INTEGRATING BICYCLE AND PUBLIC TRANSPORT IN BRAZILIAN METROPOLITAN REGIONS: CHALLENGES AND PERSPECTIVES

Maisa S. G. Tobias[1], Ilce M.D. Freitas[2], Denise Ribeiro[2], Maria Leonor Maia[3], Heloisa M. Barbosa[4]

1 Federal University of Para;
2 Federal University of Bahia;
3 Federal University of Pernambuco;
4 Federal University of Minas Gerais.

ABSTRACT

The possibilities for integrating bicycle and public transportation in metropolitan regions of Brazil were explored with case studies in Belem, Recife, Salvador and Belo Horizonte. Structured questionnaires and stated preference surveys were conducted with different approaches: household interviews (Recife), commuters at stations (Salvador, Belo Horizonte), and cyclists in the roads (Belem, Salvador). The central questions of this study are: Why integrate? Who will be integrated? How to integrate? The focus is on cyclists in the road network using bicycles for a wide array of activities; whether or not they use bus as a means of public transportation; and the acceptance of bicycles for integration purpose. The analysis process pointed out similarities and differences among cities related to the comparison of socioeconomic profile, percentage of potential users, travel patterns and barriers to cycling. Interviewees are prone to use bicycles as a feeder mode to bus/rail transportation. However, Belo Horizonte showed a very low percentage of potential users willing to use bicycle for access trips compared to the other cities. The potential users of integration have low income. The main similarities found are related to the use of bus for access trips to the stations; working as the main reason for commuting. Concerning the barriers to cycling, the reasons more often mentioned by interviewees converged to five main issues: the lack of infrastructure for bicycles, parking facilities, road safety, security and poor road maintenance. These are questions to be addressed by public sector when defining transport policies to promote the use of bicycles.

Keywords: *cycling systems, integration, public transportation; metropolis.*

INTRODUCTION

Nowadays, as a result of traffic problems in the cities, the possibility of cycling as an alternative to urban transportation is really an important issue for the government and for the population. It raises a great debate on sustainable urban mobility in which the benefits that non-motorized travel would bring to the community are highlighted, such as, traffic congestion reduction, health promotion, and ultimately an improvement in quality of life. In

addition, bicycles are known as an inexpensive means of transportation, often recommended for exercising and for an ecological, pollution and noise free atmosphere, and for improving the quality of the environment and promoting public health.

Brazilian metropolitan regions suffered an increasing loss of public transport demand in the last decade. Therefore, private transportation has been intensively used, especially motorized transportation, generating traffic congestion and the increase in the number of road accidents. Data show that, together with income reduction, the lack of quality in bus services have contributed for decreasing the number of users. At the same time, little is known about the growth in the use of non-motorized transportation, in particular cycling, in metropolitan Brazilian cities, neither the potentiality of the people's willingness to use bicycles for short to medium trips and as a feeder for public transportation.

Opportunities for cycling in Brazil present a great chance of success because cities still have a high level of public transport ridership, a large share of low income groups, high levels of traffic congestion and poor quality of local public transportation. However, care must be taken to deal with the threats of the outcome of a cycling program. These threats are the lack of a cycling culture, the lack of a large experience with bicycle planning and the strong focus on car as access mode.

In this article the possibilities for integrating bicycle and public transportation in these four Brazilian metropolitan regions were explored. This paper aims at unveiling what the most important attributes for cyclists are and how feasible it is to promote the integration of bicycles to the public transportation network in those cities, which are located as follows: one in the North, two in the Northeast and one in the Southeast regions of Brazil.

The main research questions were: why integrate? Whom integrates? How to integrate? In order to get the answers to these questions, structured questionnaires and stated preference surveys were conducted with different approaches: household interviews (Recife), commuters at stations (Salvador, Belo Horizonte), and cyclists in the road (Belem, Salvador). The survey had a qualitative nature and it was conceived by means of four case studies undertaken in the metropolitan regions of Belem, Recife, Salvador and Belo Horizonte, with 2 million, 3 million, 2.7 million and 2.37 million inhabitants, respectively, as shown in Figure 1.

COMBINED USE OF BICYCLE AND PUBLIC TRANSPORT

Among the solutions designed for urban transport there is the integration with individual means of transportation, in particular non-motorized means, walking and cycling. The alternatives of integration have been the main challenge of modern urban transport, specially the promotion of the combined usage of bicycle and public transportation. This section presents experiences and provides an understanding of the main issues concerning the combined usage of bicycle and public transportation in order to integrate them. It also brings

references about the profile of potential users and the key points to tackle the lack of interest for using bicycles as a feeder mode to train and buses.

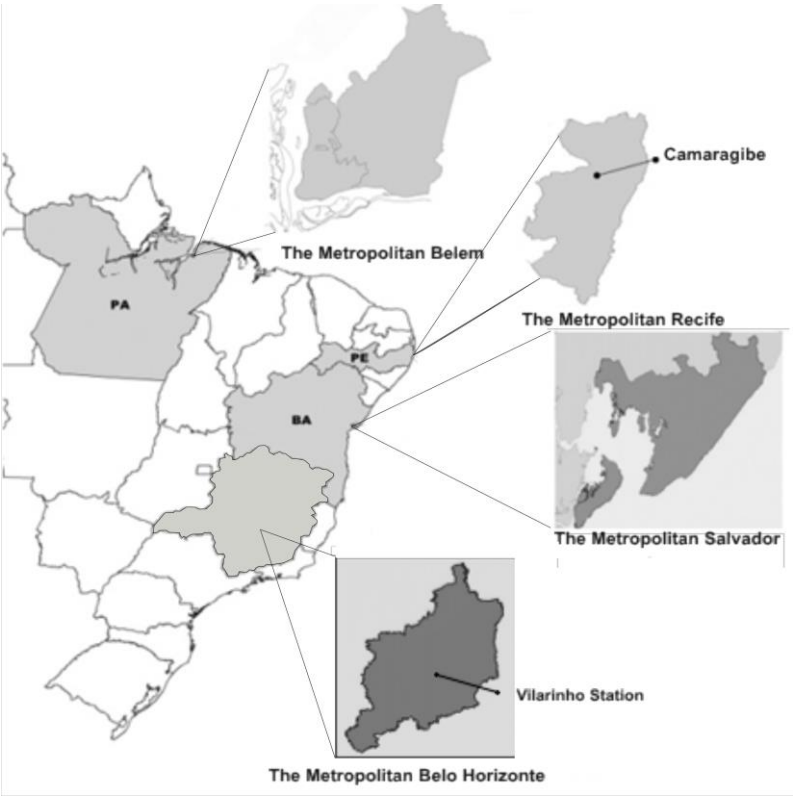

Figure 1: Metropolitan Belem, Recife, Salvador and Belo Horizonte – study areas

According to Martens (2002) data for the Netherlands, Germany, Denmark, and the United Kingdom reveal that: first, there is no direct relation between the general use of the bicycle in a country or a city and the presence level of bike and ride. Second, the presence level of bike and ride can be substantially higher than the share of the bicycle usage in all trips. Finally, there is a strong relation between the type of public transport and the share of bike and ride. Rail transportation and faster types of public transportation show higher presence levels of bike and ride than bus transit and slower types of public transportation.

There are several reasons for this, according to the author. First, faster types of public transportation tend to have relatively long distances between two stops or stations, resulting in relatively long pre-transportation and post-transportation distances. Second, passengers of faster types of public transportation tend to travel over longer distances. Finally, faster types of public transportation tend to attract passengers from a farther distance because of their high quality in terms of travel speed. All these factors thus point out that faster types of public transportation have longer pre-transportation and post-transportation distances (MARTENS, 2002). On the other hand, this makes bicycles a relatively attractive access means compared to walking, which is the most popular means of public transportation that is used to travel for relatively short distances (city bus, tram, metro) (VAN DER LOOP, 1997 apud MARTENS, 2002).

A survey undertaken in Porto Alegre, Brazil, interviewed 627 rail users at the five busiest stations out of 17 stations in the entire rail line. 27.5% of them declared themselves cyclists and 14.3% stated that a bicycle-rail integration was a way of saving money (BRAGA and MIRANDA, 2006). According to Ribeiro and Freitas (2005, apud BRAGA; MIRANDA, 2006), in Salvador, 60% of 775 bus and train users, declared that they would use the bicycle if there were an integration with public transportation, and bicycle parking. In this survey carried out in four train stations, only 2% arrived by bicycle due to lack of parking, although 35% of them used bicycles as a means of transportation in a regular basis, and 53% of them had at least one bicycle at home.

Silveira, Balassiano and Maia (2011) studied the potential of subway Center Line stations for bicycle integration using a survey with social approach and qualitative nature, conceived by means of a case study. Questionnaires were applied on the boarding platform at three selected stations. The result according to users' profile indicated that gender, age and occupation do not have influence on the intention of doing the integration. In relation to instruction levels and income, it was observed that persons with low income and low education level are keener to the integration of bicycle and subway.

According to the authors, in Recife there is a lack of: public sustainable policies to promote the use of bicycle as a means of transportation to all social classes; educational programs for sharing traffic between cyclists and drivers; cycling infrastructure to provide safety for cyclists; and an integrated public transport network. Furthermore, there is a lack of safety in stimulating the use of bicycle, as well as an integration of bicycle and subway. The biggest obstacle to promoting the interest in integrating bicycle and subway relies on the lack of public safety, as pointed out by the field survey.

From the Dutch experience, Martens (2007) draws some lessons for other countries and localities. First, the lack of attention for the bicycle as a feeder mode for public transportation trips even in a country like the Netherlands suggests that measures to promote bike-and-ride are hardly likely to be implemented without a deliberate bike-and-ride policy. Second, bicycle usage in access trips can be promoted by simply providing sufficient and attractive bicycle parking facilities. The fact that travelers did not use bike-and-ride before the placement of parking facilities, despite the availability of safe routes, suggests that cities and towns with more than negligible levels of bicycle ridership could also promote bike-and-ride by simply improving bicycle parking facilities at key stations and stops. And third, the chances to promote bicycle use for egress trips in other countries and cities seem to be limited.

The generally lower levels of bicycle ridership and less developed bicycle infrastructure will substantially reduce the number of people that may consider using the bicycle as an egress mode. This implies that measures aimed at bicycle usage in egress trips will need to focus on public transport stations and stops with high numbers of passengers.

The potential of integration in transportation planning is presented through various aspects, including measures involving improvements in infrastructure, operational management and

pricing, and the integration involving the various means of transportation available in the area in question. Urban transport integration requires essential investments, innovations, and changes in installed operating systems. In the case of the usage of bicycle with public transport, the integration has two main goals: i) inclusion of bicycle as usual means of transportation in urban travels and; ii) strengthen the collective means as the main means of transportation for medium and long travel distances for people in medium and large human settlements.

A good conditioning of the integrated transport system requires special attention from the government in order to make bicycle present at terminals and at places of high demand such as subways, trains, barges, boats, ferries, road and urban buses, allowing the recovery of collective means and expansion of the action radius for cyclists in cities and regional areas. This can be accomplished by creating bicycle parking lots, which can be billed, for example, full-time or, in other situation, by the presence of bicycles on board of means of transportation. The most common ways of integration of bicycles into public transportation in urban areas are (TOBIAS *et al,* 2012*)*:

- Integration bicycles-buses: it is one of the most important alternatives for integration. In Brazilian cities, the government initiatives to encourage the use of the bicycle with the bus are increasing. Following the examples of some European countries, in the 90's these countries were pioneers in developing projects for the integration of these systems in their cities. However, the lack of parking lots for bicycles and integration with buses is still common in Brazil and studies are currently been carried out about the feasibility of promoting the integration. On the other hand, tests are under way in cities where integrated systems are present, such as Rio de Janeiro city. Furthermore, in transportation corridors, it is usual the presence of spontaneous integration, with bicycles parked at various places, where the cyclist can leave it and take a public transport.

- Integration bicycles-trains: another important way of integration, especially in big cities. In Brazil, there is bicycle – train integration in some cities like Rio de Janeiro, Porto Alegre and São Paulo. For the operation of these systems there are some measures in order to make the service more effective: i) cards for access control; ii) assigning "streets" and parking spaces; iii) mechanical assistance; iv) assistance offered for bicycle members, in case of bicycle breakdown; v) covered parking for older members and; vi) training for cyclists about cycling inside and outside the parking lot.

- Integration bicycles-subway: it is the greatest potential for integration of large population centers. In some European countries, this integration system is vital for the promotion of urban mobility, such as Amsterdam and Copenhagen, where the government and private enterprises are always looking for improvements to cycling, encouraging more sustainable mobility. In Brazil, cities like Rio de Janeiro and Sao Paulo are increasingly investing in accessibility for cyclists at stations with well-structured and low-priced bicycle parking. In some cases, on weekends and holidays, cyclists still have the alternative of carrying their bikes along pre-determined wagons. Brasília, Salvador, Fortaleza and Belo

Horizonte, also have subway lines and favorable conditions for the integration between the two means of transportation.

- Integration of bicycles-boats / ferries: Brazil is a continental country and has a gigantic hydro capacity; therefore it has the possibility of integrating bicycles to the fluvial and sea transportation. This is the case of Santos and Guaruja, at the coast of São Paulo, with fare exemption for cyclists on board of the ferry crossing. The north of Brazil, which has the largest watershed in the world, with potential for integrating bicycle with fluvial and road transport, bicycles carried in boats and ferries are quite common, as in the case of crossing from Belem to the Marajo Island.

Given the above, this article explores the conditions and the current cyclists' profile prone to accept the integration system of bicycle and public transportation, as an aid to the decision making process by the government while implementing projects for cycling. In order to reach its objectives, the study employs a research methodology that combines different types of surveys, depending on the situation and the available information to obtain the desired answers to the three questions listed above.

METHODOLOGY

The development of this research is based on case studies conducted in four Brazilian cities. The methodology involved the conduction of documental and opinion surveys. Documental surveys based on institutional maps and reports containing information about land use, transportation, geography, topography and economy were carried out for general characterization of the study area and the urban transportation system of each city. Opinion survey is recommended to obtaining feedback from users on issues related to the quality of transportation, price, or even to collect suggestions on a specific or general issue. The opinion survey can be conducted at the bus stops, in public transportation vehicles (on board), inside stations (terminals), on the streets or at households. Empirical method was applied based on secondary data about the urban transportation network and on primary data about users' socioeconomic profile and their perception about integration and attitudes towards cycling.

Description of the study areas

Belem Metropolitan Region, which is located in the North of Brazil, is known as the gateway to the Amazon with 2 million of population (IBGE, 2010) and is also part of a metropolitan region that includes four municipalities comprising 1800 km2. Belem is located in a peninsula at the Guajara bay, and comprises two sectors: the continent and the islands (Figure 1). The urban transportation system consists of buses, minibuses, taxis, boats, vans and moto-taxis. Buses are predominant with 162 conventional service lines, carrying 1 million daily passengers in average. The fleet is composed of 1700 vehicles making 14,000 trips per day. The city already has some cycling projects. The origin-destination matrix, from 10 years ago

(JICA, 2001), presented 51.1% of households with bicycles and modal share of trips by bicycle in 6% of urban trips. At that time the urban population of Belem was 1.5 million, 25% less than the current population. Since then, it has been observed an ever increasing flow of cyclists in urban areas.

Salvador Metropolitan Region, located in the Northeast of Brazil, is composed by two geographically distinct areas - the mainland and islands as shown in Figure 1. By land, it borders three municipalities and, by sea, through Aratu and Todos os Santos Bays, it limits six municipalities. The population exceeds 3.5 million (IBGE, 2010) and urban sprawl happened initially on the flat tops of the hills and, since the twentieth century, it began to extend more fully the slopes and valley bottoms, with the deployment of new road systems. Urban transportation system of Salvador is composed traditionally by rail, with trains, barge, barges with ferries, buses, minibuses, taxis and vans. Among the urban means of transportation, buses are the most used, with a fleet of 2,500 vehicles.

Research developed by the Municipal Urban Transport in 1995 showed that buses are the most used (52%), followed by on foot walking with 29% of made trips. It also stated that bicycles have a higher percentage than trains and barges. However, it is the only means that is not seen on the transportation plan for Salvador. Since 2004, with the Master Plan for Urban Development in Salvador (SEPLAN/PDDU, 2004), actions have been developed to promote and prioritize the use of bicycles in the city, but in a disconnected way and it does not constitute a comprehensive policy to promote cycling as a complement to the displacements by the urban public transportation.

Recife Metropolitan Region, located in the Northeast of Brazil, is composed by 14 municipalities, with 3.3 million inhabitants and comprises 2,800 km^2 (Figure 1). Camaragibe, a municipality in the north of the Metropolitan Recife, has 144,506 inhabitants (IBGE, 2010). The urban transportation system comprises subway lines (over ground), buses, minibuses, taxis, vans and moto-taxis. The Recife subway and buses are part of the Integrated Structural System (SEI), which comprises seven terminals and 49 bus lines and covers the whole metropolitan region of Recife. It contains both radial and perimeter lines. At the intersections of these axes there are terminals for connections allowing passengers to transfer lines without paying a second fare.

In Belo Horizonte city, the rail system has a very significant role in relation to urban mobility. According to the rail company, in average 148,000 passengers per weekday were transported in 2010. Despite its relevant role, the metropolitan train is far from addressing the city mobility problems as long as the network is still undeveloped. The system operates with just a single 28.2 km long line, which comprises 19 stations and five integration terminals (bus-subway) serving two municipalities only, Belo Horizonte and Contagem. Currently in the transportation system there are three intermodal stations (bus/rail), which are the system's busiest stations. There are bike racks in these stations, but effectively it is not known whether bicycle integration with rail really occurs.

Vilarinho station has a bus sector for metropolitan lines (North sector) and another sector for municipal lines (South sector) adjoining the metropolitan train rails. In the south sector there is a bus feeder system composed by three lines. Vilarinho is the biggest intermodal station (rail/bus) of the public transportation system of Belo Horizonte Metropolitan Region, located in the junction of two important transportation corridors, and it has fundamental importance for over one million inhabitants of North region neighborhood and other six municipalities. The station was designed to serve a daily demand of approximately 120,000 users and it has a circulation capacity for a fleet of approximately 400 buses in peak hour.

Field Surveys

The target population surveyed in Belem and Salvador were primarily cyclists who sometimes use bicycle or public transportation for a wide array of activities; bicycle users only or even use it in conjunction with public transport. In Salvador surveys were also conducted at three bus stations in order to interview public transport passengers, not necessarily cyclists.

The survey in Belem was conducted at the public transport network and surrounding areas of fairs and ports, and with cyclists, who were riding near the route of the buses. In the case of Salvador cyclists were interviewed at three stations or in their surrounding areas. In Camaragibe, Great Recife, the research was based on a household survey and the population sampled was over 15 years old, who are were to ride a bike, but not necessarily used it as a means of transportation. In Belo Horizonte the survey was conducted at a multimodal station where users of public transportation (trains) were interviewed, not necessarily cyclists.

Belem

There was a pre-selection of places, where strategic bicycle flows convert, either on the road or at places such as fairs and ports to carry out the interviews. At those points counts of bicycles were made on weekdays and weekends, in the morning and in the afternoon peak, assuming a flow greater than 1,000 bicycles during the peak in all the days of collection. From these surveys twelve points were identified as the most relevant regarding flows of cyclists. Adopting a binomial probability sample, with 95% of confidence and 10% of error, interviews were conducted at the twelve selected points using a questionnaire covering socioeconomic data, travel patterns and opinions about cycling, the usage of the bus and, finally, about the integrated usage of bicycles with bus and the corresponding infrastructure. There were about 1,152 cyclists interviewed.

Salvador

Field work in Salvador was undertaken using two survey approaches: (i) passengers interviews at three stations; and (ii) cyclists interviews on roads surrounding the stations. A total of 1299 passengers were interviewed. According to the calculated sample size, 466 questionnaires were applied at Mussurunga (bus station), 528 questionnaires at Lapa (bus station) and 305 questionnaires at Calçada (rail station). A total of 222 cyclists were

interviewed on the roads of the area around the stations: 83 cyclists near Mussurunga surroundings, 50 in Lapa station surroundings and 89 questionnaires at Calçada station surroundings. The survey consisted of a direct approach to the interview by fulfilling questionnaires, involving socioeconomic data, travel patterns, evaluation of the attributes regarding the quality of service and opinions about the integration between bicycle and public means of transportation, as well as facilitators and barriers to that.

Recife

In Recife, the research was based on the argument that the implementation of bicycle parking areas at metro stations would facilitate bicycle-train integration; that it would increase the attention to public transportation for the people living in the surrounding of these terminals, and improving accessibility to the stations. Its main objectives were to determine the cycling potential around the subway station, proposing the use of bicycles as a feeder mode of these systems and encouraging bike-train intermodality. The empirical study was made in the neighborhoods that surround the Camaragibe Station which is the fourth most important subway station in terms of numbers of daily passengers (20,000) in the subway system. SEI is also important for those who live in the Western zone of great Recife.

The methodology consisted of a household survey, where the probability method of cluster sampling SAS was used, in two stages, in the area located in a radius between 500 and 1000 meters around the axis of the metro station. The first stage was sampling randomly the streets to be covered (14 were randomly selected out of 74) and the second one referred to the households to be surveyed (72 out of 361). The research worked with a 95% confidence level. 101 questionnaires were applied with householders above 15 years old and who were able to ride a bicycle.

Belo Horizonte

At Vilarinho station interviews were conducted concerning socioeconomic issues in order to identify the profile of users prone for bicycle integration. A stated preference survey was carried out to assess the intention of integrating bicycle and public transportation, namely the metropolitan train. In order to trace the potential users' profile, a questionnaire was elaborated involving questions related to socioeconomics such as: gender, age, income, occupation and education. Travel pattern: reasons; means of transportation and travel time to the station. And specific questions about the usage of bicycle: ability to ride a bicycle; obstacles in using bicycles; reasons for not using it; place to park bicycles.

In the stated preference survey the respondents were asked to rank hypothetical situations related to bicycle-rail integration. For this experiment, four attributes were considered: cycle paths in the route to the station (cycle path); possibility of taking the bicycle inside the train (taking the bike); parking lots at the station (parking); public security in the route (security). Two levels were established to each attribute, one corresponding to the occurrence of the attribute and the other one corresponding to the inexistence of the attribute. Information was presented in card format to interviewees in order to rank the scenarios in preference order.

Table 1 summarizes the main characteristics of the surveys carried out in the four case studies, such as type, sample size, location where the survey was undertaken and the area of influence (study area).

Table I – Summary of field survey characteristics

	Type of survey	Sample	Location	Study area
Belem	Volume counts	28,485	On the road	Bus corridors
	Structured Interviews	1,152	Sites on the road	
Belo Horizonte	Structured interviews	170	Boarding platform (Public transportation users)	Intermodal station
	Stated preference	100		
Recife	Structured interviews	101	Household surveys	Households in a radius between 500 and 1000m around the axis of metro station.
Salvador	Structured interviews	1,299	Station (Public transportation users)	Bus stations and rail station
	Structured interviews	222	On the road	Nearby the stations

RESULTS

The results are focused on the profile of people who want or are willing to integrate; the reasons for integration; and also how to integrate, specifying important system components for this to happen and, finally, the challenges for integration. Firstly, the results for each municipality are presented, and in the end an analysis is carried out comparing these four cities.

Belem results

The socioeconomic profile has shown the relationship between age and income of cyclists, especially the presence of most cyclists in the first income ranges, and a predominance of young cyclists in receiving up to one Brazilian minimum wage a month. Also, most of cyclists are men, especially in higher income brackets and with absolute majority in all areas. In lower income brackets, the ratio between men and women is similar, especially in Belem outskirts, and most of them earn one minimum wage.

The transportation network in Belem is concentrated and the macro accessibility is significantly compromised by the lack of paved road system, the middle and long travel distance by bicycle culminate in sharing the infrastructure of bus transportation in major corridors in the region. The effective use of bicycle for work activities is observed in all urban areas and in average these trips takes from 20 to 30 minutes in Central and Middle areas. Travel time increases to more than 30 minutes as trips approach the expansion area. Regarding the use of public transportation, 63% of cyclists were bus users and access trips

are predominantly on foot or by bicycle. Furthermore, 78% of cyclists interviewed agreed that having a bicycle rack near a bus stop would be an important or very important issue.

The field survey showed that for 90% of cyclists a bicycle – bus integration was important or very important, and that 70% would be willing to pay to park their bicycles. The most important attributes for a bicycle parking lot are: being covered and free. The results indicated a predominantly demand of young, male and low income cyclists, who use bicycle mainly for work. The greatest potential was observed in the expansion area, where travelling outside this area is very important and lasts in average over 30 minutes, which characterizes the group of interest for integration with bus. It was also identified the willingness of cyclists in integration, since there would be an infrastructure to park bicycles at an affordable cost. A demand of 4,000 cyclists who travel at peak times from the area of expansion to the Central / Middle area was identified from volumetric counting. Considering internal and external travel within the areas studied, 28,485 cyclists were counted at peak times in the twelve survey points.

Salvador results

At the stations, there was a balance between male and female cyclists and the predominance of cyclists in the two first income brackets (53.6%). Their age is between 18 and 35 years old (approximately, 50%). Around the stations, the cyclists are male by absolute majority with predominance of young cyclists. The income is concentrated from 1 up to 3 Brazilian minimum wages a month.

At the three stations the majority of cyclists claimed to be able to ride a bicycle (in average 77.7%). However, they do not use bicycle any day a week, or rarely. When using the bicycle, their main purpose is leisure. Among the main reasons related to the rare use of bicycle there are: dangerous traffic (in average 26%) and inadequate road surface (in average 25.3%). As for travel times, the majority of cyclists spends over 30 minutes (in average 31.5%). Outside the stations, the situation changes dramatically: most cyclists use the bicycle every day of the week (in average 73%) for working. Travel times vary in the regions, but most cyclists spend over 30 minutes per trip (44.6%). Among the advantages of using bicycle: the agility (12%); health (17.1%) and the practice of physical exercise (16.9%). The majority of interviewed cyclists had never used a bicycle, much less left it nearby stations (in average, 72%) due to reasons such as insecurity and lack of public parking facilities.

Most of the interviewees at the stations would use the bicycle as a means of transportation; integrating, if there were parking lots for bicycles (in average, 78.6%), safe parking (in average, 30%), sheltered facilities (in average 21%) and situated inside or near the station (in average, 18%). The users were willing to pay for the use of the parking lot (in average, 84%) as long as the price were affordable. Outside the stations, proportionately, the intention of the interviewees in using the bicycle integrated to public transportation remained the same as the intention of the interviewees at the stations. However, the willingness to pay decreased.

Recife results

As a general result, it is possible to consider that bicycles can work as an important feeder of the transport system and can be used mainly for short distance - micro accessibility to bus/subway stations, working as complementary transport systems and services. The empirical evidence shows that there is a potential for cycling in the researched area, according to the socioeconomic background of the population and the flat topography predominantly in the region. It was also observed the willingness of the researched population to travel by bicycle as a means to integrate with the public motorized transport system (bus and subway) at the terminal.

The socioeconomic backgrounds of the population are similar to the one observed in other researches. About 80% of the individuals earn up to two Brazilian minimum wages a month. Workers and students are 76% of the population and they are the ones who more frequently cycle to their daily activities. Besides, 83% of the researched population made trips by subway or by bus to their daily activities using the Integrated Structural System. Among them, 58% arrive at the integrated terminal (bus/subway) traveling by bus and 33% by walking. It is possible to argue that these trips could easily be made by bicycle, once the survey was undertaken in an area between 500m to 1km from the terminal. The majority of the surveyed population (63%) does not cycle, even though it is able to ride a bike.

About the barriers to cycle to the terminal, the most important aspect mentioned was the lack of parking facilities. For 65% of the surveyed population this facility would stimulate trips made by bicycle to the station. Aspects related to security, climate conditions, topography and public lighting were not considered as relevant. Risks of accidents were a relevant barrier especially to those who never travel by bicycle. Concerning the features and services provided in the parking area, 37% prefer it to be located inside the subway station, 36% prefer it to be a sheltered parking, 28% prefer it to be free of charge. It is important that 27% of the population has never cycled to the terminal because they do not own a bicycle.

Belo Horizonte results

It was necessary to filter the information in order to distinguish the potential users of bicycle integration with public transportation from those not willing to use bicycle at all as a means of transportation. Those respondents that mentioned they would not use bicycle to reach stations for reasons related to the lack of infrastructure for bicycles were considered as potential users of bicycle integration. The remaining reasons, not associated to the lack of infrastructure, considered that the obstacles for cycling were: not owning a bicycle, unfavorable physical conditions and distance. The filtering process pointed out a small percentage (22%) of people willing to use the system integration, and 95% were female against only 5% of male individuals. The profile of the potential user is: female, age from 21 to 30 years old; access trips by bus; travel reason is working; travel time from 10 to 20 minutes; income between one and two Brazilian minimum wage; predominant occupation is

private sector employee; high school education. Bus is the most used means for access trips to the station, 63% for potential integration users and 71% of non-potential users.

In relation to the stated preference survey, it was concluded that the most relevant attribute to promote the integration bicycle-public transportation is public security on the roads, and the less relevant is the possibility of taking the bike inside the train. As this survey is based on probabilities, the distinction between those who effectively are willing to use the integrated system and those who are not was not made. The resulting scenarios from the given answers are hypothetical and only allow concluding that if those scenarios were to occur, even for non-potential users, the necessary conditions for a good intermodal integration would be achieved.

In relation to the existing demand for available bicycle racks at the station, there is an indication that its use do not correspond to the population that normally uses the train. It is probably related to users that leave their bicycles in the racks and then travel by bus, as there is integration to bus lines at the station; or it can be related to people that work at the station and use bicycle. Considering the issue of parking facilities, the respondents answered it by order of priority the following options: it should be inside the station; safe; sheltered; and free. Only the responses of the population receptive to integration were considered, and 58% named "safe" as first priority, and “free of charge” as second place with 26% of responses.

Among the reported reasons for the lack of disposition to use the bicycle, it is highlighted: weather; unable to ride a bicycle; distance; physical conditions; sedentary lifestyle; faster journey by bus; residence near the station.

Comparisons among cities

The characteristics of the surveys undertaken in the four cities have different approaches as previously shown in Table 1. Therefore, comparisons among cities have to be made considering the similarities of the survey methods and the analysis carried out. Table II summarizes the main findings of the surveys concerning the following aspects, which had similar treatment: socioeconomic profile, percentage of potential users and travel patterns. Belo Horizonte city does not appear in this table as the data obtained from interviews were processed in a different way, in order to point out the profile of the potential bicycle user: female, between 21 and 30 years old, income up to two Brazilian minimum wages.

As a result of different survey approaches, related to the questions of the interview, the findings cannot be fully compared. For instance, the interviews in Salvador pointed out a higher percentage of the usage of the bicycle for leisure, not evaluated in the other cities. On the other hand, interviewees from Recife, Salvador, Belo Horizonte and Belem are prone to use bicycle as a feeder mode to bus/rail transport. However, in Belo Horizonte it was identified a very low percentage (22%) of potential users willing to use bicycle for access trips, when compared to the other cities shown in Table II, which presented percentages varying from 64% up to 80%. Since there is a great amount of cyclists in Belem, the survey

could point out the percentage of cyclists receptive to integration (90%) as well as cyclists willing to pay for parking facilities (70%).

Table II: Summary of main findings concerning socioeconomic profile, potential users and travel patterns

City	Socioeconomic profile	Percentage of potential users	Travel patterns
Belem	77%: 26 to 48 years old 51% up to 1 minimum wage/month	78%	63% use bicycle for commuting
Recife	80% of interviewees receives up to 2 Brazilian minimum wages	80%	63% access trips by bus; 58% for working purpose
Salvador Lapa	97.1% of interviewees receives up to 3 Brazilian minimum wages	74%	75.9% use bicycle for leisure and 9.3% for working purpose
Salvador Mussurunga	98.1% of interviewees receives up to 3 Brazilian minimum wages	64%	72.3% use bicycle for leisure and 18.4 % for working purpose
Salvador Calçada	88%of interviewees receives up to 3 Brazilian minimum wages	64%	64.4% use bicycle for leisure and 18.8 % for working purpose

As a result of different survey approaches, related to the questions of the interview, the findings cannot be fully compared. For instance, the interviews in Salvador pointed out a higher percentage of the usage of the bicycle for leisure, not evaluated in the other cities. On the other hand, interviewees from Recife, Salvador, Belo Horizonte and Belem are prone to use bicycle as a feeder mode to bus/rail transport. However, in Belo Horizonte it was identified a very low percentage (22%) of potential users willing to use bicycle for access trips, when compared to the other cities shown in Table II, which presented percentages varying from 64% up to 80%. Since there is a great amount of cyclists in Belem, the survey could point out the percentage of cyclists receptive to integration (90%) as well as cyclists willing to pay for parking facilities (70%).

The main similarities among these four cities are related to: (i) the use of bus for access trips to the stations; (ii) working as the main travel reason; and (iii) the barriers to cycling. The most mentioned reasons by the interviewees in all cities converge to five main issues: the lack of an infrastructure for bicycles, parking facilities, road safety, security and poor road maintenance, as can be seen in Table III. The potential user of integration has low income in all surveyed cities.

FINAL REMARKS

In general, the challenges for integrating bicycle and public transportation in Brazilian metropolitan regions depends on a better planning and public investment in the system as part of a policy to promote urban mobility. Following the lessons from the Netherlands, measures to promote bike-and-ride are hardly likely to be implemented without an explicit bike-and-ride policy. Therefore, the policy should take into account the barriers mentioned by respondents at the four case studies. Thus, bicycle use in access trips could be promoted by simply providing sufficient and attractive bicycle parking facilities and also attractive bicycle road infrastructure (cycle lanes and cycle paths).

Table III: Main findings concerning barriers to cycling

CITY	Barriers to cycling
Belem	Lack of parking facilities Unsafe traffic Lack of security
Belo Horizonte	Lack of security Lack of road safety Lack of bicycle infrastructure
Recife	Lack of parking facilities Risk of accidents Lack of bicycle acquisition program
Salvador - Lapa	Unsafe traffic (62%) Inadequate road surface (18%)
Salvador - Mussurunga	Unsafe traffic (57%) Inadequate road surface (12%)
Salvador - Calçada	Unsafe traffic (49%) Insufficient signing (22%)

From the surveys in Belem, it was found a high percentage of people willing to pay for parking facilities. In Salvador, both public transport users and cyclists said they would use bicycle as an access mode if there were bicycle parking lots at the stations. Many cyclists pointed out the economic aspect as the main factor influencing the use of bicycle. However, in both cases, most of the interviewees had never used a bicycle to get to stations or rode it because of dangerous traffic conditions.

In the case of Camaragibe, Greater Recife, the results show that there is a strong evidence of cyclist potential for bicycle-subway integration, considering the socioeconomic profile of the area and the environmental conditions, which are favorable to the intermodality to occur. It was evident that parking areas for bicycles at the subway stations directly influence the decisions of choices for means of transportation for the residents living in the vicinity. It is important to note that some measures need to be taken in order to promote cycling and its integration as a feeder mode to the public transportation system.

The results from the survey in Belo Horizonte reflect the users of Vilarinho station, which 65% of them are female. Among the people who could ride a bicycle, 65% were female, aging from 21 to 30 years old. Providelo and Sanches (2010) found significant differences related to cycling acceptability in a municipality of Sao Paulo state: gender (men are more favorable to cycling), age (older person are more favorable), type of cyclist (cyclists who considered themselves very experienced), and frequency of bicycle use (individuals who use bicycle more frequently are more favorable). All of the characteristics reported by the authors do not correspond to the predominant characteristics of the sample at Vilarinho station. This fact may be an explanation to the lower percentage of bicycle usage found in Belo Horizonte.

Associating the current situation of Vilarinho station, where there is already integration between bus and rail, with the results of the research conducted, it is concluded that for that station user population cycling integration with public transport has a reduced viability, since the percentage of those not interested in the integrated system is very high. Essentially, from the answers given by respondents, it is possible to conclude that bicycle is still an unattractive means of transportation for the sample population. Thus, it can be concluded that in order to promote the integration of cycling with public transportation, it would be necessary public policies to improve security for the population in order to promote the usage of bicycle. This measure can be associated to transportation planning through the deployment of infrastructure for the safe traffic of bicycles, as well as operational improvements at stations to provide safe areas for bicycle parking.

The most frequently requests by the population are: (i) provision of sheltered parking facilities, inside the terminal, safe and preferable free of charge; (ii) traffic calming measures around the terminal providing a safer environment for cyclists; (iii) financial support for bicycle acquisition. These provisions would probably improve the attraction to the public transportation for the people living in the surroundings of these terminals and their accessibility. Finally, our findings suggest benefits of activity space analysis in investigating implications of transport infrastructure decisions, offering insights into which combinations of new planning policies and strategies can potentially lead to a certain pattern of activities.

Considering the cases described, it was evident that the participation of cyclists in the public transport system may contribute to reduce traffic conflicts in corridors of public transportation and to promote social inclusion through public transportation. Furthermore, the implementation of parking facilities for bicycles has been indicated as an important measure for the integration between bicycle-public means of transportation, as well as a way to stimulate the usage of public transportation and that should be considered in any urban planning policy.

Moreover, an important contribution this work brings is the divergence regarding the adherence to integrating bicycle and public transportation, which indicates the necessity of more detailed local surveys to assess the interest on integration. Divergences related to the use of bicycles were also identified in the study conducted by Monteiro (2011) in Rio de

Janeiro city, according to the location and land use in the surroundings of the three surveyed stations.

Thus, it may be concluded that in order to promote bicycle integration with public transportation, public policies would be necessary to improve the population security to encourage the use of bicycles, associated with transport planning through the implementation of a safe cycling infrastructure, as well as operational improvements in the station to provide safe areas for bicycle parking.

Acknowledgements
The authors would like to thank the following sponsors for financing this study: CNPq (Brazilian Funding Agency for Technological Development) and FAPEMIG (Funding Council in Minas Gerais State).

REFERENCES

Braga, M. G. C. and Miranda, A.C.M. (2006) *Análise dos Sistemas Cicloviários Brasileiros e propostas para seu desenvolvimento*. Pluris 2006 – Congresso Luso Brasileiro para o planejamento urbano, regional, integrado e sustentável, Portugal.

IBGE - Instituto Brasileiro de Geografia e Estatística (2010) *Censo demográfico – população residente.* Rio de Janeiro.

JICA, Agência de Cooperação Internacional do Japão, Plano Diretor de Transportes Urbanos. Região Metropolitana de Belém. Belém, JICA/COHAB, 2001. Relatório Final.

Loop, J.T.A. van der (1997) *Intermodality: successes by integrating public transport modes and cycling.* In: Public transport planning and operations. Proceedings of Seminar G held at the European Transport Forum Annual Meeting, Brunel University, England, 1-5 September 1997. European Transport Forum, Volume P416.

Martens, K. (2002) *Bike and ride - International experiences and lessons for Israel*. Final Draft. Transport Today &Tomorrow. Tel Aviv, June, 91 pages.

Martens, K. (2007) Promoting bike-and-ride: The Dutch experience. *Transportation Research* Part A, 41 – 326-338.

Monteiro, F. B. (2011) Avaliação de espaços urbanos para pedestres e ciclistas visando a integração com o transporte de massa. *Dissertação de Mestrado, Instituto Militar de Engenharia*.

Providelo, J. K. and Sanches, S. P. (2010) Percepções de indivíduos acerca do uso da bicicleta como modo de transporte. *Transportes*, v. XVIII, n. 2, p. 53-61.

Ribeiro, D.M.S. e Freitas, I.M.D.P. (2005*) A bicicleta como modo de transporte alternativo e integrado - O caso de Salvador*. Anais do XIX ANPET Congresso de Pesquisa e Ensino em Transportes, Recife, apud Braga, M. G. C. e Miranda, A.C.M. (2006) Análise dos Sistemas Cicloviários Brasileiros e propostas para seu desenvolvimento. Pluris 2006 – Congresso Luso Brasileiro para o planejamento urbano, regional, integrado e sustentável, Portugal.

SEPLAN/ PDDU – Secretaria Municipal de Planejamento de Salvador (2004) *Plano Diretor de Desenvolvimento Urbano de Salvador*. Minuta de Lei. Prefeitura Municipal de Salvador.

Silveira, M. O. (2010) Mobilidade Sustentável: A bicicleta como um meio de transporte integrado. *Dissertação de Mestrado em Engenharia de Transportes (COPPE*), Universidade Federal do Rio de Janeiro.

Tobias, M. S. G.; Maia, M. L. A.; Pinto, I. M. D. (2012) Challenges for integrating bicycles and public transport in Brazilian metropolitan regions. *The Built Environment,* v. 128, p. 229-239.