Use of GPS systems with people count sensors for transport planning studies

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1. Summary:

The Buenos Aires Metropolitan Region (RMBA) is one the major urban areas in Latin America with more than 13 million inhabitants. The RMBA is the administrative, economic, industrial and cultural center of Argentina and it concentrates 37% of the country’s population.

The transport system in the RMBA is extremely complex and there is a critical need of planning, regulating and monitoring the transport system in the region and providing solutions to the inter-jurisdictional issues. Consequently, the Argentinean Secretary of Transport is aiming at creating a Metropolitan Authority and is developing the needed information to formulate an Integrated Transport Plan for the Metropolitan Buenos Aires Region.

PLATAMBA is a group within the Secretary of Transport that is performing different activities in order to develop planning tools and information with the objective of developing an integrated urban transport system plan. PLATAMBA’s main activities to assess the transportation supply and demand include:

- Counting public and private vehicles
- Origin and destination surveys
- Institutional strengthening of public agencies

Phase I of this project, concluding in 2008, has conducted a Study for Public Urban Transport in Buenos Aires (INTRUPUBA). The next phase includes:

a) A household mobility survey for the RMBA;
b) A private transport assessment consisting of private transport counts using paper forms and automated technology and an origin/destination survey for private transport in streets and public spaces.
c) An assessment of bus transport systems in the RMBA, using GPS equipment to be installed in a small sample of buses, with representation in each line, to maintain and update continuously the data collected in INTRUPUBA.

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1 Together with Ing. Edgardo Melen, Lic. Leticia Dall’Ospedale, Analista Ricardo Vázquez, Ing. Mario Aguirre, Hugo Terrile, Ing. Antonio Cortés e Ing. Germán Bussi
2 Región Metropolitana de Buenos Aires (RMBA)
d) A Young Professionals Capacity Building Program

This study shows how Phase I for this project, the INTRUPUBA study, was implemented using technologies and methodologies that were never before used for planning urban transport systems.

2. About the Author

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Licensee in Economics, graduated from the National University of Buenos Aires, with a Master in Transport Planning and Economics organized by the Economic Development Institute (EDI) and the World Bank.

Since 1978, she has performed activities in the transport sector, implementing and managing projects related with urban and interurban transport planning and economics.

Since 1994, she coordinates the working group “Transport Planning for the AMBA” (PLATAMBA) that advises and performs activities in the Secretary of Transport in areas related with urban and interurban transport policy and leads the INTRUPUBA project supervision.

3. Background

The Buenos Aires Metropolitan Region (RMBA\(^3\)) is one the major urban areas in Latin America with more than 13 million inhabitants. The RMBA is the administrative, economic, industrial and cultural center of Argentina and it concentrates 37% of the country’s population.

The region conforms a continuous urban space with territorial and physical integration. However, it consists of multiple jurisdictions, including the national government, the province of Buenos Aires, the city of Buenos Aires, and 42 municipalities. In many cases, the inter-jurisdictional limits and responsibilities are blurred creating difficulties in the efficient delivery of public services; such is the case in the delivery of urban transport services.

The public transport system in the RMBA is conformed by 342 bus lines consisting of 135 lines of national jurisdiction, 121 of provincial jurisdiction and 86 of municipal jurisdictions\(^4\). The bus system services about 1367 routes and it is complemented by 7 train lines, 6 metro lines and a light train. Furthermore, the system has approximately 60,000 taxis, 2,000 free private transport operators (charters, school buses, special services, etc), and an important, but uncounted, number of other formal and informal private transport services. Finally, according to the latest estimations, about 3 million motorized vehicles circulate in the RMBA.

In this context, the need of planning, regulating and monitoring the transport system in the RMBA seems obvious and there is an imperative need to provide solutions to the inter-jurisdictional issues. Especially, taking into an account the last Integrated Plan was developed

\(^3\) Región Metropolitana de Buenos Aires (RMBA)
in 1972\(^5\). Consequently, the Argentinean Secretary of Transport is aiming at creating a Metropolitan Authority and is developing the needed information to formulate an Integrated Transport Plan for the Metropolitan Buenos Aires Region.

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5. **The INTRUPUBA**

INTRUPUBA is a study that includes all modes of public transport in the RMBA (trains, metro, and buses from the National, Provincial and Municipal jurisdictions). Public transport systems was prioritized given their social importance since this is mostly used by the lower income population and also because the Secretary of Transport has direct intervention through regulations and subsidies.

The study has been conducted in the Buenos Aires City and 27 of the 42 municipalities in the RMBA. These 27 municipalities include the first and second belts of the RBMA, excluding the third and further away belt.

6. **INTRUPUBA’s Objectives**

INTRUPUBA’s general objective is to assess with a high level of certainty and detail, through data collection, the demand for transport services and characteristics of the transport services supply in the RMBA. Results will be used later to develop planning tools to model the current situation of public transport and to appraise different alternatives of transport policy for the region.

\(^5\) Preliminary Transport Study for the RMBA
Particular objectives include:

a) To assess and characterize the current supply of public passenger transport (routes, stations, frequencies, fares, vehicle capacity).

b) To quantify and locate the current passenger demand for public transport (metro, trains and buses from different jurisdictions, including National, Provincial and Municipal) using GPS technology and sensors to count passengers.

c) To characterize transportation demand through surveys of Origin / Destination in metro and railway stations, on board vehicles and bus stops.

7. Scope of INTRUPUBA

In order to achieve these objectives, field studies in the study area were conducted during school periods in 2006 and 2007. Main activities included:

a) Passenger counts

b) Surveys of origin and destination of travel

c) Assessment of the characteristics of bus services

8. The decision of using new technologies

When elaborating the specifications for the INTRUPUBA, we faced the challenge of assessing the complex public bus system in the region that includes around 150 private enterprises that operate 320 lines in different jurisdictions (National, Provincial and Municipal) with more than 1000 routes in a 60 km radius that surrounds the city of Buenos Aires, with a fleet of 16000 vehicles transporting more than 6 million passengers per day.

At the same time, INTRUPUBA’s study demanded to collect information that had never been collected before. It was then needed to obtain updated and reliable data of passengers boarding and descending vehicles for each stop and time of the day.

The use of traditional methodologies—manual counts of passengers where stop locations and travel time are recorded in paper forms—had very high operative costs, was very labor intensive and provided lower quality and lower reliability results with respect to the use of new technologies.

Therefore, the use of Intelligent Transportation Systems (ITS) technologies seemed appropriate for this type of study, even though, some of them had never been used before for urban transport planning studies.

In particular, the use of GPS sensors with the capacity to count passengers in order to assess the characteristics of the supply of buses and the flow of passengers represented an innovation in the field. GPS technology has been traditionally used by private transport operators for operative management purposes and, in a very few cases, to control payment evasion.

In order to check results provided by the GPS sensors, it was needed to count passengers manually in a sample of vehicles and then cross check the manual and automatic counts. In order to do this, the use of GPS sensors was complemented with another technology that replaced manual forms. These technologies are cellular phones with technology IDEN and programmed in JAVA.
9. Passenger counts

The bus system was assessed using GPS systems with passenger count sensors. Routes and distances were also recorded, including stop locations and travel times. Frequencies were assessed manually in the field.

For the railways system and metro, the supply of services data have been provided by the National Commission for Transport Regulation (CNRT).

In buses
160 GPS units with sensors were set up to count passengers in a sample of 10% to 20% of the total fleet in every bus-line. Each GPS unit was installed every week in a different vehicle and recorded all passengers boarding the vehicle and about 75% of passengers descending buses6. The units also recorded the exact time and the geographical location allowing the system to know the flow of passenger by time and bus stop. 13800 vehicles DAYS were recorded from national, provincial and municipal jurisdiction.

In the surface rail system
All passengers entering the system were counted in 280 stations during morning (from 6:30am to 11:30am) and afternoons (from 3:30pm to 8:30pm).

In the underground metro system
Entry records were provided by the operator of the system. The information provided included entry records every fifteen minutes in a typical working week.

10. Origin and Destination surveys

Passenger counts were then used to determine a sample to perform origin and destination surveys on board of vehicles and stops. 368,000 passengers were surveyed about their origin and destinations with a sample rate of 1 every 20 passengers boarding public transport services. Surveys were distributed as following: 15% in the suburban railway system, 11% in metros, 49% in buses from the national jurisdiction, 17% in buses from the provincial jurisdiction and 8% in buses from the municipal jurisdiction.

Passengers were surveyed using electronic forms, installed in PDAs, containing maps and the transport network, and including streets names and numbers and key landmarks7 with a user friendly interface to locate intersections by location. Information entered manually was cross-checked with the information from the SIG system. In the case of private neighborhoods or informal settlements the location was verified using landmarks.

The main questions in the survey referred to the characteristics of the trip, such as reason, origin and destination, modes of transport, boarding and descending stops, walking distance before and after, trip duration, costs of travel and socio-economic status, including household education level, health insurance coverage and car ownership.

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6 This is because there were installed one sensor in the ascending and one in the descending door, and some buses has more than one descending doors, in those cases some of teh descending passengers were lost.
7 Landmarks such as universities, schools, stations, hospitals, museums, etc
11. GPS equipment with people count sensors

To count passengers in buses GPS systems with sensors designed to count passengers were used. The equipment integrated a data logger linked to a GPS system with satellite connection, a radio transmission unit, and a counting passenger module that analyzed the data from door movements and was connected to two bi-directional sensors that recorded the boarding and descending movements of passengers. There was always one located in the front door and other located in the back door.

Data collected were transmitted through the radio transmission unit connected to a laptop called the hub station. As an alternative, the equipments had a RS232 port that could be directly connected via cable to the hub station laptop.

The bi-directional sensors linked with GPS systems and located in the front and back doors allowed to register the following events:

i) Vehicle location (geographical coordinates): At a minimum, buses location and time were recorded every 70 meters or 6 minutes by the GPS system;

ii) Passenger counts: the quantity of passengers boarding and descending, including location, door (front, middle or back), action performing (boarding or descending) and the exact time were recorded.

Once the binary data were sent via the radio transmission unit, the information was processed by the software and added to the database. The database, with Geographical Information Systems (GIS) support, allows knowing the quantity of passengers ascending or descending, the routes of lines surveyed, stop locations, travel times and vehicles’ speeds.
12. Manual verification of automatic passengers counts

Voice communication equipment programmed with IDEN\textsuperscript{8} technology was used to monitor and certify the accuracy of the sensors. A specialized team worked each week in a randomized sample of buses to manually count and record particular events that could affect or block, intentionally or not, the sensors, such as when too many people were crossing doors at the same time. This information was then contrasted with the electronic counts allowing adjusting the automatic data collection when data were processed and acknowledging at the end of the project the error margin of the counts.

For the manual collection of data, a software application was develop in JAVA that was installed in cellular phones and allowed operators to enter the data and send it to a server. Data entered in the voice communication equipment were: geographic coordinates and time (using GPS equipment) at the beginning and end of the data collection session, and information entered manually such as streets and street numbers, landmarks, bus line, direction, route, passengers boarding, and passengers descending.

13. Electronic questionnaire for origin and destination surveys

For the origin and destination surveys it was decided to use electronic forms in PDAs.\textsuperscript{9} The use of electronic forms allowed verifying data consistency in the field by, for example, contrasting data entered manually with the device clock. In addition, it allowed for the pre-coding of specific answers, such as reason for the trip, boarding and descending stops, means of transport, costs, health insurance coverage and education level attained. Moreover, it prevented the entry of invalid data.

Electronic forms were daily recorded in personal laptops. Afterwards, the data were validated in the software and entered in the main database.

14. Results

Preliminary results are published in the Secretary of Transport webpage: (http://www.transporte.gov.ar/inputs/index.html).

\textsuperscript{8} Technolgoy IDEN in Argentina is operated by the firm Nextel
\textsuperscript{9} PDA: \textit{Personal Digital Assistant}. 
15. Lessons learnt

Results show the relevance and adequacy of using these new technologies and methodologies to collect data. We obtained several lessons from this experience:

First, being the first ones using this set of technologies required a long trial and error time and highly associated costs to perform the necessary adjustments to the particular applications used for this Project.

Second, the rapid technological improvements outdated our data recording methods. In fact, by the time the Project specifications were drafted, data transmission using IDEN technologies was not affordable given budget constraints, while using GPRS was not reliable enough to guarantee data transmission. Therefore, it was decided that data transmission from GPS devices was to be performed via radio transmissions. However, this resulted inefficient for it was not possible to transfer data to the servers in real time, which would have allowed immediate acknowledgment of errors while adopting corrective measures to improve the quality of the results.

Third, it was recognized the need of using modular and flexible equipment and non proprietary systems that allow adjustments in the code programmed according to the particular needs of the Project.

Finally, data collection in electronic form, including searching functions and pre-coded answers has shown to be a very useful tool for this type of Projects, significantly reducing time, loss of data and errors related with entering and validating data. However, it is worth mentioning the difficulties associated with the immediate control of data given it cannot be visualized all together on-line at the same time.
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