An integration proposal to the transport system of the city of Rio de Janeiro

S. C. Vasconcellos
&
R. Balassiano
Transport Engineering Group – Federal University of Rio de Janeiro - PET/COPPE/UFRJ
Rio de Janeiro - Brazil

ABSTRACT: In many cities of the world, traffic congestion is a problem to be faced. The public transport system plays an important role in any specific strategy aiming to cope with traffic congestion problems. Low capacity road systems have turn into a new alternative of public transport in metropolitan areas of Brazil. The main objective of this research is to present a methodological procedure, based on a case study of the city of Rio de Janeiro to analyse the potential role of integration between urban road systems with diversified capacities.

RESUME: La congestion est un des plus grands problèmes dans la plupart des grandes villes au monde. Les systèmes de transport public jouent un rôle important dans le but de réduire les problèmes de congestion. Les systèmes (technologies) de transport public urbain de faible capacité deviennent une option dans les grandesmetropoles brésiliennes. Le principal objectif de ce travail est de présenter une métodologie, basée dans le cas de la ville de Rio de Janeiro, capable de vérifier et analiser le rôle potentiel d'intégration entre les systèmes de transport public urbain de différentes capacités.

1. INTRODUCTION

In many cities of the world, traffic congestion is a problem to be faced. There are many solutions proposed to tackle the problem ranging from the increase in road capacity to road pricing. The public transport system plays an important role in any specific strategy aiming to cope with traffic congestion problems. An adequate and efficient public transport system could, if properly operated and planned attract car users and consequently improve the road network utilization.

The 90´s have registered the expansion of low capacity road systems operation in many Brazilian cities. Different authors and researchers have pointed out reasons for this expansion with emphasis to: lack of formal jobs in the market; the inadequacy of services run by regular operators; some competitive advantages of running specific services compared to regular buses; lack of control by transport authorities; etc. The lack of competition in the market have also contributed to a stagnation of the road transport sector, specially in terms of creating new services or introducing new vehicles and technology to the services operated.

Low capacity road systems have turn into a new alternative of public transport in metropolitan areas of Brazil. In most cases, this means of transport compete directly with higher capacity systems in high capacity corridors, thus contributing to increase traffic congestion and the level of air pollution. A strategic planning for a transportation system should consider the importance of integration between different modes. Low capacity transport systems could operate like feeders of the principal system, increasing the efficiency of the network.

The main objective of this paper is to present a methodological procedure developed to analyze the potential role of urban public transport integration based on road systems with diversified capacities. Possible benefits generated by an integrated operation between low and medium capacity systems will be assessed under the point of view of the user, the operator, and the society as a whole. Following this introduction, section 2 describes and analyzes low capacity transport systems operation in different countries with emphasis in the Brazilian case. In section 3 a methodological procedure is described aiming at the assessment of road transport systems integration. The data required and the appropriate way of collecting this information is described. Also a possible alternative to quantifying possible benefits generated with integration is detailed. Section 4 de-

scribes a district in the city of Rio de Janeiro, considered as a case study for the implementation of the methodological procedure developed. Possible results produced with an integrated operation are contrasted with those obtained in the current situation. Finally the main conclusions of the paper are presented in section 5.

2. LOW CAPACITY TRANSPORT SYSTEMS OPERATION

Different authors highlight the importance and role played by low capacity transport systems as an alternative of public transport around the world (Araujo 2001, Cervero 1997, Cervero 2000, Guerra 2002, Klein et al.1997). North American cities such as Los Angeles and San Francisco operate the jitneys services since the beginning of the XXth century. These services were characterized by private vehicles running on public transport routes (Klein et al. 1997). In the case of New York, jitneys operation is more recent than other North American cities. According to Cervero (1997) the jitneys expansion during the 70´s could be attributed to the rapid increase in the number of Latin immigrants to the city, who were the main users of services provided.

Cervero (2000) affirms that informal transport services based on the operation of low capacity vehicles could be identified in almost all the African continent. Mini buses are common in many cities, most of them operating as a complementary service during peak hours of the day, which is the case of Adis Ababa in Ethiopia and Lasaka in Zambia. In Tanzania these services are well known as "dala dala" and in Uganda are known as "kamuny". In Kinshasa, Zaire these services are named "fula fula".

In Latin America one can observe that low capacity transport systems operate since the 40´s decade. Services such as "por puestos" initially operate as collective taxis (Ocaña 1993). In the sixties those services were regulated, what did not mean that illegal operators had been banned. Some operators continued to run services without any regulation. This scenario was established along many years, characterizing the "por puestos" services as the main means of public transport especially in the capital Caracas. Also in this decade "jeeps" began to operate public transport routes. The service operated vehicles with capacity to carry 9-12 seated passengers. These vehicles were responsible to run services between districts in the periphery and the metropolitan region of Caracas (Dourado et al. 1996).

In the case of Brazil, in the beginning of the 90´s, low capacity transport systems operated by vans were initially contracted out by companies, schools, etc. to run specific services (workers in daily home to work trips, students travelling to school, tourist services, etc.) Van operators have identified at that time a market niche not fulfilled by most regular bus services. The reduced supply of seats during peak periods of the day allowed van operators to run parallel services to bus routes. The supply increase was well accepted by users, especially those travelling in longer routes without any guarantee of a free seat during the trip. A free seat in a comfortable vehicle and a reasonable fare attracted many bus users to vans services (Vasconcellos & Balassiano 2001).

According to NTU (2000) alternative van services are running public transport routes in many Brazilin cities, with diversified levels of market share. Aracaju, Belém Brasília, Campo Grande, Fortaleza, Goiânia, João Pessoa, Maceió, Manaus, Palmas, Porto Velho, Recife, Recife, Rio de Janeiro, Salvador, São Luis, São Paulo, Teresina, and also the metropolitan regions of Belo Horizonte, Rio de Janeiro and São Paulo are important references of cities where alternative services are competing for passengers in most public transport routes.

In the specific case of the city of Rio de Janeiro a more fierce competition between van operators and regular bus companies was registered. Van operators organized their operations under route associations, establishing thus a more powerful organisation to negotiate a special regulation with public transport authorities.

The first attempt to regulate services provided by vans occurred in 1996. Some specific services were authorized by the local transport authority. The regulation was than extended to other services. The operators were authorized to run contracted out services only. Due to a lack of enforcement and the difficulty of establishing a strategy to follow up the operation of services provided, the informal services run by van operators registered an expansion on most busy transport corridors. Van services were at that time directly competing with regular trains, underground and bus services in most routes.

Alternative services provided by low capacity vehicles run different public transport routes including local district routes and radial routes towards the city centre. Services were operated by different vehicle types: the shorter local district links were operated by Volkswagen type vehicles such as "kombis" and other mini-vans; low capacity vehicles such as conventional vans operated longer routes between districts and between districts and the city centre.

Other cities of the Metropolitan Region attempted to implement specific regulation to these services but also without success. One could observe the increase in the number of vehicles running services between municipalities in the metropolitan region and also between different municipalities in the state.

Balassiano & Braga (1998) estimate that around 6200 low capacity vehicles were running passenger transport services in the Metropolitan Region in

1998. In 2000, Vasconcellos et al. (2001) registered around 4000 low capacity vehicles operating passenger transport links to the city centre only. Currently (2003) there are 6000 legalized low capacity vehicles in the city of Rio de Janeiro. This regulation authorized vehicles to run services previously offered to users in most routes. The lack of enforcement still allows other illegal operators to run services around the city and also in the metropolitan region. The estimate is that around 4000 illegal vehicles operate in the city. The total fleet running services around the whole state of Rio could have reach a total of 15000 low capacity vehicles (legal and illegal).

Licensed low capacity vehicles were not integrated to regular public transport services. Also there was no study to identify priority areas, routes, timetable or frequency to run those services. Thus it is considered in the analysis carried out in this paper that it is necessary to develop a specific plan to improve services provided, generating benefits and quality to conventional and regular services already running passenger services. The integration of low capacity vehicles such as vans to trains, underground and buses would possibly generate the desired benefits and better services to the community.

3. A METHODOLOGICAL PROCEDURE TO ASSESS ROAD PUBLIC TRANSPORT INTEGRATION

Assuming the possibility of improving transport services provided with the integration of low capacity vehicles to the conventional transport system, this section is dedicated to characterize a methodological procedure to allow the assessment of results generated in a simulation of an integrated operation between low capacity transport services provided by vehicles such as vans and medium capacity services run by conventional buses in a specific district of the city of Rio de Janeiro. It is taken into account that this kind of operation would contribute to traffic congestion reduction if the new services planned could be able to improve the transport network efficiency and consequently attract private car users to the integrated public transport services.

The proposed methodology could be split in 4 different stages: data collection; the current situation analysis; the development of an alternative scenario; the assessment of the proposed transport system in the new configuration.

3.1 Data collection

The first stage of the proposed methodology is dedicated to data collection of the necessary information to characterize the current transport system in the selected area. The main objective during data collection is to gather knowledge about supply and demand in the considered region. Thus, it is necessary to identify the public transport fleet operating in the area, frequency of services provided, the vehicles capacity, corridors and routes operated and the number of passengers carried along those routes. Also it is important to register the operating speed of vehicles, as it is related to vehicle consumption and emissions. These last two aspects would be considered in the assessment stage of the procedure to identify possible benefits generated in the alternative scenario.

Once defined the parameters need to perform modelling, it is important to exactly identify the areas of data collection. The most significant areas for public transport in the region would be identified.

Data should be collected during peak periods of the day (morning and afternoon) and also during inter-peak periods. This will provide information for different conditions of traffic flows along a typical day. Mondays and Fridays should be avoided for data collection as generally traffic and passenger flows are not regular those days. Data should be collected simultaneously along the transport network. Unfortunately this is not always possible. In the case of points in the same corridor, this procedure (collecting data simultaneously) will allow an appropriate characterization of that specific link. In both extremes of a specific link data should be collected for conventional bus services and also for alternative ones too.

3.2 Assessment of the current situation

At this stage of the procedure, data collected in the previous stage will be analysed, allowing a more clear understanding of the level of services available for users on different transport routes in the area considered. Data collected in one extreme of a specific corridor should be analysed together with data collected in the other extreme, thus allowing the characterization of the current situation in that specific link. To each extreme of a corridor or link, travel time for buses and vans will be determined. Based on the distance between these two points, operating speed will be also determined. Also the number of passengers carried by each means of transport will be obtained. The next step consists in determining total supply and demand on a specific link. Summing up the capacity of all vehicles running on that link will provide the supply in that corridor. The demand will result of the sum of all passengers observed during the field research in the specific link. In this case, the number of passengers carried by buses or vans will be considered the average of the observations registered in different days of the week or the period considered.

3.3 Alternative scenarios

Having as starting point the current situation, some alternative scenarios are proposed, to be compared and assessed in terms of possible improvements generated to the transport system. In the proposed situation, integration of the road transport system, considering low capacity vehicles (vans) and buses is taken into account. Scenarios contribute to enlarge the scope of the analysis and to assess the achieved results. According to Rodrigues & Santos (1995), a scenario could be understood as a hypothetical stage of a pre-determined system that one wants to know in a specific instant of a period of time. The scenario will be developed according to the influence of some variables that characterize the behaviour of all components of the system. Thus, scenarios allow that uncertainty about a long range forecast could be incorporated in the analysis of complex systems.

The scenarios considered in the proposed procedure anticipate two different alternatives of transport systems integration. They assume the possibility of implementing a trunk-feeder road transport option in the area analysed. The alternative operation proposed will be composed by trunk routes operating higher capacity vehicles (buses) running on busy traffic corridors. Feeder routes will also be designed to collect passengers near to their origins and redirect them to a terminal or a transfer point along the trunk route.

The determinant variable in the construction of the alternative scenarios is the selection of appropriate vehicles to run the trunk-feeder system. Finding out the best combination among different transport means or vehicles is a fundamental decision of the planning process of a new transport system or the expansion of an existing one (Vuchic 1981).

The first proposed scenario will consider a trunk-feeder system where the feeder vehicles will consist only of low capacity ones (vans). In the second scenario, the feeder system will be run by a mix of vehicles including low and medium capacity vehicles (vans and buses) according to the demand on the specific link analysed (see figure 1).

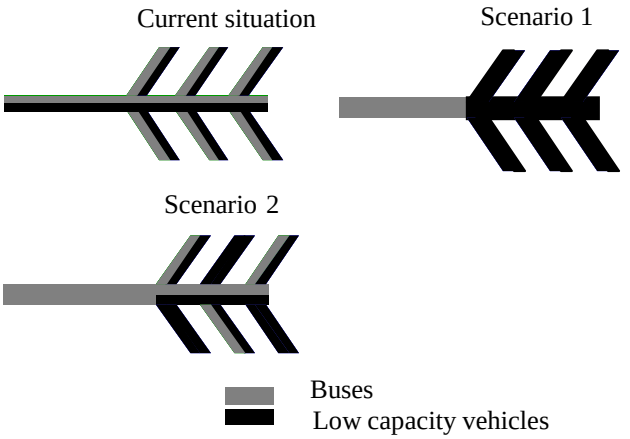

Figure 1 – Integration scenarios scheme

3.4 Assessing Possible Benefits

This stage of the procedure consists in analysing on a comparative basis the transport alternatives proposed in the previous stage. The assessment and analysis of the alternatives will be base don possible benefits generated when transport system integration is taken into account. The characteristics required for a system to be considered efficient could be assessed under three different points of view: the public transport users, the system operators and the community as a whole. Table 1 illustrates each one of these groups.

Table 1. Transport system priorities for an efficient transport system

USERS	OPERATORS	COMMUNITY
- Availability	- Coverage area	- Level of Service
- Regularity	- Frequency	- Range of services
- Travel Time	- Speed	- Environmental Aspects
- Fare	- Costs	- Energy Aspects
- Comfort	- Capacity	- Economic Efficiency
- Convenience	- Safety	- Social objectives
- Safety	- Passengers attracted	

Source: Adapted from Vuchic (1981)

Among different alternatives to develop the evaluation of the transport system the analysis will consider: improvement of the level of services to users; better efficiency in fuel consumption; environmental pollution reduction and also total operating costs reduction. The methodology proposes the observation of aspects of interest of different actors: users, operators and community. Thus, for users, waiting time will be assessed. In the case of operators, total operating costs will be the variable considered and for the community, pollution reduction and energy conservation are the variables observed (Vasconcellos 2002).

3.4.1 Waiting Time

There are many quality attributes in the public transport service to be considered in the assessment of the system under the user's point of view such as reliability, comfort, speed, accessibility, safety and economy. Based on recent surveys carried out in the

city of Rio de Janeiro, frequency of services provided is the main reason justifying users preference for low capacity vehicles in a corridor. Based on this result the procedure will consider total waiting time by users at the stop as the attribute to be assessed in the analysis.

3.4.2 Vehicle Emissions

The intense use of urban transport and the rapid urbanization process registered in many developing countries have claimed for a reduction in total vehicle emissions in these areas. On the other hand, environmental administration has been a difficult task to be performed by local authorities. This aspect could be justified by the high investments necessary to the implementation of more environmental friendly transport systems. Also, a high share of clean fuels use in public transport systems have to face the constant lack of public funds (Bajay & Berny 1981). Road vehicles contribute with significant percentages of emissions, especially in urban areas. According to Button et al. 1996, almost 60% of NO_x emissions, 80% of CO, 50% of HC and 25% of CO_2 are produced by the transport sector.

The assessment of generated benefits will concentrate in three specific pollutants: CO, HC and NO_x. The equations considered for estimating the amount of pollutants produced in each scenario are described in IPEA (1998).

3.4.3 Fuel Consumption

The increase in fuel consumption and consequently emissions (air pollution) causes concern to public authorities. Higher public health costs are one of the externalities produced by the rapid increase in traffic volumes in many countries. Some low cost measures could be implemented aiming at the reduction of fuel consumption: increasing private vehicle occupation; higher utilization of more efficient vehicles; managing the number of realized trips in order to eliminate the unnecessary ones.

Different studies have concluded that fuel consumption in urban areas is high at low speeds and decrease with higher flow speeds, reaching a minimum at 40-60 km/h. For the assessment of possible benefits generated in the alternative scenarios, two different models were chosen in order to estimate fuel consumption for buses and vans. The model developed by Santos (1980) and the one developed by Balassiano (1980) were considered for their applicability to the Brazilian context.

3.4.4 The system operating costs

The total operating cost of a transport system is a very relevant aspect in the choice of an efficient alternative. Optimizing this variable could mean reduced fares for public transport users. The analysis will consider the total operating costs of the alternatives assessed based on the total numbers of kilometres run by each vehicle. For estimating total costs for running bus routes, the procedure presented in GEIPOT (1996) will be taken into account. In the case of vans the methodology suggested by Araujo (2001) was utilized. The next section presents an application of the methodological procedure described in section 3.

4. THE CASE STUDY

The district of Ilha do Governador in Rio de Janeiro was formerly an island. Its area is almost 30km2 with half of it occupied by a military base. The International Airport of Rio de Janeiro is also located in this district and the total population comprises 200.000 inhabitants. The district is formed by 17 sub-districts where most of the traffic flows occur. The most important sub-districts are Portuguesa, Cacuia, Jardim Guanabara, Dendê, Freguesia and Bananal.

The transport system comprises mainly three different road options: conventional buses, Volkswagen type vehicles such as kombis and vans. There is also a ferry boat link to the city centre but with only a couple of daily frequencies. The conventional bus system operates 16 bus routes, with 5 of them running services between sub-districts only. Six of these bus routes operate links to the city centre and the remaining ones operate links to other districts. Low capacity vehicles running services inside the district are based on vehicles such as kombis. These vehicles operate also an important link to Bonsucesso, a neighbouring area. Vans are used on the routes operating towards the city centre. Travel time to the city centre in the ferry system is around 40 minutes but as previously referred, the frequency is poor. The headway during peak periods of the day (morning and afternoon) is almost 90 minutes.

4.1 Data collection

Data collection for this study was carried out during a two months period. Five specific points in the transport network have been selected for this specific purpose. In each point of the network, demand and supply information was gathered including bus services and also alternative services run by low capacity vehicles such as vans. Transport information was collected during three different periods of the day. In the morning peak, data collection was performed in the period between 6:30-8:30; during afternoon, the period determined for data collection was 17:00-

19:00 and the inter-peak period comprised the period between 11:30-13:30.

In each specific point of the transport network the time of data collection for each vehicle surveyed was recorded. The total number of passengers in each vehicle was also determined based on visual observations performed by researchers placed at the local stops. For travel time data collection, a specific approach was adopted. Low capacity vehicles and buses were surveyed on specific trips on the network and their travel time recorded.

4.2 Current Transport System

The transport system analysis was carried out based on the relationship between supply and demand in each sub-district. It was assumed that the current demand for services was well represented by the number of current users of the system. It is believed that in the case of the Ilha do Governador district, the current demand for places on the transport system is lower than the supply.

Although data collection comprised different periods of the day, the analysis carried out here will be based on the morning peak period only, due to higher traffic flows recorded compared to other periods of the day. Based on the analysis performed with the data collected it was possible to characterize the current transport system, its demand and supply. Headways, vehicle occupation, travel time and other relevant information have been recorded.

4.3 Transport supply

All the 16 bus routes running services in the Ilha do Governador district have data recorded during the field survey. Two of these bus routes run services linking the International Airport to specific sub-districts. Conventional buses operating routes with origin in the district, besides a total of 40 available seats, have capacity to carry 50 standing passengers. Local district services are generally run by mini bus type vehicles with capacity to carry 25 passengers.

Bus routes linking the district to the city centre offer low headway services (equal or less than five minutes during peak periods). On the other hand, bus routes linking the district to other areas of the city do not provide many options for local residents. The neighbouring district of Bonsucesso has turned into a transfer point for other destinations due to a better supply of these kinds of services.

4.4 Transport Demand

Transport demand was estimated based on the total numbers of regular users of the services provided in the district. For simplicity, private car users have not been considered, as potential users in the estimate. Passengers carried on buses, vans and kombis were suumed up to estimate total demand. The estimate of the number of passengers on each vehicle was based on visual counting. These vehicles have been observed when passing by the data collection points.

4.5 Scenarios compared

The analysis of the results obtained when comparing the current operation with the scenarios proposed, have shown that an integrated system will be an advantageous option to users, operators and the community.

Table 2 shows that in both scenarios (1 and 2) fuel consumption is lower than that recorded for the current situation. Total operating costs is also lower for both alternative scenarios. Waiting times for users is lower in both scenarios and in the case of scenario 1 where only vans would run feeder services, waiting time is even lower than in scenario 2 where conventional buses also run these services. This is probably due to a higher frequency service operation necessary when low capacity vehicles operate these routes.

Table 2. Scenarios compared to current situation

		Scenario 1 Integration with vans	Scenario 2 Integration with buses and vans	Current situation
Fuel Consumption (l/h)		426	313	682
Pollutants (g/h)	HC	6264	3754	7842
	NO_x	3517	5522	14642
	CO	72464	39782	80131
Operating Costs (US$/peak hour)		173	137	318
Waiting time (seconds)		10	18	28

Finally, pollutant emissions for all gases considered are also lower in the integration scenarios. Emissions are lower in scenario 2 when compared to scenario 1, except for NO_x. This is also probably to the higher number of buses in that scenario (2) allowing for higher emissions levels of NO_x.

5. CONCLUSIONS

The last decade registered a rapid increase in the number of low capacity vehicles running passenger services in many Brazilian cities. The operation of these vehicles brought concern to transport authorities and public transport operators. In most cases, this means of transport directly compete for passengers on high density traffic corridors, thus contributing to traffic congestion and poor network ser-

vices. Researchers and technicians have been discussing alternative ways to deal and regulate the operation of these low capacity vehicles and consequently improve the services provided. Metropolitan areas are more sensible to this kind of transport problem.

Within this context, an integration transport policy considering different means becomes an important strategy to be established by transport authorities and planners. The methodological procedure proposed and assessed in this paper confirmed the importance and feasibility of integrating different transport services in a specific area or city.

Based on the results achieved in the simulation considered in two different scenarios, there is evidence that the adoption of transport integration policies could be advantageous for different groups of the society. Public transport users, operators and the whole community could benefit from an integrated transport system and would possibly improve their quality of life. The two different scenarios assessed, when compared to the current system operation (without any integration), showed that benefits would be generated to the region considered. Fuel consumption reduction and low levels of air pollution were some of these benefits. Passengers would also benefit from lower waiting times at stops and this would possibly attract new users to the public transport system. It is possible that, if a percentage of these new public transport users transfer from private cars, better traffic conditions would also result.

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