned transit stations and being well connected to the station centers by diverse feeder services. The study stresses the importance of mobility management strategies in supporting the realization of TOD model along MRT corridors. Bus services, the current main public transport system in most MDCs, need to be continuously improved and expanded to complement and serve as a main feeder mode to the future MRT systems. In addition, it should aim to convert motorcycles from a main mode to a feeder mode of the planned MRT lines, especially where the local road networks are in poor conditions. By doing so, it is possible to make use of the advantages and address the challenges that the motorcycle may present to the sustainable development of a typical MDC in general and the development of new public transport systems in particular.

The implementation of integrated urban and transport development may encounter various challenges, such as a lack of coordination between land-use plans and transport plans, weak institutional capacity to coordinate and implement the urban and transport development plans. Such challenges will be addressed in a next step of this study project. It also recommends that further studies need to be done to fully understand urban and transport development process in a greater number of MDCs. Assessing the impacts of integrated urban and transport development on a city level should remain a future work.

6. Reference


ITS and HIDS, 2011. HCMC 21 - Towards a World Class Transit-Oriented Metropolis.

SAPI, 2013. Special Assistance for the Project Implementation for HCMC Urban Railway Project (Ben Thanh – Suoi Tien Section (Line 1)). Jica.
SUSTAINABLE POLICY FOR, AND ENVIRONMENTAL IMPLICATIONS OF, MOTORCYCLE OPERATION IN A HISTORICAL CITY, KANO, NIGERIA.

By
Abimbola Odumosu¹  Aminu Yusuf²  Bayero Farah³  Patrick Obi⁴

Abstract
Over the years, there has been an increase and significant growth in the volume of motorcycle use in many Nigerian cities including Kano. Kano city is an ancient city and commercial nerve of Northern Nigeria. Motorcycles are used both as a personal and “for hire” transport mode. The increase in the growth of motorcycle uses is partly in response to a vacuum created by declining public transport facilities.

However its operations in Kano city are synonymous with serious and fatal accidents and other environmental hazards.

Consequently, the objective of this paper is to highlight the comparison between the need and environmental degradation of motorcycle use in Nigerian cities, using Kano as case study.

Cordon Count and emission study were carried out. In addition, Focus Group Discussion (FGD), questionnaire administration and scheduled interview were also used.

Findings from the study revealed that from a total of 1,977,925 motorcycles that were counted within selected areas within Kano metropolis, the average Carbon monoxide emissions rate of 3.2% hydrocarbon emission rate of 4643 ppm and carbon dioxide at 4.37% with air coefficient of 1.12 were recorded. The health implications were notable.

Finally, Policy decisions are expected to be made on the establishment of emissions checking centres across the metropolitan Kano. Also Pollution Under Control (PUC) Certificate, should be introduced.

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1. Introduction

Motorcycle became a mode of public transportation in Kano state two decades ago. Before the advent of motorcycle for commercial use, various attempt were made at solving urban mobility problem. This did not yield desired result. Thus the emergency of the motorcycle into mainstream public transportation was seen by the public as a welcome development and a way to ameliorate urban mobility crisis.

However, in year 2002 the State Government bought two thousand five hundred motorcycles for the public to operate on commercial basis. Thus marked the beginning of the spread of its use to other town and cities in Nigeria notably Lagos, Kaduna, Sokoto and Katsina.

In Kano metropolis motorcycle use has assisted in providing employment opportunities to jobless youth in the city. Many of the youths are engaged in the operation of these modes of transport.

Its operation in Kano metropolis is chaotic, uncoordinated, and inefficient as a public transport. Their ability to travel on rough and bad roads contributed to the growth of their use for commercial purpose.

Kano city is an ancient city and commercial nerve of Northern Nigeria. Its transportation system cut across all modes of transport except by sea. These include; cars, trucks, buses, motorcycles, three wheelers and bicycle. The airport is used for domestic and international flights. The rail lines linked Kano to south and other parts of Nigeria.

The growth of motorcycle in Kano metropolis became noticeable in 1984. It was then seen as a major response of the government towards solving mobility problem in the city. Before then various attempt at solving urban mobility problem had not yielded the desired result. Thus the emergence of the use of motorcycle was seen by the public as a welcome development.

Motorcycles are used as personal and commercial purposes. Thus, its growth is because of ability to travel on bad road which is prominent in that area. Its referred to locally as Roba – Roba because of its flexible nature and ability to go to where public transport buses cannot navigate.

By year 2002 the number had risen to 4200. Also its commercial use rose rapidly. By 2013 a total of 1,977,925 motorcycles were counted in Kano metropolis alone. This is attributed to the fact that motorcycle use was seen as a major employment generator for jobless youth in the city.

However, its operation in the city is chaotic, uncoordinated, inefficient and fraught with danger.
2. Methodology

Relevant available literature and secondary data on the study were collected. The sample size and sampling technique to be adopted during the main survey were also determined through the use of 2006 National population census figures and the membership registers of the motorcycle union as guide.

As a result, 60 enumerators were recruited for traffic count on the fifteen identified routes in Kano metropolis. A number of personnel were also recruited to carry out questionnaire interview administration and the collection of relevant secondary data.

Two sets of questionnaires were administered on operators, and commuters and users. Total number of questionnaires administered were; operators 420 and 560 users of registered operators. Respondents were selected randomly. Information elicited from the questionnaire administration included; socio-economic characteristics of riders and users, service demand and supply, fare structure, safety issues, and modes of operation. Data were analyzed using descriptive statistics methods, which includes; tables, maps, graphs, percentages and photographs for emphasis.

3. Issues on Road Safety

The causes of road traffic accidents as articulated by the FRSC include Human factors, Mechanical factors and Environmental factors.
2. Methodology

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3. Issues on Road Safety

The causes of road traffic accidents as articulated by the FRSC include Human factors, Mechanical factors and Environmental factors.
Human Factors- such as lack of skill in driving, poor knowledge of traffic signs, rules and regulations, over speeding, driving under the influence of alcohol, over loading and dangerous overtaking has been noted as human factors that contribute in one way or the order to accidents on our road. Ohakwe in the study of Obinze/Nekede/Iheagwe road in Imo state found that 30.3% of the accidents recorded on the road were traceable to human factor due to reckless driving. Other studies carried out by Onakomaiya and Salifu aptly painted the picture of how human factors have contributed in no small way to the road traffic accidents recorded in Nigeria and Ghana respectively were a combination of largely illiterate or inexperienced or drunk or over-confident drivers, unconcerned about the lives of other road users are saddled with the enormous responsibilities of safety while driving. Also most of the motor garages spread across the country are filled with spots were alcohol are freely sold to both drivers and passengers alike.

It is important to note that 60% of accidents occurring on the roads are attributable to human factors; therefore to effectively reduce the carnage on our roads the different roles played by the road users must be thoroughly examined.

Mechanical Factors- Poor vehicle maintenance, failure of engine system, break system and electrical system are the various mechanical factors that have been enumerated to contribute to road traffic fatality in Nigeria. Ohakwe in the study of the road in Imo State noted that 21.5% of the RTA was due to inexperience and mechanical faults.

Environmental Factors- Poor road conditions, absence of road signs, parked, abandoned or broken down vehicles on the roads without adequate road signs and poor weather conditions have all been implicated as some of the causes of RTA on our roads. Ohakwe noted in the study that 21.1% of the accident recorded was due to poor road conditions.

With only about 40% of actual road development funding requirement being met by government and only about 25% of actual road maintenance need being met through budgetary allocations, environmental factors issues also significantly contribute to the present situation in the country as depicted in Odeleye J.A. article on Improved road traffic environment for better child safety in Nigeria where he clearly showed a comparative disparity in budgetary spending on roads between the developed and developing countries of the world.

The operators of these modes of transport play the same routes with buses. However, in terms of regulators no serious regulation is put in place by the government to regulate and control activities of the motorcycle and three wheeler operators within Kano metropolis. This in many instances revisits to chaotic, uncoordinated, inefficient and poor public transportation system, hence there is generally no standard in the entire operation of these means of transport within Kano metropolis. Furthermore, as part of the operation of motorcycle and three wheeler in Kano metropolis, there are undersigned and on official park that these mode of transport have developed for themselves irrespective of the effects on other road users as well as the impairment of free traffic flow and safety conditions many a times they obstructs the flow of traffic thereby creating congestions. More often they not these are problems associated with these means of transportation system within the Kano metropolis, they include the following:

i. Lack of spare parts for effective repair and maintenance, due to this problem many three wheelers and motorcycle have been abandoned and remain unserviceable.
ii. Absence of traffic segregation between motorcycles, three wheeler and other traffic user, this often create traffic conflicts in the metropolis.

iii. Over speeding by the riders of these modes of transport which often result into loss of livers and in some cases fractures.

4. Results and Discussions

Nigeria was ranked 191 out of 192 countries of the world in the year 2013 with unsafe roads and available data show that at least Eleven (11) Nigerians die on daily basis from fatalities caused by road crashes in the country and Forty eight (48) sustain different degrees of injuries or the other based on the annual report by the Federal Road Safety Commission of Nigerian (FRSC).

Alcohol and drug utilisation especially during festive periods of the year such as the Christmas and Sallah periods by most motorist and pedestrians have been found to be high which has necessitated the FRSC during such period of the year to carry out enlightenment campaign in motor parks and garages on the dangers involved. Also the designs of roads in the country generally do not take into cognisance pedestrians, cyclist etc as in most cases the roads are built solely for the vehicles thereby creating an easy avenue for road traffic crashes to take place once any of the road user gets drunk or tipsy. In addition alcohol and enhancing drugs are freely sold in most motor parks and garages in the country.

The main industrial Union for motorcycle operators is called ACOMORAN. It has one million, five hundred fully registered members and addition one million associate members who are not on their register. It is a male dominated industry. The repair technicians are individuals, unorganized and operate on road side. They operate mainly on congested routes within the metropolis.

Distance and time of the day affect the fare charged. Commercial motorcyclist enjoy patronage, because it offer flexible services and can easily maneuver in traffic congestion.

68.7% of users confirmed that they have been involved in accidents. Because of culture and religion reasons users of motorcycles prefer not to use safety helmet. Recklessness of the riders account for 70% of recorded accident.

The result from observatory survey on motorcycle operation within Kano metropolis showed that, overloading, riding against traffic (contra flow), over speeding, and disregard for safety helmet, are prominent among the operators.

Furthermore, the use of drug and alcohol is significant among the respondents. 67.2% of the respondents explained that they take some form of energy drink. 13.4% also smoke marijuana. In addition, 10.4% and 6.0% respondents claimed they take all from of energizers and alcohol respectively. The implication of this is increase accidents and unsafe road environment.
A total of 1,977,925 motorcycles were counted on the entire routes, with an average Carbon monoxide emissions rate of 3.2%, hydrocarbon emission rate of 4643ppm and carbon dioxide at 4.37% with air coefficient of 1.1λ.

The following indices were recorded from focus group discussions. That using motorcycle as a means of transport within Kano metropolis are; faster, flexible, generates employment but creates health problem and is unsafe.
Recommendations

i. Road Taxing for motorcycles.

ii. Separation of motorcycle Lane will reduce accidents,

iii. Motorcycle circulation restriction

iv. Total withdrawal of polluting motorcycles from circulation.

v. Implementation of mandatory safety helmet use

vi. Provision of exclusive lanes for motorcycle

vii. Technology application e.g. installation of monitoring devices (red light cameras and speed cameras).

viii. Periodic training of commercial motorcycle riders.

Conclusion

The study has shown that motorcycle operation is unsafe, and loosely regulated, notwithstanding its employment and income generation capacity.

Consequently, the authorities need to institutionalized a regulatory regime that will curtail the recklessness of motorcycle riders in Kano in particular and Nigeria in general.

Finally, enlightenment campaign for operators on risks involved and the need for safety, needs to be addressed aggressively

References

References
Onakomaiya, S. O. Unsafe at any Speed: Towards Road Transportation for Survival.


Odeleye, J. A. Improved road traffic environment for better child safety in Nigeria. Submitted for presentation at the 13th ICTCT workshop.

THE ASSESSMENT OF ROAD SAFETY IN THE ROMANIAN CITIES. 
THE INFLUENCE OF THE ASSESSMENT PROCESS ON THE SAFETY PERFORMANCE OF PUBLIC TRANSPORT BASED ON THE SAFENET PROJECT – RESEARCH ON THE ESTIMATION AND INCREASE OF THE INTRINSIC SAFETY OF URBAN ROAD NETWORKS IN BUCHAREST

Ana-Maria CIOBÎCĂ¹ and Ionuț-Sorin MITROI²

Abstract

Road safety is one of the major societal issues. The urban sprawl and a public transport that doesn’t fit the mobility needs leads to increase in the private car usage and also to traffic congestion on roads. Nevertheless the accidents are not only linked to the traffic volumes, but also to the design and management aspects of the urban road network or the behaviour of the road users.

In order to assess the urban road safety, a hierarchy of the road network elements is defined and a detailed analysis of the accidents is undertaken. Based on the statistical data, the network elements with low safety performance are analysed in terms of different attributes that influence their performance.

The paper underlines the main problems of the Bucharest urban road network in terms of safety performance, including traffic management and behavioural issues. Based on this analysis, the paper reflects on a set short-term and cost-effective safety improvement measures in order to reduce the number of accidents on the road network.

1. Introduction

The growth in the urban traffic in Bucharest and other Romanian city, but mainly the changes in car ownership along the time determined the evolution of accidents both on urban roads, but also on the national road network. In this context, the assessment of the accident causes was necessary.

The road safety issue is one of the problems that the entire European community tries to tackle and find the best suited solution to respond to their local needs.

In this context, the SAFENET project tries to identify and realize a model to analyse the accidents in relation to the road design elements and road users behaviour.

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The road safety is a major social issue, and the objective of reducing the number of accidents and by consequence the number of injured people was also included in the Transport White Paper and other European guidelines.

Statistically, at European level from 2000 to 2009, the number of injured people reduced by 38%, while in the urban areas the decrease was only 32%. On the other hand, in Romania, the European decreasing trend is not followed. In 2009, over 68% of the injured people in Romania were registered in the urban areas (DaCoTa, 2011).

In this respect, the objective of the SAFENET project is to identify the measures to reduce the risk of accidents in the areas and along the corridors identified as potential black spots.

The project gathers together specialists from different areas of activity from design to planning, from city planners to transport and civil engineers.

The technical objectives aim to:
- Create a digital model of an urban transport network at macroscopic level
- Create a set of safety performance functions to assess safety
- Assess the safety performance for an urban transport network
- Evaluate the black spots and identify countermeasures to improve the performance.

The activity was undertaken in 3 stages, as follows:
- First stage, the study of the urban network establishing attributes to the network elements
- Second stage, the evaluation of the identified black spots
- Third stage, the identification of countermeasures for safety improvements.

The network chosen for the extensive analysis was the Bucharest road network, mainly for its complexity, diversity and variation in the accidents causes. The network is the biggest urban road network in Romania, with a diversity in transport modes that are used by the citizens.

As a short description, the Bucharest has a surface area of 228 km² and is crossed by a road network with a total length of about 1,820 km, occupying 8.5% of the city's urban area.

All in all the city has a road network of 5,340 streets, of which 258 streets are vital to ensure the development of socio-economic progress, ensuring extensions of national roads or acting as major urban traffic thoroughfares. Bucharest's road network is divided mainly in two concentric rings of traffic (central and peripheral).

The distance between the main streets in the center (inner ring traffic) is approximately 1 km on the east-west axis and 2-3 km from the north-south axis.
This road network infrastructure serves as a surface public transport system having a network of about 370 km. Aside this, the city is also served by an underground public transportation system that preserves the topological characteristics of the surface network - concentric radial network configuration - a network of 69.25 km spread over four lines.

As mentioned above, this extensive network offers a good background to an extensive analysis in terms of urban road performance.

In order to evaluate the safety performance, it is important to undertake an analysis of the current conditions and the trends in terms of road network usage and car ownership.

It is well-known that Romani has a low car ownership by comparison with other European countries, but nevertheless the car ownership trend is an ascendant one. The figure 1 shows the car ownership in Romania in comparison to other European stats.

Nevertheless the tendency is an ascending one. It is important to note that even if the romanian level is less half of the levels of other European countries, Bucharest area represents an important exception. In this respect, the Bucharest area car ownership is more than twice the romanian average.
Analysing statistical evolution of Romanian car ownership, it is observed that the trend will continue to increase significantly while the road condition and the national network struggles to accommodate the increasing number of users.

The figure 2 presents the Romanian car ownership evolution, while the figure 3 presents the car ownership distribution along the Romanian counties.

Figure 2. Car ownership evolution in Romania

Figure 3. Car ownership evolution in Romania
2. Methodology

The approach of this research was a 3 stage approach, each stage having enriched impact over the entire research result.

The first stage was to identify the attributes of the Bucharest transport network and to evaluate the accidents in the studied urban area.

This first stage had a on-site approach by visualisation of each road element in order to identify its attribute.

The second stage supposes an extensive analysis of the road elements with low safety performance indicators. A number of 12 junctions were modelled and analysed using microscopic modelling software.

The third stage is an ongoing stage that intends to identify the countermeasures and the solution in order to increase the urban safety indicators of the elements analysed using the microsimulation.

In order to realize the extensive analysis of the junction the modeling activity was undertaken as part as an intensive work.

For each junction a complete team was collecting data on-site based on traffic counts, depending on junction configuration. The data were digitised and used in the microscopic traffic model of each junction.

The data collecting activity was realised over one working-day from 06 AM to 9 PM, each 10 to 15 were video recorded and then counted the next day in office. Also, the on-site activity included the signal control observation and registration of traffic lights program (cycle), the pedestrian counts and public transport vehicle counts for all the relations in the junctions.

An example of the video recording area of one of the most important junction is presented below:
For the fundamental core model, we used the car following model (Weidemann and Reiter, 1992), the lateral movement, tactical driving behaviour. On the other hand, the vehicle-pedestrian interaction was also modelled. The pedestrian modelling is realised using the social force model (Helbing, Molnar, 1995).

In terms of the car following model, a psycho-physical car-following model was used. This approach states that a driver will recognize changes in the apparent size of a leading vehicle as he approaches this vehicle of lower speed (Michaelis, 1963). Speed differences are perceived through changes on the visual angle.

The model suggests that a following driver will react to a leading vehicle up to a certain distance which is considered to be 150 m. The minimum acceleration and deceleration rate is set to be 0.2 m/s², while the maximum rates of acceleration depend on technical features of vehicles which are usually lower for goods vehicles. The model includes a rule for exceeding the maximum deceleration rate in case of emergency.

The car following model simulates as genuine as possible the real traffic conditions, in the same time as drivers decisions. A set of supplementary decision are taken into account, as well as a set of attributes in terms of driving behaviour in traffic. In this respect the micro simulation allows the simulation of safe driving and imprudent driving, adapting to the driver characteristics identified on-site for the analysed junctions.
Also, the pedestrian movements modelling as well as for the traffic vehicles the path choice used was a static routing, with fixed routed declared based on the data video recorded in the data collection step.

3. Results

Based on local police statistics and on the identification of various attributes of the Bucharest network elements, a number of 1284 accidents from the existing black spots were classified as mentioned in the table below:

Table 1. Accident classification

<table>
<thead>
<tr>
<th>Vehicle-vehicle accidents</th>
<th>626</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accidents in junction</td>
<td></td>
</tr>
<tr>
<td>3 legs junction</td>
<td>93</td>
</tr>
<tr>
<td>4-legs junction</td>
<td>257</td>
</tr>
<tr>
<td>&gt;4 legs junctions</td>
<td>44</td>
</tr>
<tr>
<td>other</td>
<td>232</td>
</tr>
<tr>
<td>accidents on links</td>
<td>77</td>
</tr>
<tr>
<td>6 lanes</td>
<td>31</td>
</tr>
<tr>
<td>4 lanes</td>
<td>10</td>
</tr>
<tr>
<td>2 lanes</td>
<td>36</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pedestrian-vehicle accidents</th>
<th>478</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accidents in junction</td>
<td></td>
</tr>
<tr>
<td>with pedestrian crossing</td>
<td>228</td>
</tr>
<tr>
<td>without median stop</td>
<td></td>
</tr>
<tr>
<td>with pedestrian crossing</td>
<td></td>
</tr>
<tr>
<td>with median stop</td>
<td>119</td>
</tr>
<tr>
<td>no pedestrian crossing</td>
<td>131</td>
</tr>
<tr>
<td>accidents on links</td>
<td>173</td>
</tr>
<tr>
<td>with pedestrian crossing</td>
<td></td>
</tr>
<tr>
<td>without median stop</td>
<td>83</td>
</tr>
<tr>
<td>with pedestrian crossing</td>
<td></td>
</tr>
<tr>
<td>with median stop</td>
<td>43</td>
</tr>
<tr>
<td>no pedestrian crossing</td>
<td>47</td>
</tr>
</tbody>
</table>

Based on this classification and on traffic flows assigned at the macroscopic level of the urban road network, the identification of the areas with great accidents potential were identified. The figure 5 illustrates the junction and links in Bucharest with great accident potential in relation to traffic flow volumes.
After the microsimulation of several junctions considered based on different criteria like the number of accidents and the type of accidents, the results are presented in tables 2 and 3 as follows:

Table 2. Description of the simulated junctions

<table>
<thead>
<tr>
<th>Junction</th>
<th>Type</th>
<th>Configuration</th>
<th>Accident cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obor</td>
<td>Main</td>
<td>circular junction</td>
<td>illegal pedestrian crossing</td>
</tr>
</tbody>
</table>

Figure 5. Areas in Bucharest with accident potential
<table>
<thead>
<tr>
<th>Road Intersection</th>
<th>Main/Secondary</th>
<th>Junction Type</th>
<th>Priority Granting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bd. Camil Ressu/str. Fizicienilor</td>
<td>Main</td>
<td>T-shape junction</td>
<td>not granting vehicle priority</td>
</tr>
<tr>
<td>str. Moroieni/str. Nicolae Canea</td>
<td>Secondary</td>
<td>T-shape junction</td>
<td>not granting vehicle priority</td>
</tr>
<tr>
<td>Str. Anghel Moldoveanu / Str. Roșiori</td>
<td>Secondary</td>
<td>T-shape junction</td>
<td>not granting vehicle priority</td>
</tr>
<tr>
<td>Șos. Mihai Bravu / Calea Vitan</td>
<td>Main</td>
<td>T-shape junction</td>
<td>illegal pedestrian crossing</td>
</tr>
<tr>
<td>Str. Alunișului / Sos. Oltenitei</td>
<td>Main</td>
<td>star shape junction</td>
<td>not granting vehicle priority</td>
</tr>
<tr>
<td>Șos. Colentina/ Str. Doamna Ghica</td>
<td>Main</td>
<td>circular junction</td>
<td>disrespecting the red light</td>
</tr>
<tr>
<td>Bd. Basarabia / Șos. Morarilor</td>
<td>Main</td>
<td>T-shape junction</td>
<td>not granting vehicle priority</td>
</tr>
</tbody>
</table>
60% of the chosen junction was the spots of accidents caused by not granting vehicle priority, while 16% of them were spots were the pedestrian crossed illegally the street (in places in which the crossings were not allowed). The rest of the junctions were places where drivers didn’t respect the color of the traffic lights.

In terms of traffic values, the table 3 offers the information necessary.

<table>
<thead>
<tr>
<th>Junction</th>
<th>Type</th>
<th>Behaviour Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Str. Dezrobirii / Str. Orșova</td>
<td>Secondary</td>
<td>T-shape junction</td>
</tr>
<tr>
<td></td>
<td></td>
<td>not granting vehicle priority</td>
</tr>
<tr>
<td>Şos. Mihai Bravu / Str. Baba Novac</td>
<td>Main</td>
<td>circular junction</td>
</tr>
<tr>
<td></td>
<td></td>
<td>disrespecting the red light</td>
</tr>
<tr>
<td>Şos. Mihai Bravu / Str. Vatra Luminoasă</td>
<td>Main</td>
<td>T-shape junction</td>
</tr>
<tr>
<td></td>
<td></td>
<td>not granting vehicle priority</td>
</tr>
<tr>
<td>Calea Moșilor / Str. Paleologu</td>
<td>Secondary</td>
<td>T-shape junction</td>
</tr>
<tr>
<td></td>
<td></td>
<td>disrespecting the red light</td>
</tr>
</tbody>
</table>
Table 3. Results of the simulated junctions

<table>
<thead>
<tr>
<th>Junction</th>
<th>Hourly traffic flow (veh/h)</th>
<th>Pedestrian hourly volumes (pedestrian/h)</th>
<th>Simulated average speed (km/h)</th>
<th>Behaviour parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obor</td>
<td>6268</td>
<td>16302</td>
<td>20</td>
<td>- temporal difference to the vehicle entering/exiting the conflict area - 0.1 s;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- safety distance multiplication factor -1;</td>
</tr>
<tr>
<td>Bd. Camil Ressu/str. Fizicienilor</td>
<td>3822</td>
<td>925</td>
<td>25</td>
<td>- temporal difference to the vehicle entering/exiting the conflict area - 0.5 s;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- safety distance multiplication factor -1;</td>
</tr>
<tr>
<td>str. Moroieni/str. Nicolae Canea</td>
<td>678</td>
<td>148</td>
<td>25</td>
<td>- temporal difference to the vehicle entering/exiting the conflict area - 0.3 s;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- safety distance multiplication factor -1.5;</td>
</tr>
<tr>
<td>Str. Anghel Moldoveanu / Str. Roșiori</td>
<td>123</td>
<td>96</td>
<td>31</td>
<td>- temporal difference to the vehicle entering/exiting the conflict area - 0.5 s;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- safety distance multiplication factor -1.5;</td>
</tr>
<tr>
<td>Şos. Mihai Bravu / Calea Vitan</td>
<td>5305</td>
<td>2787</td>
<td>11</td>
<td>- temporal difference to the vehicle entering/exiting the conflict area - 0.5 s;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- safety distance multiplication factor -0.6;</td>
</tr>
<tr>
<td>Street Name</td>
<td>Volume 1</td>
<td>Volume 2</td>
<td>Safety Distance Factor</td>
<td></td>
</tr>
<tr>
<td>--------------------------------</td>
<td>----------</td>
<td>----------</td>
<td>------------------------</td>
<td></td>
</tr>
<tr>
<td>Str. Alunişului / Sos. Oltenitei</td>
<td>3973</td>
<td>5405</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- temporal difference to the vehicle entering/exiting the conflict area - 0.5 s; - safety distance multiplication factor -1;</td>
<td></td>
</tr>
<tr>
<td>Şos. Colentina/ Str. Doamna Ghica</td>
<td>6621</td>
<td>4926</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- continuous decision model to amber colour (same behaviour as for green); - temporal difference to the vehicle entering/exiting the conflict area - 0.5 s; - safety distance multiplication factor -1;</td>
<td></td>
</tr>
<tr>
<td>Bd. Basarabia / Şos. Morarilor</td>
<td>4287</td>
<td>2442</td>
<td>25</td>
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<td>- temporal difference to the vehicle entering/exiting the conflict area - 0.5 s; - safety distance multiplication factor -1;</td>
<td></td>
</tr>
<tr>
<td>Str. Dezrobirii / Str. Orşova</td>
<td>881</td>
<td>119</td>
<td>35</td>
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<tr>
<td></td>
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<td>- temporal difference to the vehicle entering/exiting the conflict area - 0.3 s; - safety distance multiplication factor -1.5;</td>
<td></td>
</tr>
<tr>
<td>Şos. Mihai Bravu / Str. Baba Novac</td>
<td>5905</td>
<td>2812</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- continuous decision model to amber colour (same behaviour as for green); - temporal difference to the vehicle entering/exiting the conflict area - 0.5 s; - safety distance multiplication factor -1;</td>
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</tbody>
</table>

It is observed that the average speed is around 24 km/h. Also, only 40% of the analysed junctions have volumes over 5000 vehicles/hour, while 25% have volumes under the value of 1000 vehicles/hour.

4. Conclusions

The main issues observed are that even if the journey speeds are low, the accident rates are high. None of the above analysed junctions has the capacity over passed by the flows.

The main reasons of accidents identified are the road users’ behaviour, the need in optimisation of the traffic signalling programs and the nature of buildings and street furniture along the streets that sometimes offers little visibility.
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The main reasons of accidents identified are the road users’ behaviour, the need in optimisation of the traffic signalling programs and the nature of buildings and street furniture along the streets that sometimes offers little visibility.
The next step in the research is to improve the technical characteristics of the junction and to evaluate some of the mentioned countermeasure based on different simulation scenarios.

5. References

DaCoTa Project. Road safety knowledge system. Available at: www.dacota-project.eu/index.html

Safenet Project. Research on estimation and enhancement of intrinsic safety performances for urban traffic networks. Available at: www.safenet.pub.ro


Abstract

Urban areas in lower middle-income countries face specific challenges in mobility and accessibility. As cities expand in area and income grows, centres of attraction become dispersed and dependence on motorised transport increases. In this context, walking may be regarded as a residual activity, of lower priority to urban policy. However, insufficiencies in the walking environment in some neighbourhoods may reduce physical activity and restrict the accessibility of some groups to jobs and services. Planning for walking is then an important instrument for promoting public health and social equity. This paper analyses walking conditions in the capital of Cape Verde islands. It contributes to the literature on walkability by measuring indicators relevant to cities in developing countries and to fast-growing African cities in particular. The indicators measure the availability of destinations accessible on foot and the quality of walking trips in each neighbourhood. These types of measures are a useful tool for policy-makers to identify areas with particular problems of pedestrian mobility. When analysed alongside the income level and the degree of urban consolidation of each neighbourhood, the measures also provide insights into how mobility problems relate with social exclusion and with land use policies.

1. Introduction

Walking is a healthy activity, facilitates social interaction, and has a low environmental impact. The recognition of these benefits has lead policy-makers around the world to implement transport and urban policies that promote walking. The identification of the specific obstacles to walking in each location is an important component of those policies, because there is evidence that the propensity for walking is associated with the characteristics of the local built environment (Owen et al., 2004; Heath et al., 2006; Saelens and Handy, 2008). With that intent, researchers have been producing a large number of indicators of walkability, based on aspects such as accessibility to specific destinations (Kuzmyak et al., 2006; Iacono et al., 2010), land use mix (Frank et al., 2005) and street layout (Porta and Renne, 2005; Parks and Schofer, 2006; Neckerman et al., 2009).

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To what extent are these aspects relevant to the case of a semi-arid, post-colonial, middle-income, fast growing African city? These are the characteristics of Praia, the capital of Cape Verde islands, which is the focus of the present study. The objective of the paper is to specify and estimate a set of indicators of walkability adapted to the specific context of this city and similar African cities. The paper contributes to the walkability literature by analysing a context that is considerably different from the one of North American cities, the object of the vast majority of the studies in this field.

Many African cities have grown from settlements established during the colonial period, in locations that benefited the colonial political and economical structure. As cities expanded, they started to cover nearby areas, where life in general, and mobility in particular, are in many cases limited by the relief and environmental risk. The areas with the most severe geographic limitations tend to be occupied informally by the poorer households.

Urban growth in developing countries also shows a tendency to be accompanied by rapid decentralization (Cervero, 2013). The widening of the distance between residential areas and centres of attraction reduces the opportunities for walking. At the same time, growing income leads to higher car ownership and usage rates. The growth in road traffic demand is accommodated in new road infrastructure where priority is given to motorised modes of transport (De Langen, 2005). The negative impact of road infrastructure and traffic on pedestrians in developing countries has long been identified (Vasconcellos, 2000) but a few recent studies have started to analyse the impacts on specific aspects such as pedestrian movement (Bradbury, 2014; Mfinanga, 2014) and safety (Tulu et al., 2013; Amoako 2014) in African countries.

The type of destinations people access on foot is also different from the case of developed countries. For example, (Oyeyemi et al., 2013) included access to building materials shops, food canteens, and wells in his study of perceived walkability in Nigeria. However, we argue that in cities in developing countries and hot climates, where large parts of the urban space is informal, the object of analysis should go beyond the activity of walking as movement and consider outdoor life in general. This perspective accounts for the large proportion of people in those cities who work outdoors (such as street vendors), and for the relevance of social interactions in public spaces near homes and workplaces. There is also evidence that the propensity for walking and spending time outdoors are related to social aspects such as safety from crime (Rech et al., 2012; Villaveces et al., 2012; Oyeyemi et al., 2012).

Restrictions to walking are especially relevant in African cities, due to the overreliance on walking and the limitations of the public transport supply. Those restrictions may limit access to employment and services for woman (Porter, 2008) and poorer households (Olvera et al., 2013) and have an impact on the quality of life of the elderly (Olawole and Aloba, 2014). However, concepts used in developed
countries in the discussion of transport disadvantages may need to be adapted. Lucas (2011) argues that concept of social exclusion discussed during the last decade in developing countries, needs to take into account that transport poverty in developing countries is a problem of the majority, rather than a minority of the population. The concept of environmental justice, understood as the fair distribution of the negative effects of transport, also needs to be translated to the African context, as documented in a case study in Nairobi by Becker (2012).

This paper studies walkability taking into account the specific circumstances of fast-growing African cities and the need to produce evidence about walkability dimensions and policy concepts that have previously been applied developed countries. The analysis consists in the estimation of indicators at the level of the neighbourhood, considering aspects related with the availability of destinations for pedestrians (people, jobs, shops, services, leisure areas, and bus stops) and the quality of the walking trips (availability of public space, formal public space, safety from crime and motorised traffic, relief and flood risk). The indicators are analysed in relation with the average income and the degree of urban consolidation of each neighbourhood.

The next section is a brief overview of the case study area. Section 3 describes the methods used to estimate the indicators and Section 4 analyse their distribution across the different neighbourhoods. Section 5 reviews the lessons learnt.

2. Praia

Praia is the largest city in Cape Verde, with 130,271 inhabitants at the time of the 2010 census, representing 26.5% of the country's population. The city has been growing fast, increasing 2.5 times since 1980. This growth has lead to the urbanization of the plateaus and hills surrounding the original settlement in a plateau near the port (Figure 1). Due to geographic restrictions and to the fast and haphazard growth, the urban space is now fragmented and centres of attraction are no longer concentrated in the original settlement but dispersed throughout the city. However, some neighbourhoods have virtually no jobs or local services.

Transport is a pressing issue in the city. According to the 2010 population census, only 19% of the households have a private vehicle. However, the figure varies between 2% and 89% - unsurprisingly, in the least and most affluent neighbourhood of the city respectively. The bus network is limited and does not reach some of the poorest areas of the city. Some neighbourhoods are at a distance of several km of the nearest bus stop. The role of shared taxis for intra-urban travel is relatively small, unlike in cities in low-income countries. Walking is therefore the main means of transport available in some areas.
Walking is restricted by the hot, dry climate and by the location of the
neighbourhoods in hills and plateaus. There is also a general lack of formal public
space in the city. Outside the historical centre, public squares and green spaces are
rare. Urban parks make up only 1.4% of the urban space (CMP, 2013, Part B-01).
Despite these limitations, walking is an important leisure activity, shared by different
age and socio-economic groups, especially in the areas near the waterfront in the
early morning and evening.

The local government has started to implement policies to improve pedestrian
mobility during the last decade. Priority was first given to formal neighbourhoods,
with projects to repave or pedestrianise parts of the historical centre. Recent policies
have also covered informal areas, including street pavement, addition of pedestrian
pavements and crossings and provision of equipment such as outdoor sports grounds
and fitness parks. Despite the improvements, the tendency for the formalization of
urban space has led to some tensions, as it impacts on the livelihoods of groups such
as informal traders (Pólvora, 2013).

Due to the growing awareness about issues of spatial equity and the role of walking
in well-being, there is a need to identify the areas of the city at disadvantage in terms
of walking conditions. This assessment is particularly important in Praia due to the
diversity of land use patterns and socio-economic characteristics in the various
neighbourhoods, with differences between the more and less urbanized areas and
between the affluent and economically-deprived areas. The approach of this paper is
then to analyse indicators of walkability in relation to two variables: average income
and degree of urban consolidation of each neighbourhood.
The left part of Figure 2 shows average income per neighbourhood, using data from the 2010 census. The neighbourhoods with higher income are the historical centre and surrounding areas and the waterfront districts in the southwest part of the city. The neighbourhoods with the lowest income are the ones in the west and east fringes of the city. Income levels are highly variable: the income in the richest neighbourhood is 4.4 times higher than the income in the poorest neighbourhood.

Figure 2: Income and degree of urban consolidation

The degree of consolidation of a neighbourhood is defined as the ratio between the urbanized area and the area considered feasible for urbanization. Figure 3 illustrates the distinctions between those areas. The unfeasible area was extracted from the map of the Praia Municipal Master Plan and includes for example areas with ecological

Figure 3: Feasible space and urbanized space
value or with severe environmental restrictions to man-made uses. The urbanized area includes buildings and other types of man-made land uses. These land uses were classified into private and public space. Buildings were identified in a geographic dataset containing all the buildings in the city, provided by the Praia Municipal Government. Other land uses were identified in a variety of official maps and in orthophotos such as the one in Figure 3, also provided by the municipal government.

The map with the estimated degrees of consolidation in the right side of Fig.2 shows that the historical city centre and the geographic centre of the city have the highest values. The values become lower as we move towards the fringes of the city.

3. Methods

The unit of analysis is the neighbourhood ("bairro") as defined by the Cape Verde National Statistics Office. Neighbourhoods with less than 50 people were excluded. The remaining set includes 42 neighbourhoods. The indicators are divided into two groups, measuring the availability of destinations for pedestrians and the quality of walking trips.

3.1 Availability of destinations

The first indicator measures access to people. This indicator is included in the analysis as walking and outdoor life in general have an important role in the vitality of local social networks (Du Toit et al., 2007). Theoretically, areas with lower population density are less attractive to walking trips to meet people. In this paper, the indicator of access to people is the ratio between the resident population and the area occupied with man-made land uses.

Access to jobs is the ratio between the total number of jobs and the area with man-made land uses. The calculation of the number of jobs was based on the information in a dataset listing all the private companies in the city, provided by the National Statistics Office. The data does not include the number of people employed in each company. A second dataset provided the total number of employees in each sector of activity in the city. In a first stage, this number was divided equally by the number of companies in that sector. Corrections were then made to account for large companies, using local knowledge. The address of each company was linked to a neighbourhood and the jobs in each sector were summed up. Jobs in public services were then added, using information collected from each institution and a variety of other sources.

Access to shops is the ratio between the number of retail shops and the area with man-made land uses. The number of shops was calculated from the private companies dataset, considering companies in the retail sector. Branches of the largest supermarket chain in the city were assigned a factor of 3; other supermarkets were assigned a factor of 2. Other shops were assigned a factor of 1.
Access to services is a composite index measuring access to three types of services: administrative services, health and education. The locations of these services was identified in a variety of official sources. The density of the three types of services in each neighbourhood was first calculated. The values obtained were then used to rank the neighbourhoods in an ordered scale. Neighbourhoods with no services were ranked according to the decreasing order of the distance from the area with the centroid of its built-up area and the nearest service. The positions in the three ranks were then combined to derive an overall rank of access to services.

Access to leisure is ratio between the area of recreation places and the total area with man-made land uses. The recreation places considered were pedestrianized streets, squares and public gardens, green spaces, promenades along the waterfront, beaches and outdoor sports grounds and fitness parks. The identification of these places was based on local knowledge. Fieldwork was necessary to identify the exact areas available to pedestrians when it was not clear from the observation of orthophotos. This was especially the case of areas on the waterfront. Areas where pedestrians share the same space with motorised vehicles in formal roads were excluded. Neighbourhoods with no leisure areas were ranked according to the decreasing order of the distance to the nearest area.

Access to bus stops is the ratio between the number of bus stops and the area with man-made land uses. The location of bus stops was identified by fieldwork and refers to the situation in December 2013. The ongoing re-organization of bus services may lead to changes in the location of bus stops, as some bus lines may be added or removed from the network. Pairs of bus stops on both sides of the road in the same location were treated as one bus stop. Neighbourhoods with no bus stop were ranked according to the decreasing order of the distance to the nearest bus stop.

2.2 Quality of walking

The assessment of the quality of walking includes indicators derived from the classification of public spaces and other indicators based on data on the social and natural environment.

Pedestrian space is defined as the share of public space that can be used as a link for pedestrian movement or as a place for social interaction. The need to recognize these two functions of public space has been increasingly recognised by researchers (Jones et al., 2007). The space available to pedestrians in fast-growing cities in developing countries is considerably higher than in cities in developed countries, as the space occupied by unpaved streets in informal areas is shared by pedestrians and motorised vehicles. Figure 4 illustrates the distinction between informal (unpaved) streets and formal (paved) roads and streets, where pedestrian space is limited to pedestrian pavements. The set of pedestrian spaces considered in the construction of the indicator then contains streets and open spaces in informal areas and pedestrian pavements and public squares and gardens in formal areas. The carriageway of formal roads and streets is not considered pedestrian space. The indicator of
pedestrian space is the ratio between the area of this space and the area with man-made land uses in the neighbourhood.

![Pedestrian space](image)

**Figure 4: Pedestrian space**

*Formal* pedestrian space is the proportion of the areas occupied by pedestrian pavements and public squares in the total (formal and informal) pedestrian space, as defined in the previous paragraph.

The indicator of *traffic safety* is the ratio between the area of carriageways in formal roads and area with all man-made land uses in each neighbourhood. The assumptions are that roads create a barrier to the movement of pedestrians and that this effect depends on the total length of the roads crossing the neighbourhood and on the width of these roads. The barrier effect of road infrastructure and motorised traffic on pedestrians has long been recognised (Appleyard and Lintell, 1972). A recent article by Bradbury (2014) suggests that the effect is also relevant in the African context and should be the object of further research and policy interventions. In the current paper, the width of the road is treated as an indicator of the level of motorised traffic. The widths of all roads in Levels 1 and 2 of the hierarchy defined by the municipal government were measured individually. The widths of roads in Level 3 were measured in a sample of roads, and the average used for all roads in this level. Only the road sections crossing the space with man-made land uses are considered, as defined in Section 2, as it is assumed that pedestrians do not need to cross roads in natural areas.

The indicator of *personal safety* uses published crime data (CMP, 2013). The number of crimes is divided by the residential area of the neighbourhood. The indicator is included in the analysis because crime is an increasing concern in the city (Zoettl,
2014) and its incidence is highly variable among neighbourhoods (Pina et al., 2011). The set of 20 neighbourhoods with data also covers a mix of values for the two reference variables (income levels and degrees of urban consolidation).

Terrain is an indicator of the relief, calculated as the average slope in the pedestrian spaces of each neighbourhood. The data on slopes was provided by the municipal government.

Safety from environmental risk is the ratio of the area of all pedestrian spaces that are located inside regions considered as prone to flooding or landslides. These regions were identified in the Praia municipal master plan (CMP, 2011).

4. Results

The results are analysed based on the positions of the neighbourhoods in the ranks of the two reference variables and of the twelve indicators of walkability. The bubble charts in Fig. 5 and Fig. 6 represent respectively the indicators of availability of destinations for pedestrians and of quality of walking trips. In each chart, the two axes measure the position of the neighbourhoods in the ranks of average income and degree of consolidation. The further to the right a data point is, the higher the income; and the further up, the higher the degree of urban consolidation. The size of the bubbles is inversely proportional to the position of the neighbourhood in the rank of the indicator represented. Bigger bubbles mean better conditions for walking, as measured by that indicator.

4.1 Availability of destinations

The distribution of levels of access to people has a pattern different from the other indicators of availability of destinations for pedestrians, as the neighbourhoods with the best position are not the ones in the upper half of the income and urban consolidation ranks. In this case, the neighbourhoods with the best position are those with lower income located in more consolidated areas. This finding is consistent with the spatial patterns found in many cities in developing countries, where populations densities are high in low-income areas near the centre, but not in low-income areas at the fringes of the city. The neighbourhoods with the worst position are those with higher income in less consolidated areas. This finding reflects the low population densities in upper-end newly urbanized areas in the western extreme of Praia, which include some isolated gated communities.

The distribution of other pedestrian destinations follows a similar pattern. Access tends to be higher in areas with higher income and consolidation, and lower in areas with lower income and consolidation. The inequality between these two sets of areas is especially visible in the case of access to jobs and to services. The distribution of access to bus stops is the most equal, as the neighbourhoods with the best position appear near the centre of the chart.
The areas with higher income and lower degree of consolidation fare relatively well in terms of access to jobs, services, and bus stops, although a few of the neighbourhoods in these areas are near the bottom of the rank. The number of neighbourhoods near the bottom in these areas is higher in the case of access to shops and leisure areas. The areas with lower income and higher degree of consolidation tend to be in the middle of the rank for all types of access.

4.2 Quality of walking

The indicator of pedestrian space shows a clear pattern where neighbourhoods with lower income and lower degrees of consolidation come first in the rank. The rest of the districts are ranked according to a regular order: neighbourhoods with higher income and lower consolidation, with lower income and higher consolidation, and finally with higher income and lower consolidation.

As expected, the indicator of formal space is higher in neighbourhoods with higher degree of consolidation, especially the ones with higher income. A few of neighbourhoods with the best position in the rank are low income but almost all the neighbourhoods in the bottom of the rank are low-income.

The indicator of traffic safety shows the clearer pattern of all indicators, as the best positions in the rank are consistently located in the lower-bottom quadrant, representing neighbourhoods with lower income and located in areas with lower degrees of consolidation. This pattern contradicts the results obtained in most of the environmental justice analyses in cities in developed countries, where a link tends to be found between the incidence of risk and nuisances from transport and other urban activities and the levels of economic deprivation of the exposed populations (Braubach and Fairburn, 2010; Deguen and Zmirou-Navier, 2010). The areas with the second best position are still areas with lower-income, but located in more consolidated areas. The neighbourhoods with higher income in less consolidated areas come next and the areas with high income in more consolidated areas come at the bottom of the rank.

The chart for personal safety includes only the 20 neighbourhoods for which crime data was available. The bubbles were drawn at the same scale as the ones for other indicators, that is, the smaller and the bigger bubble have the same size as in other charts. The distribution of the indicator does not follow a clear pattern, although the highest positions occur in higher-income neighbourhoods.

The values of the terrain indicator also show a clear order, where higher-income areas have better positions, regardless of the degree of consolidation. Lower-income areas have positions near the bottom, especially in less consolidated areas. This finding is consistent with the usual pattern of residence location of poorer households in hilly areas in many fast-growing cities in developing countries.
On the other hand, areas with low income and lower urban consolidation have the best positions in terms of safety from environmental risk. The worst positions in this ranking are nevertheless occupied by lower-income neighbourhoods located in areas with lower degrees of consolidation.

![Figure 5: Availability of pedestrian destinations, income and urban consolidation](image-url)
4.3 Synthesis

The results of the twelve charts indicate that no type of neighborhood is systematically at disadvantage in terms of all dimensions of pedestrian mobility. Lower-income neighborhoods in less consolidated areas tend to occupy hilly areas and be at disadvantage in walking access to most pedestrian destinations (jobs, shops, services, bus stops and leisure areas). However, these areas have the highest availability of pedestrian space and are the least affected by risk posed by motorised traffic. Lower-income neighborhoods in more consolidated areas are the most affected by environmental risks but have the best access to social networks. Higher-income neighborhoods in less consolidated areas have the worst access to social networks but the best geographic conditions for walking, both in terms of terrain and safety from environmental risk. Higher-income neighborhoods in more consolidated areas have the least availability of pedestrian space and the highest exposure to motorised traffic, but also the best walking access to all types of destinations except social networks.

The two maps in Fig. 7 illustrate the spatial dimension of the patterns found. The maps show the position of each neighborhood in the combined ranks of the six indicators of availability of destinations and the six indicators of quality of walking trips. The availability of destinations is higher in the original settlement of the city, the geographic center, and residential areas in the west and east. Suburban areas at the fringes tend to perform worse. In contrast, the quality of walking is better in the fringes of the city. Central areas are in the middle of the scale and the areas faring the worst are small neighborhoods scattered across the city.

5. Conclusions

This paper assessed the availability of destinations for pedestrians and the quality of walking trips, measured by indicators take consideration the specific context of a fast-growing African city. The indicators were constructed based on variables of the natural and built environment and the analysis related the indicators with income...
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Figure 7: Neighbourhood positions in combined rank of walkability indicators

5. Conclusions

This paper assessed the availability of destinations for pedestrians and the quality of walking trips, measured by indicators take consideration the specific context of a fast-growing African city. The indicators were constructed based on variables of the natural and built environment and the analysis related the indicators with income
levels and degree of urban consolidation of the neighbourhood. The results show that walkability is highly variable and there are no areas of the city and social groups systematically at disadvantage. Walking access to jobs, shops, services, bus stops and leisure areas tend to be higher in higher-income neighbourhoods in more consolidated neighbourhoods. However, other neighbourhoods have advantages in terms of access to people, availability of pedestrian space, and exposure to motorised traffic.

These results have implications for public policy in Praia, which can be generalized for similar African cities. There is a clear split between the obstacles faced by pedestrians in areas with different incomes and degrees of consolidation. Policy interventions to remove those obstacles apply to all the neighbourhoods with similar characteristics in terms of those two variables. For example, in neighbourhoods with low income located in less consolidated areas, the priority is the application of economic and land use policies to increase the number of jobs and facilities within walking distance of residential areas. In neighbourhoods with low income located in more consolidated areas, transport, land use, and housing policies are needed to reduce the number of trips using routes that cross areas with environmental risk. High-income neighbourhoods in less consolidated areas require measures to reduce the dispersion of the population. In high-income neighbourhoods in more consolidated areas, the measures are similar to the ones applied in similar neighbourhoods in developed countries, such as the redesign of streets to increase the space available for walking and outdoor life, and traffic restriction measures to reduce the risks posed by motorised traffic.

However, the identification of the measures suitable to each place requires further information, calling for additional research. The analysis in this paper provided a general assessment of the relative positions of each neighbourhood in several dimensions of walkability. This approach allows for a characterization of the disadvantages of each neighbourhood in relation to the rest of the city. However, the definition of policy priorities should also take into account the conditions of each neighbourhood in relation to what society regards as minimum standards. Variations within each neighbourhood are also relevant, as obstacles to walking may be felt only in a small part of the neighbourhood. Finally, policy-makers must consider people's perceptions about the different dimensions of walkability and how they relate with the objective values measured by methods such as those recommended in this paper.

6. Acknowledgements

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7. References


Heath, G. W.; Brownson, R. C., Kruger, J., Miles, R., Powell, K. E., Ramsey, L. T., 2006. The effectiveness of urban design and land use transportation policies and practices to increase physical activity. Journal of Physical Activity and Health, 3(S1), pp.55-76.


Prioritization of the Bicycle Network Clusters Integrated with the Public Transport System in Istanbul Metropolitan Area

Dilek Col Yılmaz 1 and Haluk Gercek 2

Abstract

An ideal network design approach has to consider many details of the planning process simultaneously to yield optimal results. However, this is usually not possible due to the computational complexity. Mathematical programming approach is often limited to small networks. This study proposes a decision support model (DSM) in order to phase a citywide bicycle network plan integrated with the public transport system in Istanbul Metropolitan Area. The role of bicycle as a non-motorized transportation, and its contribution to sustainable travel goals are first presented. Secondly, layers of data produced for the GIS mapping regarding the public transport routes planned for the target year 2023, locations of transfer centers, public transport travel demand at each transfer center, and a revised citywide bicycle network are explained. The proposed bicycle network was decomposed into 14 clusters that consist of areas around the transfer centers that are accessible within 15 minutes bicycle travel time.

A survey was carried out with 42 transportation planning experts to collect data about the weights of the criteria and sub criteria considered to prioritize the clusters by using the Analytic Hierarchy Process (AHP). AHP is a multi-criteria decision-making procedure that contains both qualitative and quantitative criteria defined at several levels. The relative weights of criteria and sub criteria were calculated by pairwise comparisons. A sensitivity analysis was also included to examine the impacts of different criteria on the priorities of the network clusters. The DSM is intended to assist the municipality departments in prioritizing bicycle improvements, and help guide the implementation of the citywide bicycle network plan prepared by the municipality.

Keywords: Analytical Hierarchy Process, multicriteria decision making, bicycle network clusters, non-motorized transportation, sustainability.

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1. Introduction

Today, parallel with economic development, developing countries come across with serious issues about socio-economic differentiation, education, health and environment.

Increase in population, and collateral increase in number of motor vehicles create pressure on urban transportation systems. Besides socio-economic marginalization, air and noise pollution, traffic congestion and accidents seriously threaten the economic development and the quality of life in cities. With this process, automobile dependence becomes a characteristic of urban life; therefore automobile usage yields its place from a choice to a necessity.

Sustainable transportation has an important role in urban planning. Depending on the increase of population and private travel demand, the amount of ascending motorized travels induces greenhouse effect and climate change. In conjunction with the development of the cities, travel distances exceed the accessibility limits for pedestrians and cyclists; therefore require the use of motorized vehicles.

Beginning before the Second World War, but remarkably accelerating after it, the automobile progressively became the transportation mode that shaped the city. It became possible to develop in any direction, first filling in between train lines and then going out as far as fifty kilometres for the average half hour journey. As a result, the Auto City was born. As this process set in, the phenomenon of automobile dependence became a feature of urban life, and use of an automobile became a necessity in urban transportation. The increasing automobile dependence has created environmental, economic and social issues in cities. In order to cope with these issues, specifying mobility management strategies to encourage public transport and non-motorized transport is of vital importance. Non-motorized transportation, also known as active transportation and human powered transportation that includes walking and cycling, has an important role in mobility management.

Within the scope of this study, evaluating the factors above, the benefits of improvement and increase of non-motorized transport, providing shift from motorized to non-motorized transport are examined. The impact of the integration of non-motorized transportation and public transport on high level of mobility is evaluated; the role of bicycle on non-motorized transportation and its contribution to sustainable travel goals are discussed. The present status of non-motorized transport in Istanbul metropolitan area is evaluated, and the lack of current bicycle network is emphasized.

A decision support model is proposed in order to plan the phases of a bicycle network integrated with the public transport system within reasonable accessibility distances in Istanbul metropolitan area. By use of the planned bicycle network, it is aimed to prioritize 14 clusters that consist of impact areas within 15 minutes bicycle travel distance to transfer centres. Because of its simplicity and its ability to comply
with different conditions, enabling qualitative and quantitative evaluation, Analytic Hierarchy Process (AHP) is preferred as the analysis tool. The priorities of bicycle network clusters, integrated with public transit in Istanbul metropolitan area, are estimated, and consequently a decision support model is proposed to implement the gradual development of the projects as part of the applicable bicycle network plan.

1.1 Sustainable transportation and bicycle

Sustainable transport has emerged from three main sources:
1. Concerns about transportation’s burdens and the counter-productivity of much conventional highway-oriented planning began to emerge around the planet from the 1970’s onward as pollution increased and the often destructive effects of highway expansion upon cities attracted more attention (Stringer and Wenzel 1976; Gakenheimer, 1978; Newman and Kenworthy, 1999).

2. The recognition in some places that reducing traffic in cities through traffic calming (deliberately slowing personal motor vehicles, or PMVs) and pedestrianization (excluding PMVs from certain streets) had many benefits for mobility and the environment, including reductions in vehicular traffic (traffic evaporation) and traffic related injuries, especially those of pedestrians and bicyclists, and increases in the numbers of people walking, bicycling and using public transportation.

3. The growth of sustainability awareness, especially following the Brundtland Commission’s report (WCED, 1987) on sustainable development as ‘development which meets the needs of current generations without compromising the ability of future generations to meet their own needs’.

These three strands led to a lively discussion about sustainable transport and many excellent efforts to describe, characterize or define it since the 1990’s. While all efforts to define a field as complex as sustainable transport are fraught with difficulty, one of the most useful definitions is that of the University of Winnipeg’s Centre for Sustainable Transportation. A sustainable transport system is one that:

- allows the basic access needs of individuals and societies to be met safely and in a manner consistent with human and ecosystem health, and with equity within and between generations;
- is affordable, operates efficiently, offers choice of transport mode and supports a vibrant economy;
- limits emissions and waste within the planet’s ability to absorb them, minimizes consumption of non-renewable resources, limits consumption of renewable resources to the sustainable yield level, reuses and recycles its components, and minimizes the use of land and the production of noise.
The development of sustainable urban transportation systems may be characterised depending upon passenger and freight mobility, the effective use of land, effective use of renewable energy resources and low prized services (Crawford, 2002).

The transportation industry and governments will need to adopt a more systematic approach to address the growing need for mobility, integrated new stakeholders and technologies, and allocate resources in an optimal way to deliver sustainable solutions. Tackled in the right way, these challenges can become powerful opportunities for environmental, social and economic development (WEF, 2012).

Sustainable mobility meets the needs of society to move freely, gain access, communicate, trade and establish relationships without sacrificing other essential human or ecological requirements today or in the future, specifically (WEF, 2012).

1. Preserve the natural environment: The environment should not be degraded by transport-related activity
2. Meet the travel needs of the population: People need reliability and choice of modes in an integrated system
3. Support a good economy: Transport needs to support an economy that improves the well-being of all people
4. Minimize infrastructure costs: Transport systems need to be planned so that infrastructure and services can be funded in the long term, and that best use is made of investments
5. Maintain energy security: Transport can play a significant role in helping to decouple support of a good economy from increasing demand for fossil fuels
6. Ensure long-term viability of the transport system: Transport infrastructure and services must be continuously maintained work together as an integrated system

Cycling is increasingly recognised as a clean, sustainable mode of transport and an essential part of an inter-modal plan for sustainable urban travel. Cycling can have many advantages as a short-distance means of travel in urban areas: it is environment friendly without emissions and noise nuisance; provides cost-effective mobility, and offers an opportunity for health and physical fitness by regular exercise. On the other hand there are both real and perceived barriers to bicycle use that -with the exception of a few countries- keep cycling somewhat in the margins of urban travel. These barriers include vulnerability in accidents with motorised traffic, bicycle theft, increasing travel distances due to urban sprawl, perceived low social status, weather and topology (ECMT, 2004).

For short-distance travel, bicycles are often faster than other modes such as cars or trains. Cycling is often the quickest mode of transportation for travel within urban areas, particularly travel less than 5 km (EC DGXI, 1999).

On the other hand, the frequency of car use for short distances is significant. 30 % of motorised trips are shorter than 5 km in EU countries. There seems to be ample room to replace these shorter car trips with cycling travel (European Transport, 1998).
1.2 Non-motorized transport policies in big cities

As cities get larger they become more efficient. A thirty-two-city survey held by Peter Naess from Norwegian Building Research Institute showed that transport energy use per capita generally declines as city size increases. He chose twenty-two Scandinavian cities and found a very clear relationship between the size and as well as the density of the city and its per capita transport energy use. The cities of Copenhagen, Oslo, and Stockholm were significantly lower in transport energy use per capita than were smaller provincial towns (Newman and Kenworthy, 1999).

For decades, urban economists have been pointing to the efficiency advantages of scale as well as of density. In ecological terms, it should come as no revelation that as cities grow and become more complex and diverse, they begin to create more efficiencies. Ecosystems grow from simple systems with a few pioneering species to more mature ecosystems with diversity and interconnection.

For many years, planning and policy decisions regarding surface transportation in large central cities took place within a framework in which the roadway and transit were central, with pedestrians and bicyclists just two more components that had to be worked in where possible. However, the Intermodal Surface Transportation Efficiency Act (ISTEA) began to change this way of thinking beginning in 1991 when it provided new sources of funding for bicycle and pedestrian facilities; these provisions were extended under the 1998 Transportation Equity Act for the 21st Century (TEA-21). Nevertheless, some fifteen years later, promoting walking and bicycling while ensuring safety and mobility for the overall transportation system, continues to present a challenge, especially for large central cities, which must balance multiple and competing interests while facing limited space and funding. Further, they must address such issues with limited data in a number of areas, including safety, design, and usage.

Large central cities have several unique features relative to other locales. First and foremost is the sheer difference in size, geographically as well as overall population and density. In these cities, having more pedestrians than motor vehicles in their downtowns at certain times of the day is commonplace. Diversity is a second complicating factor in large central cities. Multiple languages and customs make encouraging stakeholder involvement, improving safety through education, and communicating policies and regulations more difficult. A third factor unique to large central cities is the degree to which transportation must function within a built urban environment. A fourth distinguishing factor of large central cities is the use of multiple modes by travellers. It is common for people to walk to and from transit or to use an automobile to park at a station, get on commuter rail, and then walk or use transit within the city. Finally, unlike their smaller urban counterparts, large central cities are more likely to have large recreational facilities utilized by bicyclists and pedestrians. Such facilities often difficult to access and tend to fall under different jurisdictional authority than the rest of the transportation system, making it difficult to fully integrate them and ensure easy and safe access (Cerreno, Novotny, 2006).
2. Material and method

2.1 Structure of AHP

The problem is built hierarchically in AHP. The prioritization process follows the configuration phase (Saaty, 1990).

Once the hierarchy is built, the decision makers systematically evaluate its various elements by comparing them to one another two at a time, with respect to their impact on an element above them in the hierarchy. In making the comparisons, the decision makers can use concrete data about the elements, but they typically use their judgments about the elements' relative meaning and importance. It is the essence of the AHP that human judgments, and not just the underlying information, can be used in performing the evaluations (Saaty, 2008).

2.2 Definition of decision making problem and determination of the relations

This level includes identifying the decision nodes and the factors affecting them. AHP allows decision makers to model the problem in a hierarchic structure that shows the relations between the main goal of the problem, main criteria, sub criteria, and alternatives. This form of AHP is seen in Figure 1. The number of criteria may be more than 1, and there may be sub criteria of criteria. The determined criteria should be understandable and clear. The number of levels in decision hierarchy gets changed based on the complexity of the problem (Kuruüzüm, 2001).

![Figure 1. A Simple AHP hierarchy](image-url)
2.3 Pairwise comparisons and relative importance vector

Comparison process begins after defining criteria, sub criteria and alternatives that constitute the problem. Comparative judgements and pairwise comparisons form the second main and most important step of AHP.

In multi-criteria decision problems, the experts of the subject are interviewed and their opinions and judgements about the subject are found out. Because the results directly depend on the judgements of surveyed people in AHP, they must be expert or well informed about the study, in order to get consistent results. According to the given judgements preference, judgement or pairwise comparison matrices are generated. The matrix is formed by converting the judgements into quantitative values (Saaty, 2000).

Table 1 reports the pairwise comparison scale used in the AHP developed by Saaty (1977). It allows converting the qualitative judgements into numerical values, also with intangible attributes.

Table 1. AHP pairwise comparison matrix for criteria (Vargas, 1990)

<table>
<thead>
<tr>
<th>Criterion 1</th>
<th>Criterion 2</th>
<th>…</th>
<th>Criterion n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Criterion 1</td>
<td>( w_1/w_1 )</td>
<td>( w_1/w_2 )</td>
<td>…</td>
</tr>
<tr>
<td>Criterion 2</td>
<td>( w_2/w_1 )</td>
<td>( w_2/w_2 )</td>
<td>…</td>
</tr>
<tr>
<td>…</td>
<td>…</td>
<td>…</td>
<td>…</td>
</tr>
<tr>
<td>Criterion i</td>
<td>( w_i/w_1 )</td>
<td>( w_i/w_2 )</td>
<td>…</td>
</tr>
</tbody>
</table>

For computing the priorities of the elements, a judgmental matrix is assumed as follows:

\[ A = \begin{bmatrix}
  a_{11} & a_{12} & \ldots & a_{1n} \\
  a_{21} & a_{22} & \ldots & a_{2n} \\
  \vdots & \vdots & \ddots & \vdots \\
  a_{n1} & a_{n2} & \ldots & a_{nn}
\end{bmatrix} \]

where \( a_{ij} \) represents the pairwise comparison rating between the element 1 and element \( j \) of a level with respect to the upper level. The entries \( a_{ij} \) are governed by the following rules: \( a_{ij} > 0; a_{ij} = 1/aji; a_{ii} = 1 \)
Following Saaty (1980, 2000), the priorities of the elements can be estimated by finding the principal eigenvector $w$ of the matrix $A$, that is:

$$AW = \lambda_{\text{max}} \cdot W$$

When the vector $W$ is normalized, it becomes the vector of priorities of elements of one level with respect to the upper level. $\lambda_{\text{max}}$ is the largest eigenvalue of the matrix $A$. In cases where the pairwise comparison matrix satisfies transitivity for all pairwise comparisons it is said to be consistent and it verifies the following relation:

$$aij = aik \cdot akj$$

Saaty (1980) has shown that to maintain consistency when deriving priorities from paired comparisons, the number of factors being considered must be less or equal to nine. AHP allows inconsistency, but provides a measure of the inconsistency of the judgmental matrix can be determined by a measure called the consistency ratio (CR), defined as:

$$CR = \frac{CI}{RI}$$

Where $CI$ is called the consistency index and $RI$ is the Random Index.

Furthermore, Saaty (1980, 2000) provided average consistencies (RI values) of randomly generated matrices. $CI$ for a matrix of order $n$ is defined as:

$$CI = \frac{\lambda_{\text{max}} - n}{n - 1}$$

Saaty offers a AHP measurement scale that includes numbers from 1 to 9. Table 2 shows the measurement scale.

In accordance with the numbers in the measurement scale table, pairwise comparisons are executed by the experts. For example if the value is 7, then it is understood that criteria i is very strongly important over criteria n. In this case similarly the importance of criteria n over criteria i is 1/7 (Gungor, Isler, 2005).

The intermediate values mean the value between two main values in comparisons. The method of Saaty gives the best results for $n<10$ criteria, especially for 7 criteria. In other words, solving the multi criteria decision problems with AHP when the number of criteria exceeds 9, inconsistencies may occur.
Table 2. AHP measurement scale

<table>
<thead>
<tr>
<th>Numerical Values</th>
<th>Verbal Scale</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Equal importance of both elements</td>
<td>Two elements contribute equally</td>
</tr>
<tr>
<td>3</td>
<td>Moderate importance of one element over another</td>
<td>Experience and judgement favour one element over another</td>
</tr>
<tr>
<td>5</td>
<td>Strong importance of one element over another</td>
<td>An element is strongly favoured</td>
</tr>
<tr>
<td>7</td>
<td>Very strong importance of one element over another</td>
<td>An element is very strongly dominant</td>
</tr>
<tr>
<td>9</td>
<td>Extreme importance of one element over another</td>
<td>An element is favoured by at least an order of magnitude</td>
</tr>
<tr>
<td>2, 4, 6, 8</td>
<td>Intermediate values</td>
<td>Used to compromise between two judgements</td>
</tr>
</tbody>
</table>

2.4 AHP in transportation planning

AHP is a method that is independent from the type of the problem. Therefore, it is easily applicable to any planning of transportation mode such as highway, railway, airway, seaway, postal services, communication, and freight transportation. The method can be applied to establishments with different scale and different problems with different complexity. In other words it can be applied for the organizations making freight transport, and middle scaled organizations as well as a national railway company. It is possible to separate the problem into goal, criteria, and alternatives.

AHP can be used in transportation planning (Saaty, 1995), traffic planning (Pogarcic et al, 2008), prioritization of urban transportation alternatives (Yedla, Shresta, 2007), corridor and route selection of light rail transit line, selection of transit mode (Akad, Gedizioglu, 2007), (Banai, 2006), planning of the most feasible railway network (Gercek et al, 2004), specifying the railway system routes with geographical information systems (Ludin, Latip, 2006), selection of the most cost efficient highway route (Piantanakulchai, Saengkhoao, 2003), the classification of sustainability of transportation investments (Sadasivuni et al, 2009), evaluation of public transit fare system (Nassi, Costa, 2012), analysis of public transit service quality [40], the prioritization of public transit companies (Khasnabis, Chaudhury, 1994), the analysis of urban transportation demand with discrete choice models (Banai, 1989).

Multi-criteria approach in planning of bikeways (Chan, Suja, 2003), bikeway planning with geographical information systems, and multi-criteria decision-making
3. Implementation

3.1 Building the baseline for the study

In the extent of the study, the present situation for non-motorized transportation in Istanbul Metropolitan area is reviewed, the inadequacy of present bikeways is revealed. Furthermore, the disconnection in present and planned bikeway projects is specified while finding out the lack of an integrated bicycle network with public transport system in the city.

Building up the ‘bicycle impact areas’, public transport transfer centers that planned by Istanbul Metropolitan Municipality (IMM) for the whole city, are taken as the centre nodes for bicycle clusters. The proposed bicycle network is decomposed into 14 clusters that consist of areas around the transfer centres that are accessible within 15-minute bicycle travel time. Encircling these centres, impacts areas that show similar characteristics, are combined forming 14 bicycle clusters. Thereafter, these 14 bicycle clusters are evaluated qualitatively and quantitatively in terms of the data and criteria from hierarchy table.

The layers that will be a baseline for the study, include highway network, public transport network, planned transfer centers, household origin-destination (O-D) travel survey data of 2006, Istanbul Metropolitan Area Urban Integrated Transportation Master Plan (IBB, 2006a) traffic analysis zones data (population, employment, number of students, household income, and car ownership), bikeways data from the study of ‘The Research, Planning and Projects of Bikeways and Pedestrian Ways, and Regional Transportation and Traffic Study’ (IBB, 2006b) as well as the data of 5 m. contour lines from slope analysis. The transportation planning software of TransCAD, and Geographical Information Systems (GIS) software of ArcMap are used in the study.

The quantitative data of zones includes: Population, employment (the number of employee), workers (number of working people), number of students (at home), number of students (at school), income, car ownership, the length of the bikeways, park&ride capacity, on-road parking capacity, the number of signalized intersections, the percentage of heavy road vehicles in traffic, and volume/capacity ratios.

The visual data of zones includes: Bikeways (separated bikeways, non-separated bikeways, shared bike pedestrian path, shared bike vehicle way, pedestrian walking path with bikes), bicycle parking areas, public transport transfer centers, and number of daily passengers in these centers. The map including the data for bicycle network clusters according to the criteria is presented in Figure 2.
3.2 Building up the hierarchy

AHP, a decision support system is applied for prioritization of bicycle network clusters developing around particular focus points within accessible distances, integrated with public transport network in the city. Criteria and sub-criteria are defined in order to build the map that will be the basis for the evaluation and to apply AHP. Criteria are separated into two groups: main criteria, and sub-criteria. 6 main criteria include user characteristics, road characteristics, traffic characteristics, bikeway service and operation characteristics, public transport and transfer facilities, and land-use characteristics.

26 sub-criteria are defined in such a manner that all of them will be in relation with their own main criteria. User characteristics include socio-economic status (income, and car ownership), and employment characteristics. Road characteristics include road functional class, slope, surface type, surface condition, bicycle lane existence, number of signalized intersections, continuousness and directness. Traffic characteristics include motor vehicle traffic volume, heavy (long) vehicle traffic volume, speed limits, traffic calming enforcement, on-road parking availability, and...
security. Bikeway service and operation characteristics include travel time, travel cost, construction time, and construction cost. Public transport and transfer facilities include daily public transport demand, bicycle-parking facilities, and bikes on public transport vehicles. Land-use characteristics include land-use, compliance with historic pattern of the city, and compliance with urban and transportation plans.

After combining the ’15-minute bicycle travel time zones’, 14 clusters are evaluated with a survey conducted with 42 transportation planning experts to collect data about the weights of the criteria and sub criteria considered to prioritize the clusters by using Analytic Hierarchy Process (AHP). The hierarchy of problem is presented in Figure 3. The hierarchy consists of goal, main criteria, sub-criteria, and alternatives.

![Figure 3. 'Prioritization of integrated bicycle network clusters' hierarchy](image)

### 3.3 Pairwise comparisons

A survey was conducted among 42 transportation-planning experts. In the first part of the survey, the pairwise comparisons of main criteria in the sense of goal are made in order to find out the weights of criteria with respect to each other. Each expert is asked for choosing one of the scales 1, 3, 5, 7, 9 (1:equal, 3:moderate importance, 5:strong importance, 7:very strong importance, 9:extreme importance) for each criterion in order to define their degree of importance.
In the second part of the survey, the experts are asked to make pairwise comparisons of sub-criteria in the sense of main criteria. The scales of 1, 3, 5, 7, 9 are also given for the sub-criteria, and the importance of sub-criteria are calculated.

The calculations including pairwise comparisons are performed by ‘Super Decisions’ package software. The table of pairwise comparisons between main criteria is given in Figure 4. Figure 5 shows the hierarchy that built by the software. The super matrix is weighted by the eigenvectors that are obtained by the software.

![Figure 4. Matrix of pairwise comparisons between main criteria](image)

3.4 The synthesis of the priorities

In the third part of the survey, the ‘rating’ method is used by asking experts to give points according to the preference of alternatives in sense of sub-criteria. Each sub-criterion is given points between 1 and 5 (1:bad, 2:poor, 3:fair, 4:good, 5:excellent). In Table 3, the calculated local and global weights of criteria and sub-criteria are presented.

According to the weights of the criteria “bikeway service and operation characteristics” has the highest weight. The criteria of “public transport and transfer facilities” and “traffic characteristics” rank among second and third place. Travel time sub criterion has the highest weight as a result of pairwise comparisons according to “bikeway service and operation characteristics” criteria.

The score results of alternatives are given in Table 4. Alternatives that include the clusters of 11, 12, and 5 share the first three in grading. The development of bicycle network in metropolitan area will systematically take place with respect to these ranking.
### Table 3. The weights of criteria and sub criteria

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Local Weights</th>
<th>Sub Criteria</th>
<th>Local Weights</th>
<th>Global Weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 USER CHRCT.</td>
<td>0.0768</td>
<td>11 SOCIO-ECONOMIC STATUS</td>
<td>0.607</td>
<td>0.047</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12 EMPLOYMENT CHARACTERISTICS</td>
<td>0.393</td>
<td>0.030</td>
</tr>
<tr>
<td></td>
<td></td>
<td>21 ROAD FUNCTIONAL CLASS</td>
<td>0.083</td>
<td>0.015</td>
</tr>
<tr>
<td></td>
<td></td>
<td>22 SLOPE</td>
<td>0.181</td>
<td>0.033</td>
</tr>
<tr>
<td></td>
<td></td>
<td>23 SURFACE TYPE</td>
<td>0.045</td>
<td>0.008</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24 SURFACE CONDITION</td>
<td>0.068</td>
<td>0.013</td>
</tr>
<tr>
<td></td>
<td></td>
<td>25 BICYCLE LANE EXISTENCE</td>
<td>0.285</td>
<td>0.052</td>
</tr>
<tr>
<td></td>
<td></td>
<td>26 NUMBER OF SIGNALIZED INTERSECTIONS</td>
<td>0.072</td>
<td>0.013</td>
</tr>
<tr>
<td></td>
<td></td>
<td>27 CONTINUOUSNESS</td>
<td>0.192</td>
<td>0.035</td>
</tr>
<tr>
<td>2 ROAD CHRCT.</td>
<td>0.1843</td>
<td>28 DIRECTNESS</td>
<td>0.075</td>
<td>0.014</td>
</tr>
<tr>
<td></td>
<td></td>
<td>31 MOTOR VEHICLE TRAFFIC VOLUME</td>
<td>0.231</td>
<td>0.038</td>
</tr>
<tr>
<td></td>
<td></td>
<td>32 LONG VEHICLE TRAFFIC VOLUME</td>
<td>0.147</td>
<td>0.024</td>
</tr>
<tr>
<td></td>
<td></td>
<td>33 SPEED LIMIT FOR VEHICLES</td>
<td>0.098</td>
<td>0.016</td>
</tr>
<tr>
<td></td>
<td></td>
<td>34 TRAFFIC CALMING ENFORCEMENT</td>
<td>0.098</td>
<td>0.016</td>
</tr>
<tr>
<td>3 TRAFFIC CHRCT.</td>
<td>0.1634</td>
<td>35 ON-ROAD PARKING AVAILABILITY</td>
<td>0.167</td>
<td>0.027</td>
</tr>
<tr>
<td></td>
<td></td>
<td>36 SECURITY</td>
<td>0.260</td>
<td>0.043</td>
</tr>
<tr>
<td></td>
<td></td>
<td>41 TRAVEL TIME</td>
<td>0.373</td>
<td>0.081</td>
</tr>
<tr>
<td></td>
<td></td>
<td>42 TRAVEL COST</td>
<td>0.179</td>
<td>0.039</td>
</tr>
<tr>
<td>4 BCY SRV CHRCT.</td>
<td>0.2177</td>
<td>43 CONSTRUCTION TIME</td>
<td>0.243</td>
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<td></td>
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<td>44 CONSTRUCTION COST</td>
<td>0.205</td>
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<td></td>
<td></td>
<td>51 DAILY PUBLIC TRANSIT DEMAND</td>
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<td>0.063</td>
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<td></td>
<td></td>
<td>52 BICYCLE PARKING FACILITIES</td>
<td>0.318</td>
<td>0.063</td>
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<td>5 PT TRNS FAC.</td>
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<td>53 BIKES ON PUBLIC TRANSIT VEHICLES</td>
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<td>61 LAND USE</td>
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<td>6 LAND USE CHRCT.</td>
<td>0.1601</td>
<td>62 COMPLIANCE WITH HISTORIC PATTERN</td>
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<td></td>
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<td>63 COMPLIANCE WITH URBAN AND TR. PLANS</td>
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Table 4. Scores of alternatives

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3.5 Sensitivity analyses

Sensitivity analysis is made to determine how “sensitive” a model is to changes in the value of the parameters of the model and to changes in the structure of the model. Sensitivity analysis helps build confidence in the model by studying the uncertainties that are often associated with parameters in models. The analysis allows the modeller to determine what level of accuracy is necessary for a parameter to make the model sufficiently useful and valid.

The changes in alternatives and the changes in the whole result are observed in case of a change in the weight of a particular sub-criterion. In the extent of the sensitivity analyses, certain highest value sub-criteria are taken into consideration, and their weights are changed to find out how other sub-criteria and alternatives are affected. Microsoft Office Excel package software is used for sensitivity analyses.

Considering the results of expert opinions, the weight of “travel time” sub-criterion with a weight of %8.1, is tested for the cases of %0 and %100. When the weight is accepted as %0, no change in the ranking of the alternatives is observed. When the weight is accepted as %100, Alternative-1 changes its place from 6th rank to 2nd.
As the weight of “bikes on public transit vehicles” gets % 0, the ranks of first two alternatives are changed, as it gets % 100, Alternative-1 gets on 1st, Alternative-13 gets on 3rd rank.

4. Results and discussion

In this study, an important sustainable transportation mode, bicycle transportation has been examined in terms of policies and planning. The study proposes a decision support model (DSM) in order to phase a citywide bicycle network plan integrated with the public transport system in Istanbul Metropolitan Area.

As a result of several analyses and interpretation of these analyses, a solution is generated which shows the levels of developing the bicycle network around specified transfer centers. It has been seen that “bikeway service and operation characteristics” criteria, and “travel time” sub-criteria have more importance over other criteria.

As a result of the calculations, observing the weights of criteria, the local weight of bikeway service and operation characteristics criterion with the value of 0.2177 ranks first while public transport and transfer facilities criterion comes next with the value of 0.1978, and road characteristics criterion follows with the value of 0.1843.

After prioritizing the bicycle network clusters, the proposed bicycle network should be implemented starting from the clusters 11 and 12 in Asian side, following the cluster 5 in European side, and getting along with the cluster 13 on the same axis.

The network development is estimated to occur along Uskudar, Kadikoy, Maltepe, and Kartal axis in Asian side, and along Zeytinburnu, Bakirkoy ve Avcilar axis in European side. The Sariyer axis and other independent network clusters in both sides follow these clusters.

Considering the ranking, the bicycle network extending along the coast on an axis in both sides of the city is prioritized in clusters where there exists a relatively more regular road hierarchy, lower slopes, more opportunities of using seaway transportation, and easier intermodal transportation integration.

The clusters that take place on the last ranks show the characteristics of more irregular land-use pattern including high-density residential areas with commercial use, warehouse and industry. The clusters also encloses areas where inadequate public transport system, narrow roads, and high slopes are observed with the intersections on main arterial roads and highways such as D-100 and TEM, having low capacities with bottlenecks, and uncontrolled level junctions. These clusters include the districts of Bayrampasa, Esenler, Gungoren, Gaziosmanpasa, and Sultangazi.

After the determination of alternatives’ ranking, the sensitivity analysis is performed in order to find out how the alternatives are affected when the weights of the sub-
criteria change. As a result of series of analysis, the differentiation in the rankings of alternatives, according to different weights of sub-criteria, is calculated.

The study has a flexible characteristic that provides a makeover entering new/updated data and adding new alternatives. With regards to provide prospective foresights, the data can be revised and updated regularly, in parallel with changes in housing and population, socio-economic development, and transportation system.

For further studies, the process of weighting the criteria and rating can be extended by taking the opinions of different stakeholders such as decision makers, executors, and civil authorities.

5 Acknowledgements

This study is part of the PhD thesis “Prioritization of Integrated Bicycle Network Clusters in Istanbul Metropolitan Area Using Analytic Hierarchy Process” in the programme of Transportation Engineering in Istanbul Technical University, Institute of Science and Technology.

6 References


Sadasivuni, R., O’Hara, C.G., Dumas, J., “Rating the sustainability of transportation investments: corridors as a case study”, ASPRS Annual Conference, Baltimore, Maryland, 2009.


ACHIEVING SUSTAINABLE URBAN TRANSPORT IN HARARE, ZIMBABWE: WHAT ARE THE REQUIREMENTS TO REACH THE MILESTONE?

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ABSTRACT

Sustainability has become a buzz word within the socio-economic development agenda. Sustainability creates and maintains conditions under which society can cope and viably support livelihood requirements. Lack of economic growth and a rapid rise in urban population have created unintended consequences impacting on the economy, social fabric and the environment. Africa is urbanizing at an annual growth rate of 3.4% (United Nations 2011). Zimbabwe, akin other developing countries is also urbanizing at a high rate. Ironically, as urban population grew, conventional public transport declined, mainly as a result of an adverse operational environment. The twin factors of increasing population and the dearth of conventional public transport stimulated the growth of the informal public transport and private car ownership. As the informal sector and private motorisation expands, the city’s main urban public space is increasingly more congested impeding rather than facilitating the urban population’s ability to access the required social and economic services. A clear mismatch between the demand for traffic space and its availability is evident. Demand for traffic space exceeds its supply, inevitably resulting in congestion which can be protracted. Urban productivity is key to the growth of our urban economies and this requires the provision of a reliable, efficient transport system to move goods and labour. The paper examines and assesses the various strategies that can contribute to achieving a sustainable urban transport system. Data was collected through unstructured interviews from key stakeholders in both private and public sector. Stakeholders are agreed on the need to improve transport in Harare and proffered solutions which included mass transit, infrastructure improvements, institutional capacity and good governance among others.

1. INTRODUCTION

Sustainability has become a buzz word within the socio-economic development agenda. According to Beatley (1995), there is no universally accepted definition of sustainability, sustainable development or sustainable transport. The European Union Council of Ministers of Transport (EUCMT 2004) defined sustainable transport as allowing “the basic access and development needs of individuals, companies and society to be met safely and in a manner consistent with human and ecosystem health, and promotes equity within and between successive generations … affordable … limit emissions … while minimizing the impact on the use of land and the generation of noise”. Other authors (Black and Nijkamp, 2002; Litman, 2008; Richardson, 1999; TRB, 1997; Tumlin, 2012) have also proffered definitions
of sustainable transport. These definitions have brought to the fore the key measures of transport sustainability which includes economic, social, environmental and financial dimensions. Thus, sustainability creates and maintains conditions under which society can cope and viably support livelihood requirements. Sustainable transport is threatened when transport becomes inefficient, is perceived as unsafe, contributes towards a deteriorating air quality standard, and creates delays and bottlenecks for users inter alia. Urban transport in many cities of the developing countries, exhibit these shortcomings.

1.1 Trends in Urban growth

Worldwide, urbanization is growing in both the developed and developing countries. In 2008, for the first time in history, more than half of the world’s population were living in towns and cities (UNFPA 2007). The proportion of the world’s urban population is expected to increase to 5 billion people by 2050 (Ibid). Figure 1 illustrates the growth in urban and rural population from the 1950s and projections up to 2030.

![Figure 1: Growth in urban and rural population with projections up to 2030](image)

**Source:** United Nations (2005) World Urbanisation Prospects, the 2005 Revision Department of Economic and Social Affairs, Population Division

It is in cities of the developing world where rapid increases in population is occurring. According to the African Development Bank (AfDB 2012), more than
90% of future population growth will be accounted for by the large cities in the developing countries. Africa in particular, has experienced unprecedented urban growth. According to the United Nations (2011), urban population in African cities has been increasing by an annual rate of 3.4%. The rapid rate of urbanization in Africa, is a result of natural growth as well as the movement of people from rural areas to cities (rural-urban migration) in order to seek economic opportunities. This high growth in population has in turn increased pressure on services and in some cases resulting in the proliferation of slum.

Urbanisation in Zimbabwe, exhibits the worldwide trends discussed above. The population of Zimbabwe is approximately 12.97 million with an annual growth rate of 1.1% (ZimStat 2012). Urban population increased from 608 446 people in 1964 to 4.93 million by 2012. Urban population is 38.6% of total population with a growth rate of 3.4% (The Zimbabwe Demographics Profile 2013). Greater Harare, which is the subject of this paper has a current population of 2.1 million people representing 16.2% of the total population in the country (ZimStat 2012). The rising population has in turn resulted in the physical expansion of the city as well as an increase in density.

1.2 Background to the City of Harare

Harare is the capital and industrial and commercial city of Zimbabwe. It was declared a municipality in 1897 and became a city in 1935. Formerly dubbed ‘the sunshine city’, Harare has in the last few years been affected by the country’s debilitating macro-economic situation. The once glamorous streets are now characterised by potholes and litter.

Harare once prided itself with a reasonably good 4,000 km of surfaced road network. The road network system is failing to cope with increases in the number of vehicles. Notwithstanding the adverse economic environment, the people have found a reasonably cheap source of motor vehicles from Japan and Asia. Vehicles arrive in the country daily in great quantities and the majority of them are destined for Harare. According to the Central Vehicle Registry (CVR 2012), the number of vehicles in the country increased by approximately 6% from 522 682 in 1999 to 973188 by 2009. Albeit the non-availability of figures by city, it is estimated that about 70% of these vehicles are in Harare. It is evident that there is a clear mismatch between increases in the number of vehicles plying the streets of Harare and provision of road space resulting in severe congestion. The city experiences high levels of congestion which can be protracted for several hours. Residents in Harare at times casually tell a joke that the number of vehicles plying the streets outnumbers the population. Clearly, as this is an exaggeration, it however highlights the magnitude of congestion in the city.

Congestion is compounded by small vehicles which are used as modes of public transport. Figure 2 shows the level of congestion on one street which minibus drivers have unilaterally converted into a terminus. Up to 1983, public transport in Harare
was solely provided by conventional buses. Progressively, the increasing public-supply/demand gap compelled the proliferation of pirate taxis (informal sector) which started to surface on high density corridors. The growth of the informal sector was given impetus by the Economic Structural Adjustment Programme (ESAP), which was introduced in 1990 (Government of Zimbabwe 1993). In essence, the main objective of ESAP was to liberalise the economy. This culminated in the deregulation of urban passenger transport in 1993 when privately operated public transport vehicles were for the first time legally permitted to operate in urban areas. Privately operated vehicles in the form of minibuses (officially known as commuter omnibuses in Zimbabwe) have mushroomed and now dominate the entire public transport market in Harare resulting in the dearth of the conventional bus operator. In addition, some operators (illegal) have taken advantage of unmet demand and are plying on short routes. These small cars and minibuses park willy-nilly blocking other traffic and causing congestion as illustrated in Figure 3.

Figure 2: Street totally blocked by minibuses  
**Source:** Authors

Figure 3: Minibus loading in the middle of a road

During the rush peak hour periods, congestion in Harare can reach *gridlock* levels increasing frustrations to motorists who at times vent their anger against each other. Some motorists try to avoid congestion by choosing alternative routes but as one respondent remarked: “You should not assume that you are the only rational commuter. Choosing an alternative route or even using back roads won’t work because other motorists will take similar decisions resulting in congestion on these alternative routes”. Thus, congestion in Harare is a real challenge which causes delays and in turn affects production negatively.

Traffic jams in Harare have also increased accidents. According to statistics provided by the Traffic Safety Council of Zimbabwe (TSCZ 2012) total vehicle accidents in Harare increased from 20 676 in 2007 to 25 404 in 2010 and the number of people killed increased from 540 to 604 during the same period. Although current accident
and fatality statistics are not available, these could be considerably higher due to the increase in the number of vehicles and the deteriorating infrastructure characterised by potholes and malfunctioning traffic signals. A considerable number of these accidents are attributed to minibus operations. A recent accident (The herald 26 May 2014) that killed 10 passengers in Harare when a minibus hit a tree exposed the uncaring behaviour of operators and drivers. The driver was speeding and had no licence. These practices are perceived to be common in this industry.

In summary, the city of Harare is facing grave challenges which inter alia include an increase in population and the number of motor vehicles, a deteriorating transport infrastructure, severe congestion, an inefficient public transport and a high rate of accidents. All these snags have implications on achieving a sustainable transport and hence the need to raise the question on the requirements of achieving sustainable transport for the city.

2. METHODOLOGY

In this study, a qualitative research method was followed. Information was sought from a group of key urban transport stakeholders. The first group was comprised of Government (Ministries of Transport and Local Government), City of Harare, and the Traffic Safety Council of Zimbabwe. The second group covered the private sector and interviews were conducted with the Chartered Institute of Logistics and Transport, Consultancies and companies. The third group encompassed minibus operators. The fourth group was confined to academics and the fifth and final cluster targeted users of public transport and interviews were conducted at termini. Thus, there are five identifiable categories from which information was sought, namely, the public sector which represents policy formulation, the private sector, academia, public transport operators and public transport users.

For this type of study, unstructured questionnaires were found to be the most suitable. Respondents are not confined to a set of answers and can therefore express their views without any limitation.

Questions revolved around the respondents’ understanding of sustainable urban transport and how it can be achieved. Responses were grouped according to sectors of interviewees in order to discern any meaningful trend from the groups of stakeholders identified above.

3. FINDINGS

3.1 Is urban transport sustainability understood?

The question brought mixed responses from stakeholders. For the general members of society who invariably are commuters, urban transport sustainability is associated with the improvement of public transport in regard to two key factors, adequacy and affordability.
Most interviewees from the public sector (Government, Local Authority, Parastatals) responded to this question by making reference to the National Transport Policy document which stipulates one of the objectives of urban transport as the “improvement of the supply of public transport services without compromising passenger safety and comfort” and one of the strategies to achieve this objective was “to promote high capacity transport public transport vehicles and embarking on gradual phasing out minibuses” (Government of Zimbabwe 2012). An official in the Department of Physical Planning, in the Ministry of Local Government summarised urban transport sustainability as making “cities resource efficient, environmentally friendly, transport and land use being integrated and public interest must be in the forefront”.

The private sector’s main concern and understanding of transport sustainability revolved around cost reduction and making cities productive. An efficient urban public transport system was considered to be a necessary ingredient to economic growth.

Divergent views emerged from minibus operators. One group expressed the view that sustainable urban transport revolved around minibuses which are providing a vital service to commuters and their ‘operations need to be sustained’. The other group associated urban sustainable transport with big buses which they described as “efficient users of road space”. This group is aware and influenced by Government’s new policy to phase out minibuses. Therefore the group wants to take a proactive approach to seek assistance to invest in bigger buses so that when the policy is implemented, they will not be found to be on the wrong side of the law.

As expected, academia expressed views that reflected depth of knowledge on the concept of sustainability. One academic defined urban transport sustainability as “the provision of transport facilities to enable people to use the system without compromising future generations”. This definition resonates the sustainable development definition that was popularized in Our Common Future (World Commission on Environment and Development, 1987) in which sustainable development was defined as the “development which meets the needs of the present without compromising the ability of future generations to meet their own needs”.

The three pillars (economy, society and environment) of sustainable transport were articulated by academia. A male academic defined sustainable urban transport as “the need to achieve economic, social and environmental equilibrium, it is about facilitating movement, pricing being just to users and minimising emissions”.

Another angle of sustainability expressed by academia was on the importance of not only providing the requisite transport infrastructure, but managing and maintaining it as well. The crumbling urban roads in Harare, which are full of potholes due to lack of maintenance, were cited as an example of unsustainability.
4. REQUIREMENTS TO REACH THE MILESTONE

This section provides a critique on how sustainable urban transport in Harare can be achieved in light of the definitions proffered in the introductory section as well as suggestions and views expressed by stakeholders. Although many suggestions were made, the most recurrent and relevant ones to be considered in this paper are, mass transit system, institutional capacity, infrastructure improvements, and governance. Surprisingly, Travel Demand Management (TDM), a technique that can considerably contribute to sustainable urban transport was not mentioned, but will be discussed in this paper.

4.1 Mass transit

There is a growing realization that the present public transport system in Harare which is dominated by minibuses is unsustainable. The majority of stakeholders expressed the view that the introduction of mass transit in the form of bigger buses is the ‘only’ solution to the present unreliable public transport system. This is a reasonable suggestion because the present public transport system is characterised by small vehicles and the operations are fragmented and inefficient as they are run by individuals. Secondly, mass transit vehicles carry a far higher number of passengers, making them an efficient user of road space ultimately decongesting the city. Thirdly, due to their sizes and ability to carry people en mass, the cost per passenger kilometre is lower, making them affordable to users. Fourthly, as mass transit systems carry more efficient engines, they can save fuel better than small vehicles. Finally, their impacts (negative effects) on the external environment is lower compared to small vehicles. From the foregoing discussion, mass transit provides solutions to the economic, social, energy and environmental challenges in the city.

In probing the stakeholders on the practicability of achieving mass transit, two views were expressed. The first entails a ban on importation and licensing of small capacity public transport vehicles. This suggestion bodes well with Government policy on phasing out public transport vehicles with a sitting capacity of less than 26. The Minister of Transport has also indicated Government’s intention to ban minibuses. This cannot be instant but a process which takes time. It is inconceivable and unrealistic to go for an abrupt ban as small vehicles are at present the backbone of public transport in Harare. Authorities need to act decisively and start the process to phase out minibuses by not licensing new ones. Concomitantly, they need to curb on all unregistered vehicles which is a significant proportion of the minibus population.

Empowering the current operators to acquire and operate bigger buses was the second option suggested by stakeholders. This entails the present operators combining their resources or partnering with the local authority and other interested parties to buy bigger buses. Already, a group of minibus operators who have responded to the policy direction of mass transit have formed an association with the intention of importing conventional buses. The initiative is a move in the right direction as operating under the umbrella of an association reduces the number of
individual operators. Urban operations are not ideal for individual operators. Therefore the initiative needs to be supported by Government. For instance, Government needs to provide the necessary guarantees to enable these operators to buy buses. However, Government, as the decision maker has failed to ‘walk the talk’ in its support of the mass transit system. In its budget presented on 19 December 2013, the budget was silent on improving public transport.

Franchising of routes is another option that the City Council can use to introduce bigger buses on high demand corridors. For the successful implementation of this option, there are conditions that should be met. Minibuses must not be allowed to operate on these routes and strict enforcement is required. The city Council and the company operating on a franchised route should agree and sign a performance contract that would guarantee an acceptable level of service. The awarding of a contract need to take cognisance of the company’s ability to deliver the required service and not to be based on favouritism. Contracts based on favouritism do not last (not sustainable) and service delivery is poor.

### 4.2 Institutional capacity

Institutional capacity is an essential ingredient for a sustainable urban transport in the city of Harare. Currently, there is a serious lack of technical skills to address urban transport challenges at the City. The Traffic and Transport Department at the City of Harare has no employee with relevant qualifications and experience in transport. In order to plan and implement appropriate transport projects that would contribute to a sustainable city, the City of Harare needs to acquire skills capacity. While the capacity requirements is urgent, sadly, the state of the economy is not conducive to the attraction of these skills. Due to financial constraints experienced by the Local Authority, even outsourcing the requisite capacity becomes difficult. Capacity remains an intractable issue whose resolution appears to be remote and even stakeholders could not come up with concrete suggestions.

### 4.3 Infrastructure improvements

Transport infrastructure is in dire need of improvement. As one respondent (University of Zimbabwe Lecturer) in response to the necessary requirements to achieve sustainable transport pointed out “After providing infrastructure it has to be well managed and maintained”. In Harare, roads are characterised by potholes, most traffic signals are malfunctioning and public transport termini are in need of face lifting. Potholes and malfunctioning traffic signals are external factors that also contribute to higher levels of congestion and pollution in the city. Both factors do not allow traffic to flow smoothly and such delays affect the economy through loss of production. Clearly, infrastructure improvement is a necessary condition of a sustainable urban transport. Again, akin the case of institutional capacity, infrastructure improvements are being constrained by financial resources. A senior officer in the City’s Engineering Department on 29 March 2012 had this to say,
'there has been no functional budget for the last 10 years. In 2009, the division got $8 million for road maintenance but the amount of money only existed on paper’”

4.4 Governance

According to Birner (2007), Governance is the exercise of economic, political, and administrative authority to manage a country’s affairs at all levels. The concept is an important one in assessing the relationship between the ‘governors’ and the ‘governed’. Governance is participatory, transparent, and accountable and promotes the rule of law. Birner (2007) in the International Food Policy Research Institute publication, quoted the former Secretary General of the United Nations, Kofi Anani saying “Good governance is perhaps the single most important factor in eradicating poverty and promoting development”(reference with page number).

The issue of good governance featured either explicitly or implicitly in all the interviews conducted with stakeholders. Most stakeholders argued that the macro socio-economic and political landscape in the country was not conducive to the achievement of sustainable transport. The economy is depressed and investment is not forthcoming. Projects such as mass transit and improvement of infrastructure that are required to reach the sustainable transport milestone cannot attract funding both locally and internationally. The realisation of these vital projects is depended on good governance and it is only the Government which can create an enabling environment for investment.

The second governance concern cited by stakeholders pertains to institutional setup. There are a multiplicity of actors, Government Ministries (Local Government and Transport), Local Authority, Zimbabwe National Roads Administration (ZINARA), Zimbabwe Republic Police (ZRP) and others involved in transport matters. The situation was deemed to be disjointed as a coherent and systematic approach is missing. For instance ZINARA is responsible for collecting vehicle fees and the City laments the meager amounts it receives. The ZRP was blamed for mounting endless roadblocks compounding the problem of traffic flow. The roles of the Ministries of Transport and Local Government are not clearly defined albeit both being involved in urban transport matters. Some stakeholders suggested an Urban Transport Authority as a way of resolving the current institutional dysfunctional challenges. While the suggestion is plausible, the Authority can only succeed if it is given space to perform its functions without external interference.

Finance is one of the key pillars for sustainable urban transport. One of the challenges facing the City of Harare, is shortage of funds and inability to raise same in order to finance critical transport projects, let alone maintaining existing infrastructure. Ironically, its revenue base was further reduced when the Minister of Local Government unilaterally ordered all Local Authorities to write off debts owed by residents from February 2009 to the end of June 2013. Using ministerial powers under both the Rural District Council Act and the Urban Councils Act, the Minister said: "Councils are directed to write off debts in respect of rentals, unit tax,
The directive was given eight days before a crucial general election and was interpreted in some quarters as a way of buying votes. One interviewee described the Minister’s action as follows: “technically the Minister’s decree to write off debts was a non-starter as it has left local authorities with dire financial difficulties”. Local Authorities who were not consulted described the directive as ‘populist cheap politicking’ and not in favour of this directive as it was against the participatory and consensus-oriented principles of good governance. The reduction in funds as a result of an ill-advised decision has adversely affected the ability of the Local Authority to address transport requirements which include road building and maintenance among others.

The outrageous earnings paid to City of Harare executives dubbed ‘obscene salaries’ were deemed by stakeholders as a hindrance to achieve sustainable transport in Harare. The clandestine pay roll for executives, which had been kept a secret for years only got revealed after exertion of external pressure. According to the Herald (14 January 2014), (Nineteen (19) senior council employees were earning a combined US$500 000. The stakeholders’ argument was that the high salaries for a few executives, meant a diversion of money from critical projects. In addition junior staff whose salaries were at the time lagging by three months get disillusioned and fail to effectively perform their functions, which in terms of transport include planning and enforcement of traffic by-laws.

Clearly, sound national and local governance albeit not directly related to transport, is essential in achieving sustainable transport. Good governance requires transparency to enable all stakeholders to be aware of how decisions are made and justification thereof. The executive salaries of City of Harare officials cited above lacked transparency. Accountability calls for involvement, which was not the case with the Minister’s directive to write off Local Authority debts.

4.5 Role of Travel Demand Management

The role of Travel Demand Management (TDM) was not mentioned by any stakeholder, notwithstanding its importance in contributing to sustainable urban transport. The fact that TDM was not mentioned may be a reflection of the lack of capacity and paucity of a deeper knowledge on how to tackle transport challenges in the country. The achievement of sustainable urban transport cannot be accomplished without implementing some TDM measures. Equally, this paper would be incomplete without an appreciation and reference to TDM.

Demand Management is a technique that uses various strategies to increase transportation system efficiency (Victoria Transport Policy Institute, 2011). In essence, TDM measures are concerned with the alteration of travel behaviour in order to enhance the efficient use of the existing road infrastructure and facilities. The City of Harare would greatly benefit by employing TDM as the Local Authority
has no funds to build new roads that are required to accommodate growth in traffic. Even assuming that the City has the requisite funds, any attempts to match the demand for road space with supply are untenable, as more traffic would be generated clogging the new road space provided and compounding the congestion and pollution problems.

Traffic flow can be improved by shifting the trip in terms of the use of alternative times through measures such as staggered working hours. It would be more effective to encourage the corporate world to promote these schemes voluntarily rather than making them mandatory.

A reduction on car dependence trips is necessary in order to minimise congestion in urban areas. This can be achieved by encouraging people to share their cars. A significant shift to public transport would also reduce trips but this has to be concomitantly undertaken with the improvement of public transport in terms of adequacy, efficiency and reliability.

Transport land use integration is another TDM tool that the City can implement to achieve urban transport sustainability. The local authority needs to implement land use planning policies that integrate residential and employment areas. Effective transport land use integration minimises travel costs and reduces congestion as the number of vehicles travelling to the Central Business District (CBD) are reduced.

Another TDM measure that the Local Authority can implement with minimal financial injection is parking supply restrictions. This can be achieved either by limiting the physical supply of parking space in the central area or charging parking space to discourage private vehicles entering the central business district. Again this measure (a stick) should be balanced by the provision of a good quality public transport (a carrot).

In order to decongest the CBD and rein in on the traffic lawlessness propagated by minibus drivers and touts, the City Council constructed a huge minibus holding bay on the outskirts of the CBD. Minibuses are required to drop passengers in the CBD and then proceed to park at the holding bay. Radio systems would be used to control the movement of kombis (minibuses) between the holding bay and the rank in the CBD. This innovative scheme falls within the realm of TDM. Its success is depended on the level of compliance by minibus drivers as well as enforcement by the local authority. The Local Authority and other stakeholders see this intervention as the panacea to the traffic congestion problem. “We are really worried about the state of affairs in the CBD and we have plans to establish a holding area far away from town to reduce the chaos,” remarked the Executive Secretary of the Rural Urban Councils Association.

The project was launched on 4 August 2014. At the time of writing this paper, only five days had passed after the holding bay project was launched. It is therefore too early to make any conclusions on the success or otherwise on this intervention.
However, very few vehicles were seen using the holding bay in the first three days. Concerns are being raised on the capacity of the local authority to manage the system. Some minibus drivers see the holding bay as “a threat to their source of livelihood” (Newsday, 9 August 2014) and may not comply. Minibuses that are not legally registered will shun the holding bay and may continue to use undesignated ranks. Council’s traffic enforcers are on numerous occasions involved in cat and mouse chases with non-compliant kombis that use undesignated ranks.

The minibus holding bay project is a litmus test for the City of Harare to demonstrate its commitment to decongest the CBD. It needs to enforce compliance, prove that the system works and is beneficial to minibus operators and other stakeholders.

4.2 CONCLUSIONS

Urban transport in Harare is in need of transformation. Transport infrastructure is crumbling and the road network is characterised by potholes. Congestion has reached gridlock levels, in turn increasing business and community costs. Small vehicles which solely provide public transport are inadequate, inefficient and unreliable. As the number of vehicles continue to increase, the problem is bound to worsen if interventions are not forthcoming.

The need to move towards sustainable urban transport in Harare cannot be overemphasised. For sustainable transport to be achieved, the following measures are critical to reach the milestone:

- Investing in mass transit systems which are efficient users of road space due to their high carrying capacities,
- Urgent transport infrastructure improvements to repair potholes, traffic signals and public transport termini is required,
- Building capacity and retain skills
- Improvements in transport infrastructure
- Implement Travel Demand Management projects which are less costly and capable of early implementation.

In order to implement the above, the bottom line is good governance. Government, the municipality, industry, commerce and residents must all have a common goal and see the same target. As for Government, there is need for the country to improve its image and create a congenial environment for infrastructure investment.

REFERENCES


Government of Zimbabwe, 1993, Economic Structural Adjustment Programme


Newday, 9 August 2014, Few kombis as Harare holding bay is opened

Richardson B., 1999. Towards a policy on a sustainable transportation system, Transportation Research Record 1670, TRB (www.trb.org) [Accessed 10 August 2014]

The Herald, 26 May 2014, Commuter omnibus disaster matrix: the operator driver, traffic cop

The Herald, 26 May 2014. Commuter omnibus disaster matrix: The operator, driver, traffic cop

Traffic Safety Council of Zimbabwe (TSCZ 2012). Accident statistics figures given orally

TRB, 1997. Committee for a study on Transportation and a Sustainable Environment, Toward a Sustainable Future; Addressing the Long-Term Effects of Motor Vehicle Transportation on Climate and Ecology, National Academy Press, cited in Sustainable Transportation and TDM, Planning That Balances Economic, Social and Ecological Objectives, TDM Encyclopedia, Victoria Transport Policy Institute, June 2014,


United Nations, 2005. World Urbanisation Prospects, the 2005 Revision Department of Economic and Social Affairs, Population Division,


Zimbabwe Demographics Profile 2013. www.indexmundi.com/zimbabwe/demographics_profile. [Accessed 6 August 2014]

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Thème : Changement climatique, qualité de l’air et défis énergétiques :
le rôle des politiques de transport urbain et des mesures préventives
dans les pays en développement et les économies émergentes
Sous-thème 1 : Problèmes et externalités du transport

LA PLANIFICATION INTEGREE, OUTIL DE DEVELOPPEMENT DURABLE
DES TRANSPORTS URBAINS :
CAS DU GRAND ABIDJAN

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Abstract

Within the framework of the conference CODATU XVI, the present entitled communication « the integrated planning, the tool of sustainable development of public transports: case of Great Abidjan » dedicated to the sub-theme 1: « problems and externalities of public transport » would want to bring to light the advantages waited regarding sustainable development of the public transports of the successful implementation of the urban master plan of Great Abidjan (SDUGA) of 2014 which realized in a document the urban planning and the planning of transport.

Indeed, since Côte d’Ivoire’s independence, Great Abidjan was endowed, at regular intervals, with document of urban planning and with strategic studies to assure the coherent development of its territory. However, the elaboration separated from the documents of urban planning and from transport in different times(periods) did not still produce convincing results in particular in terms of reductions of the negative externalities of the system of public transports.

The SDUGA 2015-2030 will integrate the approaches or concepts of planning directed to the sustainable development to know the commitment of the Government to realize a study of environmental and social impact for the approval of new developments, the creation of a compact city and development centred on the mass transport, the concentration of labor pools, reduction of the poverty, and standards of planning taking into account the density and the constraints of the land’s value.

The present communication will thus attempt to raise the environmental advantages waited by implementation of public mass transport projects.

KEY WORDS : Abidjan, public transport, sustainable development, master plan, town planning
Résumé

En effet, depuis l’indépendance de la Côte d’Ivoire, le Grand Abidjan a été doté, à intervalles réguliers, de document de planification urbaine et d’études stratégiques pour assurer le développement cohérent de son territoire. Toutefois, l’élaboration séparée des documents de planification urbaine et de transport à des époques différentes n’a pas toujours produit des résultats probants notamment en termes de réductions des externalités négatives du système des transports urbains.
Le SDUGA 2015-2030 envisage intégrer les approches ou concepts de planification orientés vers le développement durable à savoir l’engagement du Gouvernement à réaliser une étude d’impact environnemental et social pour l’approbation de nouveaux aménagements, la création d’une ville compacte et de développement axé sur le transport de masse, la concentration des bassins d’emploi, la réduction de la pauvreté, et les normes de planification prenant en compte la densité et les contraintes de la valeur des terres.
La présente communication s’attacherà donc à relever les avantages environnementaux attendus par la mise en œuvre des projets de transport public de masse.

MOTS CLES : Abidjan, transport public, développement durable, Schéma Directeur, urbanisme
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1. Cadre et objet de la communication

1.1. Contexte et opportunités


A la fin de la crise post-électorale de 2010-2011, la coopération japonaise a accordé au Gouvernement ivoirien, un don pour financer le projet pour le développement du Schéma Directeur d’Urbanisme du Grand Abidjan (SDUGA).

L'objectif d'élaborer un SDUGA durable et conforme à la politique nationale de développement devrait être atteint par (1) l'évaluation et l'analyse préalable du Schéma Directeur d'Urbanisme de 2000, (2) l'élaboration du Schéma Directeur d'Urbanisme à l’horizon 2030, y compris le Schéma Directeur des Transports Urbains, et (3) la réalisation des études de faisabilité pour 2 ou 3 projets structurants ou intégrés de transports urbains.

La zone de planification du SDUGA est la région du Grand Abidjan composée des treize (13) communes du District Autonome d'Abidjan (DAA) et de six (6) communes voisines, à savoir Grand-Bassam, Bonoua, Alépé, Azaguié, Dabou et Jacqueville. L'étude du SDUGA couvre une superficie d'environ 3 492 km². Elle comprend le District Autonome d’Abidjan (couleur verte) et six (6) nouvelles communes (couleur jaune) et sous-préfectures (hachurées) à savoir Alépé, Azaguié, Bonoua, Dabou, Jacqueville et Grand-Bassam. La zone totale contient une population estimée à 5 375 000 qui devrait atteindre 8 413 000 en 2030.

Figure 1 : zone de planification du SDUGA 2030

Source : Mission d’étude de la JICA

Comme le sous-tend l’intitulé, nous présenterons dans cette communication les avantages d’une planification intégrée du grand Abidjan pour un développement des transports urbains.

1.2. Problématique

Tous les documents antérieurs de planification du Grand Abidjan, élaborés séparément n’ont pas permis un développement efficient du système des transports urbains notamment la mise en place d’une offre de transport public de masse suffisante, moins consommatrice d’espace et d’énergie, respectueuse de
l’environnement pour faire face à la demande croissante de déplacements, consécutif à une urbanisation incontrôlée.

1.3. Résultats attendus
La présente communication vise à analyser le SDUGA, document de planification intégrée de la ville et des transports, pour relever en quoi, il peut être un outil au service du développement durable des transports urbains dans le Grand Abidjan.
A près avoir situé le lecteur sur le cadre socio-économique et l’état de la planification du Grand Abidjan, nous présenterons un large aperçu des principales conclusions du SDUGA notamment en matière de réseaux de transport public de masse.

2. Cadre socio-économique du Grand Abidjan
Le cadre socio-économique qui tient à la fois du domaine social et du domaine économique détermine les principaux indicateurs, comprenant la population, l'emploi et la croissance économique dans le Grand Abidjan. A ce titre, il joue deux (2) fonctions principales dans la planification urbaine :

☐ Primo, il fournit les secteurs d'activités urbaines et leur étendue géographique avec des bases communes de même que des objectifs indicatifs globaux de planification. Cette fonction est d’une importance capitale dans la planification multisectorielle intégrant la planification urbaine.

☐ Secundo, il fournit également une base pour les estimations de la demande des installations, infrastructures et services nécessaires à la planification du secteur, y compris la planification des transports.
La Côte d'Ivoire a une superficie de 322 462 km² et une ligne côtière Est-Ouest de 515 km avec de nombreuses lagunes, surtout dans sa partie Est. Abidjan a toujours été une ville portuaire bordée par la lagune Ebrié. Le pays est entouré par le Ghana, le Burkina Faso, le Mali, la Guinée et le Libéria.
Les terres sont essentiellement plates à l'échelle nationale. La végétation varie des forêts tropicales du Sud à la savane au Nord. Avec beaucoup de précipitations, la partie Sud est caractérisée par l'agriculture d'exportation tropicale, la production alimentaire et forestière, tandis que les cultures de terres arides telles que le coton et la noix de cajou, ainsi que l'élevage sont les principales activités de production dans la partie Nord. Il y a quatre (4) grands fleuves, du Nord au Sud, comprenant les fleuves Comoé, Bandama, Cavally et Sassandra.
Les terres nationales comprennent les terres agricoles représentant environ 20%, les prairies et pâturages permanents qui sont d’environ 40%, et les terres forestières d’environ 33%.

La population nationale est estimée à 20,316 millions en 2013 alors qu’elle est de 5 375 000 dans le Grand Abidjan, ce qui représente environ 25% du total national. La croissance de la population nationale est, à l’heure actuelle, d’environ 2%, ce qui est inférieur au taux de croissance moyen en Afrique estimé à 2,3%.
Selon les données de la Banque mondiale, le PIB national s'élève en 2012 à 24 680 millions de $ US et le PIB par habitant s'élève à 1 220 $ US (méthode de l’Atlas et basé sur la parité de pouvoir d’achat). Le PIB par habitant est comparable à la moyenne de l’Afrique sub-saharienne qui est de 1 345 $ US pour la même année.
La plus grande source de PIB repose sur l'agriculture, l’industrie manufacturière et l'exploitation minière. Le secteur le plus dynamique est l'exploitation minière, celle...
du pétrole en particulier. La part des services dans la formation du PIB n'a cessé d'augmenter.

Au plan de l'emploi les secteurs primaire, secondaire et tertiaire absorbent respectivement 48%, 7% et 45%, de l'emploi total, soit 9 492 000 personnes en 2012, selon les statistiques de l'institut national de la statistique (INS).

La Côte d'Ivoire a exporté pour 9 046 millions de $ US et en a importé pour 5 664 millions de $ US en 2012. Pendant la période 2010 - 2012, elle a exporté pour 10 126 millions de $ US et a importé pour 6 744 millions de $ US par an en moyenne.


Selon le Centre de promotion des investissements de Côte d'Ivoire (CEPICI), la répartition entre les investissements étrangers et nationaux est de 50 / 50 en 2011.

La Côte d'Ivoire connait un déficit alimentaire tout en présentant une suffisance alimentaire globale estimée à environ 70%.

La consommation de céréales a été de plus en plus dépendante de l'importation qui n'a cessé d'augmenter depuis le début des années 1980 et a dépassé la production nationale depuis 2004. La pénurie chronique et l'intensification des denrées alimentaires mêlées parfois aux hausses de leurs prix sont dans la plupart des cas des justificatifs de l'instabilité sociale potentielle connue par le passé.

3. **Etat de la planification dans le Grand Abidjan**

Les principales conclusions de l'évaluation, en termes de réalisation du Schéma Directeur de 2000, ont montré que les objectifs n’ont pas été atteints en raison des principales difficultés exposées ci-après :

- les projets de logements stratégiques, d’emploi, de services publics en réseau et de transport urbains retardés en raison de l’instabilité politique sur la période 1999-2011 et de l’absence d’investisseurs privés ;
- la répartition inégale des projets achevés ;
- les emprises du réseau routier principal et les réserves foncières publiques occupées illégalement ;
- les zones d’expansion urbaine partiellement aménagées ;
- les structures de mise en œuvre inadéquates ;
- le manque de financement.

Sur la base de ce constat, les principaux projets à poursuivre dans le SDUGA 2030 sont les suivants :

- **La structure spatiale** : les futurs projets de développement sont organisés en six (6) unités urbaines comprenant les communes contiguës. Des unités supplémentaires seront identifiées pour intégrer toutes les communes à l’intérieur du Grand Abidjan.

- **Les zones d’expansion urbaine** : celles-ci n’ont été que partiellement développées depuis que le Schéma Directeur de 2000 a été établi. Elles seront
maintenues pour définir la limite de la zone urbaine d'Abidjan. Dans certains cas, des zones d'expansion supplémentaires seront définies pour tenir compte de la nouvelle croissance découlant de récents projets de voies structurantes.

- **La densification urbaine** : le développement intensif envisagé a été quelque peu sporadique. Cette proposition sera poursuivie et associée à la densification des centres civiques et des zones TOD (Transit Oriented Development).

- **La rénovation urbaine** : la restructuration des quartiers les plus anciens de la ville n'a pas eu lieu, entraînant une détérioration du tissu/paysage urbain. Le renouvellement urbain sera un élément essentiel dans le futur Schéma Directeur.

- **La conservation** : la perte des terres naturelles non aménagées - forêts et zones de captage d'eau a continué et avec des questions telles que la perte de la biodiversité, la qualité de l'environnement, la santé et la sécurité générale. Il est impératif que la protection des ressources naturelles du Grand Abidjan soit ramenée au premier plan de la future stratégie de développement durable.

- **Les logements publics** : la fourniture de logements publics pour les personnes à faible revenu a chuté bien en dessous de la demande. Ainsi, plus de 32% de la population du DAA occupent des habitations informelles ; d'où l'urgence de fournir des logements à loyer modéré.

- **Les logements privés** : le secteur privé fournit principalement des logements aux personnes à revenus moyens et élevés en offrant des logements économiques et des propriétés plus haut de gamme. En raison des facteurs ayant entraîné le développement, la densification spontanée des propriétés urbaines existantes a pris le pas sur la demande, mettant une pression énorme sur les capacités des infrastructures publiques. Les nouveaux logements du secteur privé devront être concentrés dans les zones d’expansion et à travers le redécoupage et les logements en hauteur.

- **Les installations illégales** : depuis le Schéma Directeur de 2000, les terrains occupés, les densités et la population de ces zones a augmenté. La délocalisation sera nécessaire dans certains endroits pour exécuter des projets stratégiques de voirie et assurer la santé et la sécurité de la zone urbaine.

- **Le transport** : le réseau de voies structurantes et de systèmes de transport public n’est pas achevé et, de ce fait, constitue la base de la future stratégie de transport. C’est l’absence d’une offre de transport public adaptée qui est l’une des causes des dysfonctionnements observés.

- **Les services publics** : ceux-ci n’ont pas suivi le rythme de la croissance et la répartition de la population. Les normes de planification existantes datent, dans certains cas, de 20 ans et doivent être actualisées.

- **L’industrie** : une seule des zones industrielles proposées a été construite, les autres seront incluses dans la planification future.

- **Les infrastructures** : les grands équipements publics ont été retardés ; ceux-ci seront intégrés dans le Schéma Directeur de 2030.

- **L’agriculture** : bien que les plantations aient été identifiées dans le Schéma Directeur de 2000, les zones urbaines aménagées actuellement n’occupent que 18% de la superficie totale du Grand Abidjan. Des propositions pour le développement agricole seront nécessaires dans la planification future, à la fois...
pour protéger la zone de l’étallement urbain et augmenter la productivité agricole en vue d’assurer la sécurité alimentaire du Grand Abidjan.

4. **Présentation des résultats de l’étude SDUGA 2015 - 2030**

4.1. **Développement durable du Grand Abidjan autour d’une planification intégrée de l’urbanisation et des transports**

4.1.1. **Stratégies de développement durable**

L’engagement de la Côte d’Ivoire au futur développement durable est énoncé dans le document élaboré en 2011 par le Ministère de l’Environnement, de la Salubrité Urbaine et du Développement Durable (MESUDD) sur la « Stratégie Nationale pour le Développement Durable et son Plan d’Action 2012 -2016 » qui est une ébauche de la loi d’orientation sur le développement durable.

Cette loi adoptée au deuxième trimestre 2014 par l’Assemblée Nationale à « … pour objectif de définir les modalités de mise en œuvre de la politique nationale en matière de développement durable. Ses axes fondamentaux concernent les engagements de l’Etat à être exemplaire en matière de développement durable, l’instauration de dispositifs pour mesurer les progrès nationaux dans ce domaine, l’obligation faite aux grandes entreprises de faire connaître les efforts consentis en matière de responsabilité sociétale et l’information régulière du parlement »… »

Les principaux éléments stratégiques de la durabilité sont :
1. promotion de la production et de la consommation durable ;
2. paix, sécurité de personnes et des biens et promotion de la bonne gouvernance ;
3. promotion du patrimoine culturel et de la diversité ;
4. gestion durable des ressources naturelles, de la biodiversité et renforcement de la lutte contre le changement climatique ;
5. maîtrise de la dynamique démographique et du développement des secteurs sociaux ;
6. renforcement de la coopération et de l’intégration ;
7. promotion de l’éducation, de l’information et de la communication.

Abidjan a un besoin urgent d'accélération de sa croissance économique en vue de satisfaire à la fois l'objectif national de devenir une économie émergente en 2020 mais également les attentes grandissantes d'une population croissante, dont environ un quart vit dans des quartiers précaires.

Cet impératif de la relance économique doit être mis en regard de la croissance de la population qui a entraîné une expansion de l'urbanisation, particulièrement visible à travers la perte de terres agricoles à la périphérie de la zone urbaine actuelle et la menace pour les zones de captage d'eau qui alimentent la lagune Adjin et la lagune Potou, où l'eau potable est stockée.

L'impact, en termes de dégradation de l'environnement, dans le Grand Abidjan peut se résumer par :

- une forte dégradation des sols ;
- l'érosion des sols et des pentes, le long des vallées fluviales ;
- la pollution des rivières, des lagunes et des ressources en eaux souterraines ;
- la déforestation à grande échelle ;
- la perte de la diversité biologique en raison de l'urbanisation ;
l'insuffisance des équipements pour l'évacuation des eaux usées et l'élimination des déchets solides dans les zones urbaines ;
les embouteillages dans la ville, ainsi que le bruit associé, la mauvaise qualité de l'air et les externalités négatives relatives à la sécurité ;
et les mauvaises conditions de vie dans les habitations informelles.

4.1.2. Objectifs de développement du système des transports urbains
Les objectifs de développement du système des transports urbains poursuivis par le SDUGA pour répondre aux défis du développement durable sont 1) l'efficacité, 2) l'équité et 3) un environnement de qualité.

1) Efficacité
Un système de transport efficace doit être élaboré pour renforcer les fonctions urbaines, améliorer la qualité de vie des populations, faciliter les activités économiques et soutenir la croissance économique stable à Abidjan. Il est particulièrement important d'atteindre l'efficacité en réduisant les externalités négatives telles que la perte économique des temps de déplacement, causée par l'accroissement du trafic routier.
L'efficacité dans le transport peut être réalisée en équilibrant la demande croissante des déplacements et la fourniture d'infrastructures de transport. Il existe trois (3) façons d'équilibrer l'offre et la demande: 1) par l'augmentation et l'amélioration de la capacité des infrastructures pour répondre à la demande, 2) en optimisant l'utilisation des infrastructures de transport existantes à travers des mesures efficaces de contrôle des transports (TCM), et 3) en diminuant la demande accrue de la circulation routière grâce à la gestion de la demande en transport (TDM) tout en incitant les propriétaires des voitures particulières à l'usage des transports en commun.

2) Équité
L'équité signifie qu'un certain niveau minimum de mobilité doit être assuré et fourni à toutes les couches de la société.
Non seulement les voitures mais aussi tous les autres modes de transport devraient avoir le droit de partager l'espace public et se déplacer librement et en toute sécurité.
D'autre part, certaines personnes à faible revenu ne peuvent supporter les tarifs élevés de transport. Il s'agit des personnes socialement vulnérables, notamment les personnes âgées et les personnes handicapées qui ont une mobilité réduite due à leur état.
Un niveau abordable et suffisant de services de transport doit être fourni pour ces personnes, entre autres, par l'amélioration du système de transport public.

3) Environnement de qualité
Comme le laisse comprendre aisément les visions du Grand Abidjan pour « la provision d'un milieu de vie de qualité », la pollution de l'air et les bruits causés par les voitures devraient être minimisés par la promotion de l'utilisation des transports publics et le contrôle de la demande du trafic (TCM).
De même, la pollution de l'air et les bruits doivent être réduits par l'application de normes plus strictes quant aux émissions polluantes des véhicules.
Les TCM susmentionnées ont été initialement conçues pour réduire les émissions de polluants atmosphériques. En outre, la sécurité routière doit être améliorée et le nombre de victimes d'accidents devrait être minimisé par l'application des lois et règlements, des campagnes publiques intensives et la formation et l'éducation des conducteurs et du grand public. L'amélioration des installations de circulation à travers la conception d'ingénierie technique contribuera également à la réduction des accidents de la circulation.

4.2. **Urbanisation projetée du Grand Abidjan**

Suivant les objectifs de développement durable, le SDUGA comprend notamment l'élaboration du plan d’aménagement urbain du Grand Abidjan pour 2030.

4.2.1. **Contexte d’élaboration du SDUGA**


4.2.2. **Documents de planification stratégique**


4.2.3. **Objectif du plan cadre de développement urbain du Grand Abidjan**

Le plan cadre de développement urbain du Grand Abidjan définira une stratégie de planification urbaine sous la forme d’un plan cadre pour l'utilisation du sol et les politiques afférantes, pour diriger et gérer la croissance, en tenant compte des propositions de2000, d'une manière durable et équitable. **La stratégie permettra d'équilibrer les possibilités de croissance économique bénéfiques avec le caractère inhérent du paysage naturel et physique de la région.**

L'objectif est d'établir des zones de renouvellement urbain et d'expansion urbaine ainsi que des villes satellites qui fournissent des cadres de vie et de travail de grande qualité pour les résidents, les travailleurs et les visiteurs.
4.2.4. **Stratégie d’Aménagement spatial**

La stratégie d’aménagement spatial urbain du Grand Abidjan est illustrée ci-après.

*Figure 2 : stratégie de mise en œuvre de l’aménagement du Grand Abidjan 2030*

La zone urbaine devrait atteindre quelque 73 420 ha, environ 21% de l’ensemble de la région du Grand Abidjan, une augmentation par rapport à la situation actuelle de 12,7%.

Source : Mission d’étude de la JICA

Le plan ci-dessus indique la zone urbaine existante (aménagée ou terrains déjà pourvus d’infrastructures de services publics en réseaux de base), les futures zones d'expansion, les zones industrielles existantes et proposées, les zones de renouvellement urbain, les zones protégées et les futurs projets de voies structurantes et de transport public de masse.

La stratégie de mise en œuvre suppose la séquence suivante, coordonnée avec la croissance future et la fourniture d’infrastructures pour le réaménagement des zones de peuplement informelles :

1. **la relocalisation prioritaire :** les voies structurantes c’est-à-dire, le Parkway et la voie Y 4. Le réseau des routes et infrastructures stratégiques est un élément fondamental pour stimuler la croissance économique ;

2. **du court au moyen terme :** les zones soumises aux glissements de terrain, aux inondations et à la pollution, qui constituent un danger pour la santé des citoyens d’Abidjan, notamment les ravins. Ceux-ci devraient être réhabilités en tant qu’espaces publics ouverts pour améliorer le cadre de vie et la qualité de l'environnement d’Abidjan ;

3. **le long terme :** les façades des rues, les marchés locaux et les centres d’emploi à proximité, car ce sont les principales sources de revenus pour les populations des habitations informelles.

L'expansion urbaine dirigée par les principes de la ville compacte pour répondre à la croissance de la population, est calculée de sorte à obtenir une augmentation de la population urbaine existante. **La zone urbaine devrait atteindre quelque 73 420 ha, environ 21% de l'ensemble de la région du Grand Abidjan, une augmentation par rapport à la situation actuelle de 12,7%**.
4.2.5. **Présentation des unités urbaines**

Le Schéma Directeur de 2000 a organisé l’aménagement spatial en une série d’unités urbaines. La logique de ce regroupement spatial, qui prend en compte l’urbanisation historique, la création de manière interconnectée d’infrastructures routières, sociales et d’utilité publique, a été adoptée pour la stratégie d’aménagement spatial urbain du Grand Abidjan de 2030. Ainsi, les six (6) unités urbaines originales ont été élargies et modifiées pour obtenir dix (10) unités présentées dans le tableau ci-après :

**Tableau 1 : unités urbaines**

<table>
<thead>
<tr>
<th>Structure Spatiale Des Unités Urbaines</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>District Autonome d’Abidjan</strong></td>
</tr>
<tr>
<td>Unité 1 – Zone Urbaine Centrale</td>
</tr>
<tr>
<td>Unité 2 – Zone Côtière Urbaine du Sud Est</td>
</tr>
<tr>
<td>Unité 3 – Zone Urbaine Nord</td>
</tr>
<tr>
<td>Unité 4 – Zone Urbaine Est</td>
</tr>
<tr>
<td>Unité 5 – Zone Urbaine Ouest</td>
</tr>
<tr>
<td>Unité 6 – Zone Urbaine de Petit Bassam</td>
</tr>
<tr>
<td>Unité 7 – Zone Spéciale</td>
</tr>
<tr>
<td><strong>Villes Satellites</strong></td>
</tr>
<tr>
<td>Unité 8 – Grand Abidjan du Nord</td>
</tr>
<tr>
<td>Unité 9 – Grand Abidjan de l’Est</td>
</tr>
<tr>
<td>Unité 10 – Grand Abidjan de l’Ouest</td>
</tr>
</tbody>
</table>

*Source : Mission d’Etude de la JICA*

4.3. **Plan de développement de la mobilité urbaine dans le Grand Abidjan**

4.3.1. **Demande actuelle et future des déplacements dans le Grand Abidjan**

L’Enquête Ménage Déplacements (EMD) qui a été réalisée en 2013 sur un échantillon d’environ 20 000 ménages avait pour objectif de collecter les données nécessaires à l’établissement d’un modèle de prévision de la demande de transport. La zone d’enquête comprenant le District Autonome d’Abidjan et la commune de Grand-Bassam est localisée sur la figure ci-après :

*Figure 3 : délimitation de la zone d’EMD*

*Source : Mission d’Etude de la JICA*

4.3.1.1. **Configuration des ménages**

Le modèle de l’activité économique des ménages utilise quatre (4) niveaux, à savoir :

- Classe 1 : Aucun véhicule disponible (logement loué) ~ bas
4.2.5. Présentation des unités urbaines

Le Schéma Directeur de 2000 a organisé l’aménagement spatial en une série d’unités urbaines. La logique de ce regroupement spatial, qui prend en compte l’urbanisation historique, la création de manière interconnectée d’infrastructures routières, sociales et d’utilité publique, a été adoptée pour la stratégie d’aménagement spatial urbain du Grand Abidjan de 2030. Ainsi, les six (6) unités urbaines originales ont été élargies et modifiées pour obtenir dix (10) unités présentées dans le tableau ci-après :

Tableau 1 : unités urbaines

<table>
<thead>
<tr>
<th>Structure Spatiale Des Unités Urbaines</th>
</tr>
</thead>
<tbody>
<tr>
<td>District Autonome d’Abidjan</td>
</tr>
<tr>
<td>Unité 1 – Zone Urbaine Centrale</td>
</tr>
<tr>
<td>Attecoubé, Adjamé, Plateau</td>
</tr>
<tr>
<td>Unité 2 – Zone Côtière Urbaine du Sud Est</td>
</tr>
<tr>
<td>Port – Bouët, Grand-Bassam</td>
</tr>
<tr>
<td>Unité 3 – Zone Urbaine Nord</td>
</tr>
<tr>
<td>Abobo, Anyama</td>
</tr>
<tr>
<td>Unité 4 – Zone Urbaine Est</td>
</tr>
<tr>
<td>Cocody, Bingerville</td>
</tr>
<tr>
<td>Unité 5 – Zone Urbaine Ouest</td>
</tr>
<tr>
<td>Songon, Yopougon</td>
</tr>
<tr>
<td>Unité 6 – Zone Urbaine de Petit Bassam</td>
</tr>
<tr>
<td>Marcory, Koumassi, Treichville</td>
</tr>
<tr>
<td>Unité 7 – Zone Spéciale</td>
</tr>
<tr>
<td>Port d’Abidjan Port (une partie de Port – Bouët, Treichville, Yopougon)</td>
</tr>
<tr>
<td>Villes Satellites</td>
</tr>
<tr>
<td>Unité 8 – Grand Abidjan du Nord</td>
</tr>
<tr>
<td>Azaguié</td>
</tr>
<tr>
<td>Unité 9 – Grand Abidjan de l’Est</td>
</tr>
<tr>
<td>Alépé, Bonoua</td>
</tr>
<tr>
<td>Unité 10 – Grand Abidjan de l’Ouest</td>
</tr>
<tr>
<td>Dabou, Jacqueville</td>
</tr>
</tbody>
</table>

Source : Mission d’étude de la JICA

4.3. Plan de développement de la mobilité urbaine dans le Grand Abidjan

4.3.1. Demande actuelle et future des déplacements dans le Grand Abidjan

L’Enquête Ménage Déplacements (EMD) qui a été réalisée en 2013 sur un échantillon d’environ 20 000 ménages avait pour objectif de collecter les données nécessaires à l’établissement d’un modèle de prévision de la demande de transport. La zone d’enquête comprenant le District Autonome d’Abidjan et la commune de Grand-Bassam est localisée sur la figure ci-après :

Figure 3 : délimitation de la zone d’EMD

Source : Mission d’étude de la JICA

4.3.1.1. Configuration des ménages

Le modèle de l’activité économique des ménages utilise quatre (4) niveaux, à savoir :

- Classe 1 : Aucun véhicule disponible (logement loué) ~ bas
- Classe 2 : Aucun véhicule disponible (logement non loué) ~ faible ou moyen
- Classe 3 : Un véhicule disponible ~ moyen
- Classe 4 : Véhicules multiples disponibles ~ haut

Ces niveaux d’activité économique ont été vérifiés par la consommation mensuelle d’électricité des ménages. Ainsi, dans le cas de l’activité économique des classes 1 et 2 les dépenses mensuelles d’électricité sont respectivement de 5 190 et 8 490 FCFA.

A contrario pour les classes 3 et 4, les dépenses mensuelles d’électricité sont respectivement de 13 630 et 28 260 FCFA.

Ces postes de dépenses des ménages ont ainsi permis de vérifier la répartition des ménages dans les classes d’activité économique.

Les résultats de l’EMD ont permis notamment de déterminer la taille moyenne d’un ménage qui est de 4,23 personnes, en baisse par rapport à la valeur de 1998 qui était de 4,98. La taille moyenne d’un ménage d’Anyama est de 5,01 personnes, ce qui est la valeur la plus élevée tandis celle de 3,80 à Koumassi est la plus basse.

Le pourcentage de ménages possédant une voiture est de 4,90% dans la zone d’enquête. Ce pourcentage à Cocody est de 32,40%, ce qui représente le niveau le plus élevé et le taux le plus faible est à Songon avec 2,80%.

Les revenus moyens d’un ménage sont de 182 900 FCFA dans la zone d’enquête. La moyenne des revenus à Cocody est de 332 400 FCFA ; ce qui représente le niveau le plus élevé et le plus faible niveau est à Anyama avec 128 400 FCFA.

La répartition des revenus des ménages est présentée dans le graphique suivant.

Figure 4 : répartition des revenus des ménages

La distribution des revenus montre clairement que 73% des ménages ont un revenu inférieur à 200 000 FCFA par mois alors que les ménages ayant un revenu de plus de 400 000 FCFA par mois ne représentent que 9% du total.
se comporter de manière complètement différente d’une personne similaire d’une classe économique à haute activité.

Les modèles de production de déplacement et d’attraction de déplacement sont décomposés en quatre (4) catégories de motifs de déplacement :
- Entre le domicile et le travail (HBW : Home Based Work) :
- Entre le domicile et l’Ecole (HBE : Home Based Education) :
- Entre une autre activité et le domicile (HBO : Home Based Other) :
- Entre deux (2) activités non basée sur le domicile (NHB : Non Home Based).

Un déplacement basé sur le domicile a toujours comme destination finale la maison. Ainsi, un déplacement du domicile au travail, puis le déplacement inverse du travail au domicile ont deux (2) productions dans la zone d’analyse de trafic des ménages et deux (2) attractions dans la zone d’analyse de trafic professionnel.

En revanche, un déplacement non basé sur le domicile, par exemple du travail au supermarché, puis retour au travail a une production et une attraction dans chacune des zones d’analyse de trafic professionnel et scolaire.

L’affectation du trafic est réalisée dans le cadre du processus de validation finale. En raison des difficultés d’identification des types de véhicules individuels à la phase d’affectation, il n’a pas été possible de faire une comparaison fiable du relevé de la circulation et des véhicules par type de véhicules individuels.

Pour cette raison, une comparaison a été faite pour tous les types de véhicules sous la forme d’unité de voiture particulière (uvp) à travers quatre (4) lignes écran localisées sur la figure suivante.

Figure 5 : localisation des lignes écran

Source : Mission d’étude de la JICA
La comparaison numérique de toutes les lignes écran est présentée ci-après.
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Source : Mission d'étude de la JICA

Figure 5 : localisation des lignes écran localisées sur la figure suivante.

Pour cette raison, une comparaison a été faite pour tous les types de véhicules de circulation et des véhicules par type de véhicule individuels.

D’ailleurs, il n’a pas été possible de faire une comparaison fiable du relevé de la circulation professionnelle et scolaire.

En raison des difficultés d’identification des types de véhicules individuels à la phase de départ et d’arrivée, il n’a pas été possible de faire une comparaison fiable du relevé de la circulation professionnelle et scolaire.

Un déplacement basé sur le domicile a toujours comme destination finale la maison.

Un déplacement basé sur le domicile a toujours comme destination finale la maison.

Les modèles de production de déplacement et d’attraction de déplacement sont basés sur le domicile et sur le domicile.

Entre deux (2) activités non basée sur le domicile (NHB : Non Home Based).

Entre une autre activité et le domicile (HBO : Home Based Other) :

Entre le domicile et l’École (HBE : Home Based Education) :

La lecture du tableau ci-dessus appelle les commentaires ci-dessous :

Source : Enquête de trafic, mission d’étude de la JICA

Les principaux résultats de l’EMD sur la mobilité dans le Grand Abidjan sont présentés dans le tableau ci-après :

Tableau 3 : résultats de l’EMD

<table>
<thead>
<tr>
<th>N°</th>
<th>Commune</th>
<th>Taille moyenne d’un ménage</th>
<th>Revenu moyen par ménage (FFCFA)</th>
<th>% ménages possédant une voiture</th>
<th>Déplacements par ménage</th>
<th>Déplacements motorisés par ménage</th>
<th>Déplacements par personne</th>
<th>Déplacements motorisés par personne</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Abobo</td>
<td>4.48</td>
<td>160.7</td>
<td>4.9</td>
<td>6.37</td>
<td>2.6</td>
<td>1.63</td>
<td>0.67</td>
</tr>
<tr>
<td>2</td>
<td>Adjamé</td>
<td>4.33</td>
<td>170.1</td>
<td>5.3</td>
<td>6.67</td>
<td>2.5</td>
<td>1.77</td>
<td>0.66</td>
</tr>
<tr>
<td>3</td>
<td>Anyama</td>
<td>5.01</td>
<td>128.4</td>
<td>4.6</td>
<td>6.36</td>
<td>1.4</td>
<td>1.46</td>
<td>0.33</td>
</tr>
<tr>
<td>4</td>
<td>Attecoubé</td>
<td>4.15</td>
<td>140.4</td>
<td>3.6</td>
<td>5.72</td>
<td>2.5</td>
<td>1.58</td>
<td>0.71</td>
</tr>
<tr>
<td>5</td>
<td>Bingerville</td>
<td>4.01</td>
<td>160.2</td>
<td>6.0</td>
<td>5.94</td>
<td>2.5</td>
<td>1.70</td>
<td>0.72</td>
</tr>
<tr>
<td>6</td>
<td>Cocody</td>
<td>4.16</td>
<td>332.4</td>
<td>32.4</td>
<td>5.54</td>
<td>3.7</td>
<td>1.53</td>
<td>1.03</td>
</tr>
<tr>
<td>7</td>
<td>Grand-Bassam</td>
<td>4.65</td>
<td>172.2</td>
<td>6.3</td>
<td>6.92</td>
<td>2.4</td>
<td>1.71</td>
<td>0.60</td>
</tr>
<tr>
<td>8</td>
<td>Koumassi</td>
<td>3.80</td>
<td>154.0</td>
<td>6.9</td>
<td>5.58</td>
<td>2.6</td>
<td>1.69</td>
<td>0.80</td>
</tr>
<tr>
<td>9</td>
<td>Marcory</td>
<td>3.90</td>
<td>237.4</td>
<td>18.7</td>
<td>5.53</td>
<td>2.7</td>
<td>1.63</td>
<td>0.80</td>
</tr>
<tr>
<td>10</td>
<td>Plateau</td>
<td>4.59</td>
<td>302.2</td>
<td>19.4</td>
<td>6.66</td>
<td>4.1</td>
<td>1.67</td>
<td>1.03</td>
</tr>
<tr>
<td>11</td>
<td>Port-Bouët</td>
<td>3.93</td>
<td>167.9</td>
<td>4.6</td>
<td>5.10</td>
<td>2.6</td>
<td>1.49</td>
<td>0.77</td>
</tr>
<tr>
<td>12</td>
<td>Songon</td>
<td>3.85</td>
<td>107.6</td>
<td>2.8</td>
<td>5.70</td>
<td>1.6</td>
<td>1.70</td>
<td>0.48</td>
</tr>
<tr>
<td>13</td>
<td>Treichville</td>
<td>3.85</td>
<td>159.8</td>
<td>6.9</td>
<td>5.00</td>
<td>2.3</td>
<td>1.49</td>
<td>0.70</td>
</tr>
<tr>
<td>14</td>
<td>Yopougon</td>
<td>4.32</td>
<td>186.3</td>
<td>7.7</td>
<td>5.90</td>
<td>3.2</td>
<td>1.57</td>
<td>0.85</td>
</tr>
<tr>
<td>15</td>
<td>Moyenne</td>
<td>4.23</td>
<td>182.9</td>
<td>4.9</td>
<td>5.90</td>
<td>2.8</td>
<td>1.60</td>
<td>0.75</td>
</tr>
</tbody>
</table>

Source : Mission d’étude de la JICA

NB : les déplacements considérés sont ceux des personnes âgées de plus de 6 ans.

La lecture du tableau ci-dessus appelle les commentaires ci-dessous :

- Le nombre moyen de déplacements journaliers par ménage est de 5,90.
  Ce nombre est de 9,84 au Plateau ; ce qui est le chiffre le plus élevé quand le plus faible est de 6,78 déplacements à Port-Bouët.

- Le nombre moyen de déplacements motorisés par ménage est de 2,8.
  Ce nombre est de 6,64 au Plateau ; ce qui représente le chiffre le plus élevé de la zone d’enquête tandis qu’à Anyama l’on enregistre le chiffre le plus bas avec 6,63 déplacements.

- La mobilité individuelle quotidienne est de 1,60 contre 1,5 en 1998.
  La mobilité individuelle quotidienne à Adjamé est de 1,77, ce qui est la valeur la plus élevée tandis qu’Anyama possède la mobilité individuelle quotidienne la plus basse.

Une comparaison modale des déplacements est présentée ci-dessous entre les passagers observés et ceux estimés par le modèle de prévision de la demande.
La liste des voies routières identifiées pour soutenir le développement urbain du Grand Abidjan est dressée dans le tableau suivant.

<table>
<thead>
<tr>
<th>Mode</th>
<th>Observation (millions de déplacements par jour)</th>
<th>Estimation du modèle (millions de déplacements par jour)</th>
<th>% Différence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marche</td>
<td>5,505</td>
<td>5,482</td>
<td>-0.4</td>
</tr>
<tr>
<td>Public</td>
<td>6,138</td>
<td>6,481</td>
<td>5.6</td>
</tr>
<tr>
<td>Privé</td>
<td>1,450</td>
<td>1,365</td>
<td>-5.9</td>
</tr>
</tbody>
</table>

Source : Enquête ménages, Mission d’étude de la JICA
L’estimation des déplacements est de 13,3 millions alors que le nombre observé est de 13,1 millions, ce qui donne une différence de seulement 2% qui est un excellent résultat d’affectation de transport public.

Les données de planification pour les années 2020, 2025 et 2030 sont consignées dans le tableau ci-dessous.

<table>
<thead>
<tr>
<th>Année</th>
<th>Population (millions de personnes)</th>
<th>Déplacements motorisés (millions)</th>
<th>% ménages des classes économiques 3 et 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>5,541</td>
<td>7,846</td>
<td>10,5</td>
</tr>
<tr>
<td>2020</td>
<td>6,548</td>
<td>10,073</td>
<td>14,0</td>
</tr>
<tr>
<td>2025</td>
<td>7,509</td>
<td>11,821</td>
<td>17,3</td>
</tr>
<tr>
<td>2030</td>
<td>8,752</td>
<td>14,394</td>
<td>21,5</td>
</tr>
</tbody>
</table>

Source : Mission d’étude de la JICA
Le chronogramme de réalisation des futures infrastructures planifiées de transport public est présenté ci-après.

<table>
<thead>
<tr>
<th>Année</th>
<th>Rail Nord-Sud Phase 1</th>
<th>Rail Nord-Sud Phase 2</th>
<th>Rail Est-Ouest</th>
<th>Transport Lagunaire Amélioré</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>2020</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Réalisé</td>
</tr>
<tr>
<td>2025</td>
<td>Réalisé</td>
<td>Réalisé</td>
<td>Réalisé</td>
<td>Réalisé</td>
</tr>
<tr>
<td>2030</td>
<td>Réalisé</td>
<td>Réalisé</td>
<td>Réalisé</td>
<td>Réalisé</td>
</tr>
</tbody>
</table>

Source : Mission d’étude de la JICA

4.3.2. **Réseau des voies structurantes**

4.3.2.1. **Route**

Le District Autonome d’Abidjan est couvert par près de 1 800 km de routes dont 850 km sont bitumés notamment les principales artères telles que les boulevards, avenues et autoroutes traversant la plupart des communes. Deux ponts sur la lagune Ebrié relient les quartiers résidentiels septentrionaux de Cocody, Yopougon ou Abobo et la zone portuaire et industrielle du Sud qui s’étend de Treichville à l’île de Petit-Bassam.

Le réseau routier est caractérisé par des routes dégradées en surface, des liaisons manquantes et une capacité insuffisante. La congestion du trafic est constatée sur tout le réseau routier aux heures de pointe et rien n’a été fait pour changer cette tendance. **Beaucoup de projets routiers ont été planifiés mais n’ont pas encore été mis en œuvre, accentuant ainsi la pression sur le réseau routier.**

Rn raison d’un financement insuffisant, seuls quelques projets ont été mis en œuvre, tels que le 3ème pont et l’Autoroute Abidjan – Grand-Bassam, qui ont été financés par les bailleurs de fonds étrangers.

La liste des voies routières identifiées pour soutenir le développement urbain du Grand Abidjan est dressée dans le tableau suivant.
### Tableau 7 : liste des projets de voies structurantes prévues dans le Grand Abidjan

<table>
<thead>
<tr>
<th>Code</th>
<th>Projet</th>
<th>Voies de circulation</th>
<th>Fonction</th>
<th>Classe</th>
</tr>
</thead>
<tbody>
<tr>
<td>V-1-1</td>
<td>Développement de la voie périphérique Y4 – Section Songon / Autoroute du Nord</td>
<td>2x2</td>
<td>route de camionnage</td>
<td>principale</td>
</tr>
<tr>
<td>V-1-2</td>
<td>Développement de la voie périphérique Y4 – Section Autoroute du Nord / PK18</td>
<td>2x2</td>
<td>route de camionnage</td>
<td>principale</td>
</tr>
<tr>
<td>V-1-3</td>
<td>Développement de la voie périphérique Y4 – Section PK18 / Abobo Baoulé</td>
<td>2x2</td>
<td>BRT + route de camionnage</td>
<td>principale</td>
</tr>
<tr>
<td>V-1-4</td>
<td>Développement de la voie périphérique Y4 - Section Abobo Baoulé / François Mitterrand</td>
<td>2x2</td>
<td>BRT + route de camionnage</td>
<td>principale</td>
</tr>
<tr>
<td>V-1-5</td>
<td>Développement de la voie périphérique Y4 - Section François Mitterrand / Riviera 6</td>
<td>2x2</td>
<td>BRT + route de camionnage</td>
<td>principale</td>
</tr>
<tr>
<td>V-1-6</td>
<td>Développement de la voie périphérique Y4 - Section Pont de l’île Désirée</td>
<td>2x2</td>
<td>BRT + route de camionnage</td>
<td>principale</td>
</tr>
<tr>
<td>V-1-7</td>
<td>Développement de la voie périphérique Y4 - Section de l’Aérocité</td>
<td>2x2</td>
<td>route de camionnage</td>
<td>principale</td>
</tr>
<tr>
<td>V-1-8</td>
<td>Développement de la voie périphérique Y4 - Section du Canal du Vridi</td>
<td>2x2</td>
<td>route de camionnage</td>
<td>principale</td>
</tr>
<tr>
<td>V-1-9</td>
<td>Développement de la voie périphérique Y4 - Section de Jacqueville</td>
<td>2x2</td>
<td>route de camionnage</td>
<td>principale</td>
</tr>
<tr>
<td>V-2-1</td>
<td>Développement de BiARN – Rocade du Nord de Bingerville</td>
<td>2x2</td>
<td>route de camionnage</td>
<td>secondaire</td>
</tr>
<tr>
<td>V-2-2</td>
<td>Développement de BiARN - Extension du boulevard François Mitterrand</td>
<td>2x2</td>
<td>BRT + route de camionnage</td>
<td>primaire</td>
</tr>
<tr>
<td>V-2-3</td>
<td>Développement de BiARN - Elargissement de la route de Bingerville</td>
<td>2x2</td>
<td></td>
<td>secondaire</td>
</tr>
<tr>
<td>V-2-4</td>
<td>Développement de BiARN - Route BRT Bingerville</td>
<td>2x2</td>
<td>BRT + route de camionnage</td>
<td>secondaire</td>
</tr>
<tr>
<td>V-3-1</td>
<td>Développement de BaARN - Autoroute Abidjan-Bassam (en construction)</td>
<td>2x3</td>
<td>route de camionnage</td>
<td>principale</td>
</tr>
<tr>
<td>V-3-2</td>
<td>Développement de BaARN - Zone de l’Aérocité</td>
<td>2x2</td>
<td></td>
<td>secondaire</td>
</tr>
<tr>
<td>V-3-3</td>
<td>Développement de BaARN – Rocade Nord de Bassam</td>
<td>2x2</td>
<td></td>
<td>secondaire</td>
</tr>
<tr>
<td>V-3-4</td>
<td>Développement de BaARN - Elargissement de la route de Bonoua</td>
<td>2x2</td>
<td>route de camionnage</td>
<td>principale</td>
</tr>
<tr>
<td>V-4-1</td>
<td>Développement de YoARN - Voie V23 - Section Parkway</td>
<td>2x2</td>
<td>ferroviaire urbain</td>
<td>primaire</td>
</tr>
<tr>
<td>V-4-2</td>
<td>Développement de YoARN - Voie V23 – Section du 5ème pont</td>
<td>2x2</td>
<td>ferroviaire urbain</td>
<td>primaire</td>
</tr>
<tr>
<td>V-4-3</td>
<td>Développement de YoARN - Voie V2</td>
<td>2x2</td>
<td></td>
<td>secondaire</td>
</tr>
<tr>
<td>V-4-4</td>
<td>Développement de YoARN - Voie V6</td>
<td>2x2</td>
<td>BRT</td>
<td>secondaire</td>
</tr>
<tr>
<td>V-4-5</td>
<td>Développement de YoARN - Voie V9</td>
<td>2x2</td>
<td></td>
<td>secondaire</td>
</tr>
<tr>
<td>V-4-6</td>
<td>Développement de YoARN - Artère de la Zone industrielle de Yopougon</td>
<td>2x2</td>
<td></td>
<td>secondaire</td>
</tr>
<tr>
<td>V-4-7</td>
<td>Développement de YoARN - Voie V28 - Section Nord</td>
<td>2x3</td>
<td>route de camionnage + fret ferroviaire</td>
<td>primaire</td>
</tr>
<tr>
<td>V-4-8</td>
<td>Développement de YoARN - Voie V28 - 4ème pont</td>
<td>2x2</td>
<td>route de camionnage + fret ferroviaire</td>
<td>primaire</td>
</tr>
<tr>
<td>V-4-9</td>
<td>Développement de YoARN - Voie V28 - Section Sud</td>
<td>2x2</td>
<td>route de camionnage</td>
<td>primaire</td>
</tr>
<tr>
<td>V-4-10</td>
<td>Développement de YoARN - Elargissement de la route de Dabou</td>
<td>2x2</td>
<td>route de camionnage</td>
<td>primaire</td>
</tr>
<tr>
<td>V-4-11</td>
<td>Développement de YoARN –Rocade de l’Ouest de Yopougon</td>
<td>2x2</td>
<td></td>
<td>secondaire</td>
</tr>
<tr>
<td>V-4-12</td>
<td>Développement de YoARN - Elargissement de la Voie V1</td>
<td>2x2</td>
<td></td>
<td>secondaire</td>
</tr>
<tr>
<td>V-4-13</td>
<td>Développement de YoCRN – Route centrale de l’Île Boulay</td>
<td>2x2</td>
<td>route de camionnage</td>
<td>secondaire</td>
</tr>
<tr>
<td>V-4-14</td>
<td>Développement de YoCRN – Route dédié au Camionnage pour l’Île Boulay</td>
<td>2x2</td>
<td>route de camionnage</td>
<td>secondaire</td>
</tr>
<tr>
<td>V-5-1</td>
<td>Développement de AbARN - Extension Q1</td>
<td>2x2</td>
<td></td>
<td>secondaire</td>
</tr>
<tr>
<td>Code</td>
<td>Projet</td>
<td>Voies de circulation</td>
<td>Fonction</td>
<td>Classe</td>
</tr>
<tr>
<td>------</td>
<td>------------------------------------------------------------------------</td>
<td>----------------------</td>
<td>------------------------------</td>
<td>------------</td>
</tr>
<tr>
<td>V-5-2</td>
<td>Développement de AbARN – Rocade de l’Ouest d’Abobo</td>
<td>2x2</td>
<td></td>
<td>secondaire</td>
</tr>
<tr>
<td>V-5-3</td>
<td>Développement de AbARN - Elargissement de la rocade de l’Ouest du forêt du Banco</td>
<td>2x2</td>
<td>route de camionnage</td>
<td>primaire</td>
</tr>
<tr>
<td>V-5-4</td>
<td>Développement de AbARN - Elargissement de la route d’AIEPE</td>
<td>2x2</td>
<td>route de camionnage</td>
<td>primaire</td>
</tr>
<tr>
<td>V-5-5</td>
<td>Développement de AbARN - Elargissement de l’Autoroute d’Abobo</td>
<td>2x2</td>
<td></td>
<td>primaire</td>
</tr>
</tbody>
</table>

### Liste des projets routiers de la zone de Cocody

<table>
<thead>
<tr>
<th>Code</th>
<th>Projet</th>
<th>Voies de circulation</th>
<th>Fonction</th>
<th>Classe</th>
</tr>
</thead>
<tbody>
<tr>
<td>V-6-1</td>
<td>Développement de CoARN - prolongement du boulevard Latrille</td>
<td>2x2</td>
<td></td>
<td>secondaire</td>
</tr>
<tr>
<td>V-6-2</td>
<td>Développement de CoARN - Voie Y3</td>
<td>2x2</td>
<td></td>
<td>secondaire</td>
</tr>
<tr>
<td>V-6-3</td>
<td>Développement de CoARN - ancien alignement en Y4</td>
<td>2x2</td>
<td></td>
<td>secondaire</td>
</tr>
<tr>
<td>V-6-4</td>
<td>Développement de CoARN - Extension du boulevard de France</td>
<td>2x2</td>
<td></td>
<td>secondaire</td>
</tr>
<tr>
<td>V-6-5</td>
<td>Développement de CoARN - Boulevard de France Redressé</td>
<td>2x2</td>
<td></td>
<td>secondaire</td>
</tr>
</tbody>
</table>

### Liste des projets routiers du réseau routier central

<table>
<thead>
<tr>
<th>Code</th>
<th>Projet</th>
<th>Voies de circulation</th>
<th>Fonction</th>
<th>Classe</th>
</tr>
</thead>
<tbody>
<tr>
<td>V-7-1</td>
<td>Développement du CeARN - Voie Triomphale</td>
<td>2x4 +4</td>
<td></td>
<td>primaire</td>
</tr>
<tr>
<td>V-7-2</td>
<td>Développement du CeARN - 3ème pont (en construction)</td>
<td>2x2</td>
<td>route de camionnage</td>
<td>primaire</td>
</tr>
<tr>
<td>V-7-3</td>
<td>Développement du CeARN - Elargissement du boulevard de Marseille</td>
<td>2x2</td>
<td></td>
<td>secondaire</td>
</tr>
<tr>
<td>V-7-4</td>
<td>Développement du CeARN - Pont de Vridi</td>
<td>2x2</td>
<td>route de camionnage</td>
<td>secondaire</td>
</tr>
<tr>
<td>V-7-5</td>
<td>Développement du CeARN –Rocade Nord de Petit-Bassam</td>
<td>2x2</td>
<td>route de camionnage</td>
<td>secondaire</td>
</tr>
<tr>
<td>V-7-6</td>
<td>Développement du CeARN - Artère du Grand-Campement</td>
<td>2x2</td>
<td>BRT</td>
<td>secondaire</td>
</tr>
</tbody>
</table>

*Source : Mission d’études de la JICA*

L’aménagement des voies ci-dessus a pour épine dorsale la rocade Y4 en tant voie de contournement du centre-ville, c'est-à-dire une périphérique extérieure qui est localisée sur la figure ci-dessus :

*Figure 6 : développement de la voie périphérique Y4*

*Source : Mission d’études de la JICA*
L’objectif principal de cette voie périphérique Y4 est de détourner le trafic de transit et amener les camions de transport de marchandises à éviter le centre-ville.

4.3.2.2. Contrôle et gestion du trafic

Bien qu’il n’y ait pas de données fiables sur le nombre de véhicules à Abidjan, le tableau suivant présente la typologie des véhicules sur la base des inspections annuelles effectuées par la SICTA (Société Ivoirienne de Contrôles Techniques Automobiles), société concessionnaire.

**Tableau 8 : nombre de véhicules à Abidjan de 2010 à 2012**

<table>
<thead>
<tr>
<th>Type de véhicules</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Véhicules légers (y compris les voitures particulières et les vans)</td>
<td>127 760</td>
<td>125 843</td>
<td>149 050</td>
</tr>
<tr>
<td>Véhicules lourds (y compris les bus et les camions)</td>
<td>20 131</td>
<td>18 649</td>
<td>21 245</td>
</tr>
<tr>
<td>tracteurs</td>
<td>2 091</td>
<td>3 010</td>
<td>3 049</td>
</tr>
<tr>
<td>semi-remorques</td>
<td>2 608</td>
<td>3 121</td>
<td>3 549</td>
</tr>
<tr>
<td>Taxis-comeurs</td>
<td>16 047</td>
<td>15 077</td>
<td>18 773</td>
</tr>
<tr>
<td>taxis communaux</td>
<td>14 662</td>
<td>12 848</td>
<td>17 413</td>
</tr>
<tr>
<td>taxi brousse*</td>
<td>69</td>
<td>0</td>
<td>1 012</td>
</tr>
<tr>
<td>total</td>
<td>185 378</td>
<td>180 559</td>
<td>216 10</td>
</tr>
</tbody>
</table>

Note : *taxis à destination des zones éloignées.

Source : SICTA, données collectées dans cinq (5) stations du Grand Abidjan

En dehors de la réduction du nombre de véhicules en 2011, due à la crise post-électorale, la croissance annuelle est estimée à près de 10%. Les conditions de circulation à Abidjan ont déjà atteint un niveau intolérable. La demande dépasse la capacité de nombreux carrefours, provoquant une congestion sévère dans la journée.

La gestion du trafic est de plus en plus importante dans les zones urbaines où l’espace routier limité est sujet à la congestion. Des mesures visant à améliorer l’attractivité des transports publics sont également une partie de la politique de gestion du trafic pour améliorer l’efficacité globale de la circulation.

Des études de circulation ont été réalisées sur treize (13) intersections dans le Grand Abidjan pour comprendre les modes de circulation de chaque carrefour. Le niveau d'encerclement a été évalué et les résultats de cette analyse ont montré que la plupart de ces intersections nécessitent d’urgentes mesures d’aménagement. Des échangeurs peuvent être construits sur les principaux corridors routiers vers le centre-ville afin de réduire la congestion en minimisant les conflits de trafics. La liste des intersections à améliorer est dressée ci-dessous :

**Tableau 9 : liste des projets d'amélioration des intersections**

<table>
<thead>
<tr>
<th>Code</th>
<th>Projet</th>
<th>Voies de circulation</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>V-8-1</td>
<td>Aménagement d’intersection - Solibra (Treichville)</td>
<td>2x2</td>
<td>Échangeur</td>
</tr>
<tr>
<td>V-8-2</td>
<td>Aménagement d’intersection- Mairie d’Abobo (Abobo)</td>
<td>2x1</td>
<td>Échangeur</td>
</tr>
<tr>
<td>V-8-3</td>
<td>Aménagement d’intersection- Banco (Abobo)</td>
<td>2x1</td>
<td>Échangeur</td>
</tr>
<tr>
<td>V-8-4</td>
<td>Aménagement d’intersection- Palais des Sports (Treichville)</td>
<td>2x1</td>
<td>Échangeur</td>
</tr>
<tr>
<td>V-8-5</td>
<td>Aménagement d’intersection- Siporex (Yopougon)</td>
<td>2x1</td>
<td>Échangeur</td>
</tr>
<tr>
<td>V-8-6</td>
<td>Aménagement d’intersection- keneya (Yopougon)</td>
<td>2x1</td>
<td>Échangeur</td>
</tr>
<tr>
<td>V-8-7</td>
<td>Aménagement d’intersection- Sapeurs Pompiers (Yopougon)</td>
<td>2x1</td>
<td>Échangeur</td>
</tr>
<tr>
<td>V-8-8</td>
<td>Aménagement d’intersection- Samaké (Abobo)</td>
<td>2x1</td>
<td>Échangeur</td>
</tr>
<tr>
<td>V-8-9</td>
<td>Aménagement d’intersection- St Jean (Cocody)</td>
<td>2x1</td>
<td>Échangeur</td>
</tr>
<tr>
<td>V-8-10</td>
<td>Aménagement d’intersection- Palmeraie (Cocody)</td>
<td>2x1</td>
<td>Échangeur</td>
</tr>
<tr>
<td>V-8-11</td>
<td>Aménagement d’intersection- CHU de Treichville (Treichville)</td>
<td>2x1</td>
<td>Échangeur</td>
</tr>
<tr>
<td>V-8-12</td>
<td>Aménagement d’intersection- Inchallah (Koumassi)</td>
<td>2x1</td>
<td>Échangeur</td>
</tr>
<tr>
<td>V-8-13</td>
<td>Aménagement d’intersection- Zoo (Adjamé-Cocody)</td>
<td>2x1</td>
<td>Échangeur</td>
</tr>
</tbody>
</table>

Source : Mission d’études de la JICA
Les projets d’infrastructures envisagés par le SDUGA sur la période 2015 – 2030 sont matérialisés sur le schéma de structure ci-après :

*Figure 7 : emplacement des projets proposés (routes et installations)*

**Source : Mission d’études de la JICA**

4.3.2.3. *Structure du transport public*

Actuellement, le transport public à Abidjan opère principalement à travers deux (2) modes, à savoir par la route et par voie lagunaire. Dans l’avenir, il est prévu d’utiliser les transports en commun sur la ligne ferroviaire existante.

Les transports en commun (formel et informel) assurent aujourd’hui environ 9 millions de déplacements journaliers à Abidjan.

Il existe peu de politiques mises en place actuellement pour soutenir l’objectif de l’accès à une mobilité accrue pour toute la population du Grand Abidjan.

Les politiques qui devraient être mises en œuvre doivent être guidées afin de garantir un réseau de transport en commun global et intégré qui soit pratique et accessible à toutes les bourses, et au service de tous les centres urbains, à la fois dans le DAA et en banlieue, tout en offrant l’accès aux installations communautaires locales, aux zones d’emplois, aux sites de loisirs et aux sites touristiques.

A cette fin, le SDUGA entend promouvoir les initiatives clés suivantes en ce qui concerne les transports en commun :

- promotion de corridors de transport en commun de haute capacité ;
- amélioration du système d’autobus ;
- réorganisation des transports publics informels.

Un renversement de la situation existante exigera un changement de la politique du transport public routier.

De façon classique, les trajets d’autobus sont classés en trois (3) types du point de vue de la planification, à savoir, les services d’autobus longue-distance sur les
corridors de grande capacité, les services d’autobus circulant dans les grands centres tels que le centre-ville et les routes périphériques, et les services d’autobus de desserte de banlieue.

Les routes périphériques feraient la liaison entre les grands pôles d’activités sans traverser le centre-ville. La viabilité de la restructuration du réseau d’autobus dépend de la demande future de déplacements.

Si la demande le justifie, les principales artères devront être desservies par le réseau de transport public formel. Le rôle du secteur informel comme les gbaka, les taxis communaux ou woro-woro serait alors de se concentrer sur les voies de rabattement et, éventuellement, les routes périphériques si nécessaire. S’il est courant d’avoir un parcours circulaire dans un centre-ville, à Abidjan, une attention particulière devrait également être accordée à la nécessité de créer ces lignes dans les différentes communes.

Alternativement, on peut envisager trois (3) niveaux de transports en commun, à savoir, un niveau primaire, secondaire et tertiaire, à la fois avec les services de collecte et d'apport définis dans cette dernière catégorie.

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- amélioration du système d’autobus ;
- réorganisation des transports publics informels.

Un renversement de la situation existante exigera un changement de la politique du transport public routier.

De façon classique, les trajets d’autobus sont classés en trois (3) types du point de vue de la planification, à savoir,

- les services d’autobus longue-distance sur les corridors de grande capacité,
- les services d’autobus circulant dans les grands centres tels que le centre-ville et les rames périphériques,
- les services d’autobus de desserte de banlieue.

Les routes périphériques feraient la liaison entre les grands pôles d’activités sans traverser le centre-ville. La viabilité de la restructuration du réseau d’autobus dépend de la demande future de déplacements.

Si la demande le justifie, les principales artères devront être desservies par le réseau de transport public formel. Le rôle du secteur informel comme les gbaka, les taxis communaux ou woro-woro serait alors de se concentrer sur les voies de rabattement et, éventuellement, les routes périphériques si nécessaire. S’il est courant d’avoir un parcours circulaire dans un centre-ville, à Abidjan, une attention particulière devrait également être accordée à la nécessité de créer ces lignes dans les différentes communes.

Alternativement, on peut envisager trois (3) niveaux de transports en commun, à savoir, un niveau primaire, secondaire et tertiaire, à la fois avec les services de collecte et d'apport définis dans cette dernière catégorie.

4.3.2.4. Structure du futur réseau routier de transport intégré

Afin d’élaborer un Schéma Directeur des Transports Urbains conforme à la vision du plan d’urbanisme, la structure du réseau de transport stratégique a pour objectifs de :

☐ développer des infrastructures d’appui au Port d’Abidjan et un transport de fret efficace pour la croissance industrielle ;
☐ accroître le potentiel touristique avec un accès pratique ;
☐ offrir un accès fiable aux activités agricoles ;
☐ proposer un transport moderne reflétant la position de pôle financier et d’affaires de l’Afrique de l’Ouest ;
☐ construire des infrastructures de transport pour promouvoir l’utilisation des transports publics et améliorer la qualité de vie des citoyens.

La structure du futur réseau de transport stratégique pour relier les principales zones d’activités (industrielle, touristique, agroalimentaire) est schématisée ci-après.

*Figure 8 : structure du futur réseau de transport stratégique*

"Source : Mission d’Etude de la JICA"
4.3.3. **Plan de développement du transport public**

4.3.3.1. **Demande sur les lignes de transport en commun de grande capacité**

Le nombre de passagers susceptibles d'emprunter les modes de transport en commun en 2030 est d'environ 15 millions, soit un doublement des passagers des transports publics existants. La structure actuelle de transport en commun ne peut pas faire face au niveau élevé de la demande. Un système de transport en commun routier centrée sur la fourniture de matériel existant tributaire des autobus, gbakas et woros-woros ne peut pas répondre à cette demande. Cela justifie donc le développement de lignes de transport en commun de grande capacité. L'infrastructure sur ces lignes permettra de déplacer les passagers autour de la ville efficacement et en toute sécurité. Ces lignes de transport en commun de grande capacité contribueront au développement d'Abidjan en encourageant l'utilisation des terres dense et compacte tout en reliant Anyama, Grand Bassam, Yopougon Ouest et Bingerville par des voies directes et périphériques ainsi que les deux (2) centres périphériques de Bonoua et Dabou.

L’importance des populations résidentes le long des trois (3) plus gros corridors de transport en commun de grande capacité justifie leur projection en raison du trafic qui sera généré par leur réalisation.

*Le corridor Nord-Sud*, connu sous le nom de **ligne bleue**, transportera en 2030 environ un million et demi de personnes sur un kilomètre et plus de deux (2) millions et demi de personnes sur 2 kilomètres du tracé.

*Le corridor Est-Ouest de ferry du Sud*, connu sous le nom de **ligne violette**, transportera en 2030 environ un million et demi de personnes sur un kilomètre et plus d'un million de personnes sur 2 kilomètres du tracé.

*Le corridor Est-Ouest du Nord*, connu sous le nom de **ligne rouge**, transportera en 2030 environ un million de personnes sur un kilomètre et près de deux (2) millions de personnes sur 2 kilomètres du tracé.

Les populations riveraines de ces trois (3) lignes sont synthétisées ci-après:

**Tableau 10 : populations riveraines du tracé des lignes sélectionnées**

<table>
<thead>
<tr>
<th>Ligne de transit</th>
<th>Brève description du corridor</th>
<th>Rayon (distance du tracé)</th>
<th>Population (en milliers)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>An 2013</td>
</tr>
<tr>
<td>Ligne bleue</td>
<td>Anyama a Grand Bassam</td>
<td>à 1 kilomètre</td>
<td>1,159</td>
</tr>
<tr>
<td></td>
<td></td>
<td>à 2 kilomètres</td>
<td>2,186</td>
</tr>
<tr>
<td>Ligne violette</td>
<td>Songon a Bingerville</td>
<td>à 1 kilomètre du bord de l’eau</td>
<td>465</td>
</tr>
<tr>
<td></td>
<td></td>
<td>à 2 kilomètres du bord de l’eau</td>
<td>834</td>
</tr>
<tr>
<td>Ligne rouge</td>
<td>Yopougon Ouest a Bingerville</td>
<td>à 1 kilomètre</td>
<td>832</td>
</tr>
<tr>
<td></td>
<td></td>
<td>à 2 kilomètres</td>
<td>1,500</td>
</tr>
</tbody>
</table>

*Source : Mission d’études de la JICA*

Avec ces niveaux élevés de populations, une infrastructure de transport de grande capacité devrait capter un nombre significatif les passagers.

Au total, il y a huit (8) lignes opérationnelles de transport de grande capacité dont les prévisions de la demande de transport de chacune d’elles sont consignées ci-après.
Tableau 11 : passagers transportés sur les lignes de transport de masse

<table>
<thead>
<tr>
<th>Ligne de transit</th>
<th>Brève description du corridor</th>
<th>Code du projet</th>
<th>Année de mise en service</th>
<th>Trafic journalier de passagers</th>
<th>Débit maximal (passagers par heure par direction-pphpd)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ligne bleue Phase 1</td>
<td>Rail – Anyama à Grand-Bassam</td>
<td>T-1-1</td>
<td>2025</td>
<td>364 800</td>
<td>26 100</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2030</td>
<td>432 900</td>
<td>31 500</td>
</tr>
<tr>
<td>Ligne bleue Phase 2</td>
<td>Rail – Aéroport à Grand Bassam</td>
<td>T-1-2</td>
<td>2030</td>
<td>126 200</td>
<td>9 200</td>
</tr>
<tr>
<td>Ligne rouge</td>
<td>Rail – Yopougon Ouest à Bingerville</td>
<td>T-1-3</td>
<td>2030</td>
<td>369 800</td>
<td>29 000</td>
</tr>
<tr>
<td>Ligne violette</td>
<td>Ferry à haute vitesse - Songon à Bingerville</td>
<td>T-4-1</td>
<td>2030</td>
<td>215 000</td>
<td>6 600</td>
</tr>
<tr>
<td></td>
<td>Ferry à haute vitesse - Bingerville à Aéroport et Grand Bassam</td>
<td>T-4-1</td>
<td>2030</td>
<td>96 300</td>
<td>3 800</td>
</tr>
<tr>
<td>Ligne verte</td>
<td>Bateau Bus - Attecoubé à Treichville</td>
<td>T-4-2</td>
<td>2020</td>
<td>56 600</td>
<td>5 400</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2030</td>
<td>99 000</td>
<td>9 500</td>
</tr>
<tr>
<td>BRT</td>
<td>Abobo à Cocody Sud</td>
<td>T-2-1</td>
<td>2030</td>
<td>44 500</td>
<td>2 800</td>
</tr>
<tr>
<td></td>
<td>Abobo à Koumassi</td>
<td>T-2-2 et T-2-3</td>
<td>2030</td>
<td>36 600</td>
<td>3 000</td>
</tr>
<tr>
<td>BHNS</td>
<td>Bonou à Bingerville</td>
<td>T-2-4</td>
<td>2030</td>
<td>60 500</td>
<td>4 100</td>
</tr>
<tr>
<td></td>
<td>Dabou à Yopougon Ouest</td>
<td>T-2-5</td>
<td>2030</td>
<td>16 000</td>
<td>2 400</td>
</tr>
</tbody>
</table>

Source : Mission d’études de la JICA

Comme on pouvait s'y attendre, la plus forte demande sur la phase 1 de la ligne bleue, qui devrait transporter plus de 430 000 passagers par jour en l'an 2030. La deuxième phase de la ligne bleue transportera 126 000 passagers en 2030, soit un total de plus d'un demi-million de passagers par jour sur toute la ligne bleue. Le débit maximal journalier sur la ligne bleue en 2030 est de 31 500 pphpd. La ligne rouge devrait transporter près de 370 000 passagers par jour en 2030, tandis que la ligne violette, y compris son extension prévue, transportera plus de 300 000 passagers par jour en 2030. En 2030, le débit maximal journalier sur les lignes rouge et violette est respectivement de 29 000 et 6 600 pphpd. Les voies BRT combinées prévues d’Abobo au Sud de Cocody et Koumassi transporteront une clientèle combinée de 143 000 passagers en 2030. Les deux (2) lignes BHNS transporteront une clientèle de près de 80 000 en 2030.

4.3.3.2. Analyse de la sensibilité des tarifs

L'analyse de sensibilité du tarif est entreprise pour la ligne bleue, comme ce sera probablement la première ligne opérationnelle de transport de grande capacité. Cette analyse est présentée dans le tableau suivant :

Tableau 12 : analyse de la sensibilité des tarifs de la ligne bleue

<table>
<thead>
<tr>
<th>Option</th>
<th>Tarif dénommé (FCFA)</th>
<th>Tarif pour un trajet de 5 km (FCFA)</th>
<th>Trafic journalier de passagers</th>
<th>% différence avec le tarif de référence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A l'embarquement</td>
<td>Tarif par km</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tarif de référence</td>
<td>300</td>
<td>30</td>
<td>450</td>
<td>432 900</td>
</tr>
<tr>
<td>Option 1</td>
<td>300</td>
<td>30</td>
<td>450</td>
<td>432 900</td>
</tr>
<tr>
<td>Option 2</td>
<td>400</td>
<td>20</td>
<td>500</td>
<td>320 000</td>
</tr>
<tr>
<td>Option 3</td>
<td>400</td>
<td>30</td>
<td>550</td>
<td>303 300</td>
</tr>
<tr>
<td>Option 4</td>
<td>400</td>
<td>50</td>
<td>650</td>
<td>289 000</td>
</tr>
</tbody>
</table>

Source : Mission d’études de la JICA

Quatre (4) options de test de sensibilité sont présentées dans le tableau ci-dessus. La première est pour le même tarif d'embarquement comme scénario de référence,
tandis que pour les trois (3) autres options le tarif d'embarquement est fixé à un niveau plus élevé, à 400 FCFA. Le tarif moyen pour un voyage de 5 km est représenté comme une orientation de la structure relative des prix. Les résultats sont sensibles au tarif initial ou de l'embarquement. Si la partie relative à la distance du tarif reste constante à 20 ou 30 FCFA par kilomètre, le tarif d'embarquement augmente de 300 FCFA à 400 FCFA, le nombre de passagers prévu diminuera d'environ 30%. C'est la comparaison entre respectivement l'option 1 et l'option 2, puis entre le cas de référence et l'option 3.

En comparaison, pour un voyage de 5 kilomètres, quand le tarif augmente à partir de 450 FCFA, le scénario de référence, à 650 FCFA, l'option 4, une augmentation de quelque 40%, le nombre de passagers attirés va diminuer d'environ 30%. Lorsque des études de faisabilité détaillées seront entreprises pour ces lignes de transport en commun de grande capacité, on envisagera sans doute l'introduction d'un système de billetterie électronique pour une intégration tarifaire des modes.

4.3.3.3. **Lignes de transport en commun de grande capacité**
Les lignes bleue et rouge transportent des volumes de passagers de plus de 15 000 passagers par heure et par direction (pphpd) en 2030 de sorte qu'une technologie ferroviaire d'une certaine forme est nécessaire pour ces deux (2) lignes. Les caractéristiques des technologies de transport public les plus utilisées actuellement dans le monde sont présentées dans le tableau ci-après.

**Tableau 13 : comparaison des technologies de transport public**

<table>
<thead>
<tr>
<th>Sujet de comparaison</th>
<th>Subway/Metro</th>
<th>Monorail/élevé</th>
<th>Tramway</th>
<th>Bus classique de transit rapide (BRT)</th>
<th>Réseau de voies exclusives pour bus ou BHNS</th>
</tr>
</thead>
<tbody>
<tr>
<td>système</td>
<td>fermé avec connexion possible aux rails de banlieue</td>
<td>fermé mais facile à étendre</td>
<td>fermé mais facile à étendre</td>
<td>ouvert</td>
<td></td>
</tr>
<tr>
<td>niveau</td>
<td>sous terrain/élevé</td>
<td>sur la route</td>
<td>sur la route</td>
<td>sur la route</td>
<td></td>
</tr>
<tr>
<td>condition</td>
<td>rails/voie de guidage</td>
<td>rails</td>
<td>route (système ferme)</td>
<td>route (système ouvert)</td>
<td></td>
</tr>
<tr>
<td>spécificité de la ligne</td>
<td>dédiée</td>
<td>voies dédiée ou partage</td>
<td>dédiée</td>
<td>voies dédiée ou partage</td>
<td></td>
</tr>
<tr>
<td>débit maximal</td>
<td>30 000 pphpd</td>
<td>10 000 pphpd</td>
<td>30 000 pphpd</td>
<td>10 000 pphpd</td>
<td></td>
</tr>
<tr>
<td>aire de surface</td>
<td>entrée du Metro</td>
<td>4 m de large pour les piliers + accès + trottoir</td>
<td>2 voies (8.5 m) + station (2.5 m de chaque cote)</td>
<td>2 lignes (8.5 m) + station (2.5 m de chaque cote)</td>
<td></td>
</tr>
<tr>
<td>coût</td>
<td>300 millions de $ USD par km</td>
<td>60-150 millions de $ USD par km</td>
<td>20-30 millions de $ USD par km</td>
<td>5-20 millions de $ USD par km</td>
<td></td>
</tr>
<tr>
<td>justification de l'aménagement</td>
<td>coût élevé / plus d’un millions d’habitants dans la ville</td>
<td>adapté aux endroits spécifiques pour accentuer l’espace de la ville et pour les villes communautaires</td>
<td>adapté pour application immédiate et comme connexion de transit secondaire</td>
<td>adapté pour application immédiate et comme connexion de transit secondaire</td>
<td></td>
</tr>
</tbody>
</table>

Source : Mission d’études de la JICA

Le rail est la technologie adaptée pour les lignes bleue et rouge, alors qu’un ferry haut de gamme fonctionnera sur les lignes verte et violette.

Le BRT est l'option privilégiée sur les deux (2) lignes d’autobus de grande capacité proposées à partir d’Abobo, alors que le BHNS est la ligne privilégiée sur les connexions des villes extérieures de Bonoua et Dabou qui sont prévues pour créer un lien vers les extrémités Est et Ouest de la ligne rouge.
En résumé, les caractéristiques modales clés associées à chaque ligne sont consignées dans le tableau ci-après :

Tableau 14 : emplacements multimodaux principaux

<table>
<thead>
<tr>
<th>Ligne de transit</th>
<th>Stations multimodales</th>
<th>Terminaux internationaux</th>
<th>Emplacement des parcs de stationnement incitatif</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ligne rouge</td>
<td>Yopougon Ouest, Centre, Cocody Ouest, Est, et Bingerville</td>
<td>Yopougon Ouest, Cocody Est et Bingerville</td>
<td></td>
</tr>
<tr>
<td>Ferry à grande vitesse (ligne violette)</td>
<td>Songon, Plateau Sud et Koumassi</td>
<td>Plateau Sud</td>
<td>Songon</td>
</tr>
<tr>
<td>Bateau bus vert</td>
<td>Plateau Centre et Sud</td>
<td>Plateau Sud</td>
<td></td>
</tr>
<tr>
<td>BRT Abobo à Cocody</td>
<td>Abobo, Abobo-Té, et Cocody Ouest</td>
<td>Abobo</td>
<td>Abobo et Abobo-Té</td>
</tr>
<tr>
<td>BRT Abobo à Koumassi</td>
<td>Abobo, Abobo-Té, Cocody Est et Koumassi</td>
<td>Abobo</td>
<td>Abobo, Abobo-Té, Cocody Est et Koumassi</td>
</tr>
<tr>
<td>BHNS Bonoua a Bingerville</td>
<td>Bonoua et Bingerville</td>
<td>Bonoua et Bingerville</td>
<td></td>
</tr>
<tr>
<td>BHNS Dabou à Yopougon Ouest</td>
<td>Dabou, Songon et Yopougon Ouest</td>
<td>Dabou, Songon et Yopougon Ouest</td>
<td></td>
</tr>
</tbody>
</table>

Source : Mission d’études de la JICA

Une alternative à la ligne bleue, est une ligne de tramway dont le tracé lui serait parallèle sur le corridor routier Nord-Sud. Quand un tel tramway est testé en combinaison, à la place de la ligne bleue, le tramway transporte 217 000 passagers avec un débit maximal de 17 000 passagers par heure et par direction (pphpd) en 2030, nettement inférieur à la ligne bleue initiale. Ainsi, la ligne bleue ferroviaire est la meilleure option pour 2030 d’autant plus qu’elle a une vitesse commerciale plus élevée en raison du fait qu’elle fonctionne en site propre intégral. Les principaux projets de transport sont matérialisés sur la figure suivante :

Figure 9 : localisation des projets de transport public et de chemin de fer

Source : Mission d’études de la JICA
4.3.4. Plan de développement du transport de marchandises

4.3.4.1. Principaux itinéraires des camions

Le mouvement efficace des marchandises est vital pour le développement économique et la croissance non seulement du Grand Abidjan, mais aussi de la Côte d'Ivoire dans son ensemble. Les camions circulent principalement en direction ou en provenance des zones portuaires et industrielles transportant des matières premières pour l'industrie et des produits finis destinés à la consommation.

4.3.4.2. Situation actuelle

Sur la base des résultats des enquêtes réalisées en 2013, les principaux itinéraires de camions identifiés sont présentés sur la figure ci-dessous.

*Figure 10 : principaux itinéraires de camions dans le Grand Abidjan*

Source : Mission d’études de la JICA

Les deux (2) principaux couloirs de véhicules lourds sont orientés dans la direction Nord-Ouest le long de l'Autoroute du Nord, en direction de la partie Nord du pays et, dans le sens Ouest avec la route de Dabou en direction de San-Pedro.

À l'intérieur du DAA, tout le trafic de camions entrant et sortant du port d'Abidjan et la zone industrielle connexe doit acheminer à travers le Plateau et les deux (2) ponts qui traversent la lagune. Si ces infrastructures sont fermées, il n'y a plus de voies alternatives pour le transport de cargaisons.

En raison du fait que le réseau routier autour du Plateau est fortement congestionné la majeure partie de la journée et se trouve dans des zones densément développées, son expansion est difficilement réalisable.

En outre, comme la plupart des marchandises transitent actuellement par le Plateau, de nombreux impacts négatifs peuvent être observés sur le trafic, les infrastructures routières et les zones environnantes.

4.3.4.3. Objectif du futur système d’itinéraire de camions

Le futur système d’itinéraire de camions devra :

- réduire les impacts de camions sur les utilisations sensibles de terrains comme les zones résidentielles :
- minimiser la détérioration généralisée du réseau routier local en raison de la circulation de véhicules lourds :
4.3.4. Plan de développement du transport de marchandises

4.3.4.1. Principaux itinéraires des camions

Le mouvement efficace des marchandises est vital pour le développement économique et la croissance non seulement du Grand Abidjan, mais aussi de la Côte d'Ivoire dans son ensemble. Les camions circulent principalement en direction ou en provenance des zones portuaires et industrielles transportant des matières premières pour l'industrie et des produits finis destinés à la consommation.

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- réduire les impacts de camions sur les utilisations sensibles de terrains comme les zones résidentielles :
- minimiser la détérioration généralisée du réseau routier local en raison de la circulation de véhicules lourds :
- minimiser les risques de la circulation, notamment les accidents de la route.

Un équilibre doit donc être trouvé entre les besoins du commerce, les industries et la protection des zones résidentielles sensibles.

Un système d’itinéraire de poids lourds ne devrait pas interdire totalement la circulation des camions dans les quartiers résidentiels, mais exiger qu'ils empruntent les voies les plus appropriées dans la mesure du possible et limiter leur intrusion dans les zones sensibles.

Les routes existantes avec une capacité suffisante et des caractéristiques adéquates de conception pour accueillir le volume prévu de trafic doivent être identifiées comme les itinéraires principaux des camions et une nouvelle infrastructure routière (voie Y4) doit être planifiée pour dévier le transport actuel de marchandises sur le réseau routier couramment utilisé.

5. Conclusion et perspectives

Le SDUGA 2015 – 2030, élaboré avec l’aide de la coopération japonaise JICA ambitionne de faire de l’agglomération abidjanaise une ville écologique respectueuse de l’environnement dans une perspective de développement durable.

Le SDUGA 2015 – 2030 a cette particularité de réaliser concomitamment le Schéma Directeur d’Urbanisme et le Schéma des Transports Urbains dans une démarche de complémentarité et de cohérence d’ensemble en vue de garantir le développement d’une ville compacte construite autour du transport public (concept du TOD).

Les projets structurants de réseaux de transport public qui auront été validés par le Gouvernement s’ils sont réalisés permettront notamment à la Côte d’Ivoire et particulièrement au Grand Abidjan d’effectuer un bon qualitatif pour se mettre en pointe parmi les pays africains résolument engagés à améliorer le cadre de vie de leurs concitoyens en préservant leur environnement.

Cette volonté a été traduite dans la nouvelle loi d’orientation sur le développement durable qui fait obligation de rendre conforme aux objectifs environnementaux la réalisation de tout projet structurant en Côte d’Ivoire.

La prochaine étape, après l’adoption par le Gouvernement, sera notamment la mobilisation des financements nécessaires par partenariat public privaté (PPP) pour les projets dont la rentabilité économique et financière est avérée.

Cela passe nécessairement par la manifestation d’une volonté politique affirmée et mise en œuvre.

L’espoir est permis dès lors que le Président de la République a fixé le cap d’une Côte d’Ivoire émergente en 2020 et que le Gouvernement s’attèle à traduire en actes concrets cette volonté politique.
Références

☐ Agence Japonaise de Coopération Internationale (JICA) - Ministère de la Construction, du Logement, de l’Assainissement et de l’Urbanisme (MCLAU)
   Rapport intérimaire du projet de développement du Schéma Directeur d’Urbanisme du Grand Abidjan (SDUGA)
   Oriental Consultants Co., Ltd., Japan Development Institute, International Development Center of Japan, Asia Air Survey Co., Ltd.
   3 volumes, volume 1, 65 pages, volume 2, 370 pages et volume 3, 562 pages

☐ Agence Japonaise de Coopération Internationale (JICA) - Ministère de la Construction, du Logement, de l’Assainissement et de l’Urbanisme (MCLAU)
   Rapport d’avancement du projet de développement du Schéma Directeur d’Urbanisme du Grand Abidjan (SDUGA)
   Oriental Consultants Co., Ltd., Japan Development Institute, International Development Center of Japan, Asia Air Survey Co., Ltd.
   2 volumes, volume 1, 395 pages et volume 2, 431 pages

☐ KONAN Yao Godefroy, 15 - 17 septembre 2010
   Les modèles d’organisation du transport urbain - Golf Hôtel – Abidjan
   Colloque international SOTRA - 50 ans de la SOTRA : bilan et perspectives, 18 pages

   Evaluation de la régulation des transports urbains dans l’agglomération abidjanaise par l’AGETU Université d’Abidjan Cocody – Côte d’Ivoire -, 134 pages

☐ KOUAKOU Romain, Ingénieur, Economiste des Transports, Chef d’Unité Transport au BNEDT, KOUAME Alexandre, Urbaniste DEIAU, Conseiller Technique du Directeur Général du BNEDT et KOALLA Célestin, Urbaniste DEIAU, Chef secteur foncier et Habitat/BNEDT, 15 – 17 septembre 2010
   Le transport urbain dans la planification urbaine du Grand Abidjan - Golf Hôtel – Abidjan
   Colloque international SOTRA - 50 ans de la SOTRA : bilan et perspectives, 35 pages

☐ MARCHAL Jean – Dr N’DIAYE Alassane B. – Dr DANOH Charlemagne, 28 avril 2008
   Stratégie générale de développement d’un plan intégré de transport
   Notions générales, techniques d’analyse des systèmes de transport
   Eléments de développement de projets intégrés en transport
   Université de Liège, 97 pages

☐ MARCHAL J., 1992, Institut de Formation Internationale aux Transports - Etablissement d’un plan de transport, Service d’Analyse des Systèmes de Transport
   Editions L.H.C.N – 1992, 36 pages
PUBLIC TRANSPORT SMART CARD SYSTEMS IN TURKISH CITIES: THE CHALLENGE OF PARATRANSIT

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Abstract

Wide range of smart card operations were recently introduced in some developing countries, in principle to increase the use of public transport by providing free transfer opportunities and multimodal urban transportation, and thus to decrease the private car usage. Turkey launched a comprehensive smart transport network project, proposed to be completed by 2023, with the aim of creating an intermodal transportation network on a national scale. This countermeasure policy faces some country-specific problems. In Turkey as in most other developing countries, paratransit system caters the mobility needs of citizens. Turkish system, dubbed as “dolmuş industry”, covers shared-taxis and minibuses, operates partially informal and challenges with public transport. In some recent researches, modal split tables of the metropolitan cities showed that paratransit system still has a high share in total urban transportation network. A set of pilot smart card projects were introduced by some local governments to integrate all transportation modes including paratransit. These efforts failed in practice, not only because of the financial concerns of the paratransit operators, but also as a result of the reactions of the passengers who felt uncomfortable on grounds of loss of flexibility of paratransit. This study discusses the advantages and challenges of smart card ticketing system including paratransit for different stakeholders of the system namely; operators, passengers and local governments and proposes a framework for a comprehensive transport policy.
PLANNING AND MANAGEMENT OF BIKE-SHARING: LESSONS FROM THE TURKISH CASE STUDIES

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Abstract

Traffic congestion, energy dependency and air pollution problems, depending on excessive use of private car, different transport alternatives to ensure sustainable urban transportation have come into question. Particularly in some European countries, bicycle use, which has been an environmentally friendly mode and uses resources and road space at a minimum, has appeared as a sustainable alternative for urban transportation and besides, recently bike-sharing systems have contributed to this process positively. Bike-sharing systems, which introduce a number of bike stations in a definite urban part to encourage citizens to take a bike from one station and then leave it at any other one, further promotes the usage of bikes for urban transport purposes. The system has numerous examples today in Europe, Asia, and North and South America. It has recently been launched in some Turkish cities too, while many other cities are planning to introduce this system.

This research analyzes the planning and operating approaches in bike-sharing implementations. The worldwide experiences in this new approach are reviewed, and best practices in the world will be studied with a view to reveal some criteria for the successful planning and operation of these systems in Turkey. The first three bike-sharing systems, those in Kayseri, Konya and Istanbul will be assessed. The underlying objectives are to provide a better understanding of the current experience in bike-sharing systems in Turkey, to reveal the strengths and weaknesses of the systems implemented so far, and to provide recommendations for the planning, implementation and operation of future systems.
THE CHANGE OF REGIONAL TRANSPORT ACCESSIBILITY OVER TIME BY USING SPATIAL ANALYSES

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Abstract

All transport modes (road, railroad, air and maritime transport) have been reconfiguring according to European Union regulations and major transport infrastructure projects of rehabilitation of current lines with new ones and/or roads take place in the current agenda. These projects are essentially big scale investments which aim to integrate national transport networks into the Trans European Transport Networks. Accessibility level is a very important indicator in terms of this network integration. It was investigated in this study that how the regional transport accessibility changes over time and what the consequences of this change would be. A geographical information system based methodology in co-ordinance with ex-post assessment was implemented in a selected region, Izmir (TR310), so that the accessibility level of the region before Izmir-Çeşme Highway (O-32) and after the construction of this new extension to the existing network were investigated by using remotely sensed data, land use data together with road transport maps. In conclusion, outcome of the spatial analyses indicated in which amount of the regional transport accessibility level was changed after the construction of Izmir-Çeşme Highway comparing to the past condition at the regional road network. The achievements of the analyses are going to be used for further studies.
HOW NEW URBAN SETTLEMENTS CAN EFFECT THE URBAN TRANSPORT DEMAND IN ISTANBUL: A CASE STUDY OF KAYAŞEHIR

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Abstract

According to the TurkStat data, Turkish economical indicators are shown that the purchasing power getting increase in the last decade in Turkey. It makes a sensible changes in the daily life style from health to transport, education to consume habits. According as the jobs diversification, İstanbul is one of the major capitals for the unemployed workers. As a result of this circumstance as well as natural increasing of population, population of metropolitan area increases approximately 250 thousand people every year. Currently, İstanbul Metropolitan population reaches to 15 million people. Because of increasing population, local and central authorities decided to make new settlements in İstanbul. Kayaşehir area is one the places in which new settlements will constructed. Today, nearly 50 thousand habitants live in there and projected population for Kayaşehir is about 350 thousand till 2023.

Total automobile number in İstanbul is more than 2 million and with each passing day the number getting increase. However, by the new construction of settlements, the transportation demand would be also changed and there would be huge automobile, train, subway traffics as well as pedestrians and cycling.

This paper aims to calculate the demand of transport in the new settlements. In the case study gravity model method uses to determine the demand and regression analysis to find out how this demand distributed in the city. Result and the evaluation are mentioned at the end of the study.
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