CRITICAL ASPECTS OF TRANSPORT SURVEY AND DEMAND MODELLING IN AMAZONIA: THE CASE OF BELÉM

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ABSTRACT

Belém metropolitan region (BMR) has two million inhabitants and is located in the delta of the Amazon River. Despite its geographic features, its urban transport infrastructure is almost entirely road based. The transport service of the 70,000 islanders has never been considered strategic by the official state agenda. The D-Fluvial Project carried out surveys to assess the transport demands of the islanders and to inform the design of a new boat aiming at implementing viable fluvial public transportation in BMR. This paper reports the achievements and findings of the Project.

1 INTRODUCTION

Similarly to what happened in other towns in the Amazonia in the middle of the 20th century, the metropolitan region of Belém (BMR) was populated in order to guarantee the political control of the region. Fluvial transport played a very important role in the social and economical development of the region until the middle of the 20th century. However, its importance has declined since then due to the advent of road transport, which is the current prevailing mode of transport in the region. As a result, the territorial occupation patterns in the region have changed as well.

Belém Metropolitan Region (BMR) is located in the delta of the Amazon River, more specifically, on the shores of the Guajará Bay. It is 1,819 km² large and consists of five towns: Ananindeua, Marituba, Benevides, Santa Bárbara and Belém, which is the capital city of the state of Pará and the largest town of the five. In 2009, the estimated population of BMR was 2, 105,621, from which 68% lived in Belém and 24% in Ananindeua. These figures attract most of the state investments to Belém and Ananindeua (Figure 1). The territorial area of Belém extends along the Guajará Bay for 52 km northwards and displays a heterogeneous distribution of its urban infrastructure. The territorial occupation started in the South. Due to an industrialization trend that has taken place in the region in the last 40 years, low income population has started to settle down in its more central area, specially in the District of Icoaraci. Meanwhile, tourism has influenced the occupation of Mosqueiro Island, in the northern part of the region.

Ananindeua lies northeast of the historical centre of Belém. The town has undergone a recent population boom due to territorial restrictions of Belém and to state housing policies. This growth has turned Ananindeua into a dormitory town for Belém. The tertiary sector represents the major economical force in BMR. Because the historical centre

of Belém holds most of the economical activities of the region, Belém and Ananindeua have strong business ties. Furthermore, Belém and Ananindeua municipalities have 44 islands. Actually, 30% of the metropolitan area of Belém is composed of islands where there are 70,000 people living in extreme poverty. Lack of access to proper means of transportation is a factor of social exclusion since the islanders depend on the poor transportation service available to obtain basic services such as health and education, and to meet their basic needs such as food and potable water.

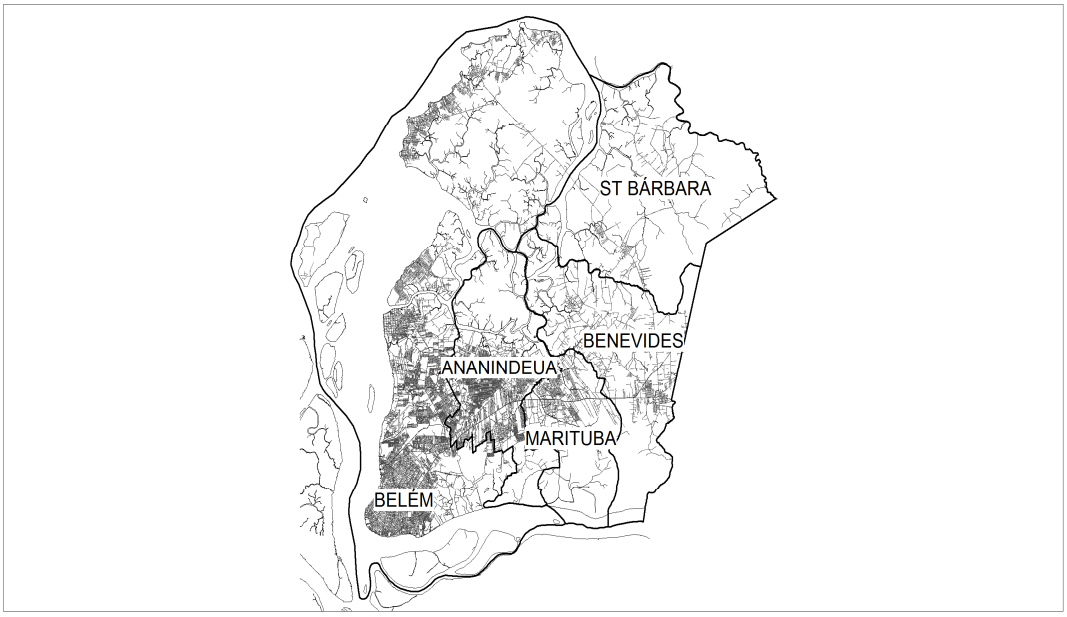

Fig. 1 Cities of the Belém Metropolitan Region - BMR

This paper reports the achievements and findings of the research project called D-Fluvial. The project was developed and carried out by two universities – University of Amazonia (UNAMA) and of Federal University of Pará. The emphases of the paper is on the adjustments the survey itself underwent during the research; the demand modelling with a behavioural focus; the development of a project of a conceptual boat to meet the demands surveyed; and the environmental impact assessment of the project. The project had two equally important motivations – help bring the issue of fluvial transport of passengers into the BMR governmental strategic planning agenda as an instrument of social inclusion; discuss the methodological procedures for such enterprise based on the experience carried out in BMR. The paper comprises five other sections besides this introduction – Section 1. In Section 2, the central problem of the research and the transport demand modelling are presented. In Section 3, the methodological approach is described. In Section 4, the obstacles encountered and the solutions adopted are discussed. In Section 5, the results are discussed and, finally, in Section 6, the conclusions are presented.

2 THE PROBLEM

Two possible approaches to assess demands were available. One is an estimation based on transport demand behaviour standard rates employed in historical studies of the area. The other is the development of a new survey to assess the modelling of the connection between transport demand and socio-economic variables, transport technologies and land use conditions. The former is cheaper, faster and very sensitive to the instability and heterogeneity of the studied area or to similar areas in which those standards have been originally developed. The latter is more expensive, time consuming, but more flexible,

which makes it more adequate to deal with the peculiarities of the studied area. The D-Fluvial Project objective of designing a new boat aiming at catering to better fluvial transport services also posed an analysis challenge. The basic questions to be answered had to with the boat size, its speed and the amenities that could be made available to the passengers. These three issues have a complex relationship with the number of trips demanded. For instance, while a set of different combinations of size and speed produces an equal hourly capacity, the hourly demand does not display the same response even with identical sets of amenities.

In Brazil, a number of efforts to collect and statistically organize transport behaviour data have been made. In spite of such efforts, they still are too isolated to allow the use of the first previously mentioned demand assessment method. Despite the availability of the data, the Brazilian social and urban reality has changed a lot in the last 30 years. This state of affairs has made unreliable any long term projection based on production and attraction rates or mode split. Besides that, the social differences among the country regions and the intraregional social classes reduce the reliability degree of the available data, which supposedly sample the reality observed in the studied area.

The heterogeneous behaviour displayed by the Brazilian transport passengers enforces the need for a cautious modelling as well. As observed by Paiva Junior and Waisman (2010), aggregated models can produce good and transferable theoretical models of high aggregated transport behaviour, but populations with different purchasing power have specific behaviours that can be totally different from the behaviours of the aggregated model. D-Fluvial Project faces the assessment demand problem of predicting the number of passengers of the fluvial links between the islands and the mainland in BMR without considering previous information and without considering the perceptions of a specific segment of the population as far as the new transport service and technology are concerned.

3 THE APPROACH

3.1 Rotes and planning areas

The present study investigates five fluvial routes along the shores of the Guajará Bay and the Guamá River. Some of these routes are currently at service and some others have already been interrupted. This study focus on the travel behaviours of the BMR islanders and their needs for infrastructure and transport services. In order to understand the behaviours of the research focus group, data on their transport were collected. The research procedures included creating planning areas, data collection, their analysis and later comparison with findings from former studies. Eight planning areas were selected – three in islands with road links, three in the mainland with actual and potential fluvial activities, and two new ones since they had not been considered in former studies (Figure 2).

3.2 Demand transport survey

Just as any transport service system design, D-Fluvial Project needed to determine the parameters for the behaviour of the transport users. This behaviour comprises time, space economical and subjective factors. These factors were translated into mathematical models that support technical decisions and produce the engineering parameters and technological solutions aimed at meeting the users' needs. However, transport survey methods are

between the actual transport users and the ideally modelled transport ones. The main goal of this study was to develop a new sustainable fluvial service system able to meet the needs of the islanders. In order to achieve such goal, it was necessary to calculate the number of trips to and from the studied areas at peak hours and the modal market share.

Four types of transport survey were carried out. They were based on the classical transport survey methodology and underwent some adjustments in order to overcome some critical aspects. These adjustments are described ahead in the paper. The surveys employed were:

- Origin-Destination Survey of Fluvial Trips (OD Survey);
- Survey of Boarding and Alighting of Bus Lines;
- State Preference Survey; and
- Traffic Counts.

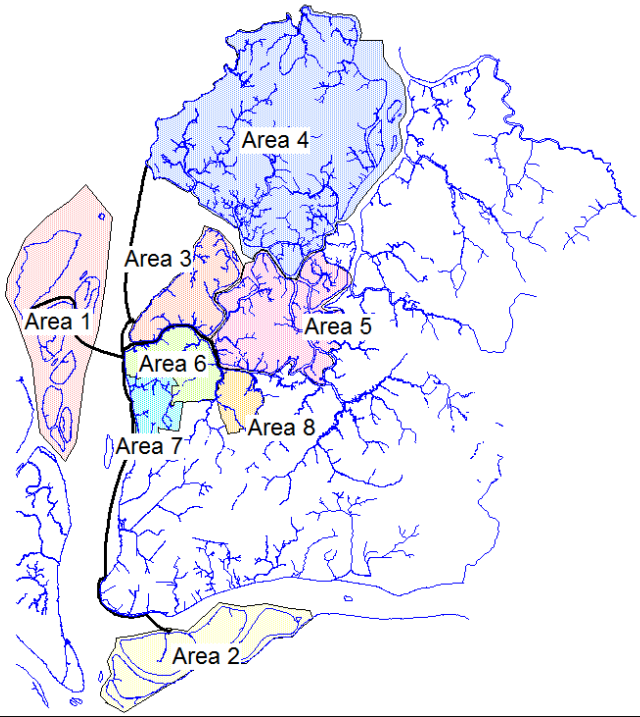

Fig. 2 Studied areas

The OD Survey was used to complement the origin-destination matrix of BMR Urban Transportation Master Plan for 2001 (BMR UTMP 2001), which originally did not include Areas 1 and 2. Therefore, the objective of this methodology was to measure the number of islanders or any occasional users travelling from or to the islands (new OD traffic zones). The Survey of Boarding and Alighting of Bus Lines was used for operational purposes such as service schedules and capacity specifications. In this study, it was applied as an evaluation tool to validate the OD matrix for 2008 that was projected based on the 2001 household survey (BMR UTMP 2001). By sampling the main bus lines of BMR, it was possible to find out what the needs for lines were at the time the D-Fluvial Project (2008) was carried out. The analysis of these 2008 projected lines showed no significant changes at the macro zone level.

The two previously mentioned surveys supplied D-Fluvial Project with information to estimate passenger flow demands for the BMR fluvial transportation network proposed. It was possible because of the fluvial network simplicity and its few number of nodes, which

is compatible with a macro-zone level system. However, this procedure is not adequate to apply to city transit and car network because of its complexity. Actually, knowing what the flows of passengers are in a link allows re-planning of the system provided that the technology is preserved. Designing a new service with different technology required understanding how users would react to the new service and to what it offers. Collecting these information demanded the use of the State Preference Survey.

Finally, after demand modelling survey, a fourth transport survey was performed with the objective of assessing the potential environmental benefits of the D-Fluvial Project. These environmental benefits would result from improvements on motor vehicle traffic at strategic places of BMR.

3.3 Modelling transport

D-Fluvial Project did not intend to project the medium or long term fluvial transport demand for BMR. The objective was to find a sustainable alternative to meet the islanders' transportation needs. It is expected that meeting the needs for transportation in the studied areas does not require large scale investments or demand the same time and concern with the analysis of the impacts as other transport technologies proposed for BMR do. Therefore, mathematical modelling of D-Fluvial Project did not require new generation, distribution or allocation models. In fact, it only required BMR UTMP 2001 OD matrix updating. As stated in Section 3.2, evaluating the impact of a new boat with different attributes from those observed in land and fluvial transport market implies estimating a new discrete model modal split choice.

The structures of discrete models are unlimited, but the most common ones are those based on probabilistic models, such as: Linear; Probit; Logit; Arctan and Exponential (LOUVIERE, HENSHER e SWAIT, 1993). Logit and Probit are by far the most frequently employed ones in transport modelling. The former is also greatly used in preference surveys due to its estimation simplicity. Since the study performed within the D-Fluvial Project involved estimating the potential market division among more than two transport alternatives, it used the multinomial logit model (Equation 1). The D-Fluvial Project evaluated a set of utility functions for each planning area in order to facilitate both the field and the modelling researches due to the peculiarities of each area.

$$P_{iq} = \frac{e^{U_{iq}}}{\sum_{j=1}^{J} e^{U_{iq}}} \qquad (1)$$

Where:

P_{iq} Probability of *"i"* alternative to be chosen by *user "q";*

U_{iq} Utility of *"i"* alternative, perceived by *user "q";*

$U_{iq} = a_{0i} + a_1 Tf_i + a_2 Tv_i + a_3 Am_i$

a_{0i} – Alternative specific constant.

a_1, a_2, a_3 – Generic parameters of the utility function;

Tf_i – Transport out of pocket cost of alternative *"i"*;

Tv_i – Total travel time of transport alternative *"i"*;

Am_i – *Dummy* variable representing the presence ($Am = 1$) or absence ($Am = 0$) of amenities offered by transport alternative *"i"*.

3.4 Boat project

The demand forecasting resulted from the modelling survey (Section 3.3) provided the boat designers with parameters to be used with the objective function of a linear programming model. By considering technological options, economic and financial factors, cost and technical constraints such as capacity and speed, this model helped naval engineers to design a boat able to meet the passengers' comfort and safety needs.

3.5 Assessment

Besides the technical aspects concerning demand modelling, technology designing and transportation service offering, the Project took its social and environmental impacts into consideration. Analysing the social issues of any enterprise is very complex since it involves large and slow cause and consequence processes. Thus, the socioeconomic evaluation focus reported herein was to examine the relationship between the BMR passengers' socioeconomic statuses such as education, age and purchasing power and their difficulties in accessing transport services. As for the environmental impact assessment, the D-Fluvial Project indirect benefits at strategic points along the BMR road system were studied.

3.5.1 Social impact assessment

Spatial segregation of certain population segments was taken as a major social indicator of social exclusion. Spatial economy argues that the distribution of socioeconomic sectors is determined by land value and logistical costs in carrying out socioeconomic activities among which transport costs play an important role. Those less competitive sectors that are characterized by people with lower education, lower purchasing power and less employability lost the dispute to overvalued urban spaces. Correlating the socioeconomic status of the population and its access to transport services was done through observation of the spatial distribution of the BMR socioeconomic segments, which was determined by the means of cluster analysis.

3.5.2 Environment assessment

The environmental impacts of the new BMR transport system might be felt at local level in three dimensions – physical, biological and human. These impacts can have short, medium or long term lasting effects that might start right after the new transport system is put into operation. The D-Fluvial Project will contribute to ease heavy traffic congestion of BMR road transport system and to intensify the socioeconomic activities that are dependent on urban fluvial transport. Other benefits of the Project include opening of new markets, increased mobility of the islanders because of improved access to transport services, and changes in land use and occupation patterns in the planning areas.

In order to envisage the initial environmental performance of D-Fluvial Project, only the physical aspects have been examined so far. The environmental physical outcomes were measured by calculating the decrease in greenhouse gas emissions and noise that had happened by reducing vehicle traffic at strategic points in BMR and by increasing average speeds.

This approach contends that greenhouse gas emissions, noise and any other observable damages caused to the physical and biotic environments along the waterways will have the harmful strength of their residues reduced in an area of greater absorption capacity, away from populated areas.

4 THE CHALLENGE

4.1 Logistic and local problems

BMR geographical and cultural specificities posed two sets of challenges to the researchers during the survey planning and execution stages. First, difficulties in conducting site visits to the new areas considered in the study made it more difficult to establish and assist the survey teams thus requiring more rigorous training. These difficulties included poor access to the island communities, the socioeconomic statuses of these communities and their lack of infrastructure. Second, difficulties in conducting the survey itself because of the low receptivity to the D-Fluvial Project displayed by the islanders. This low receptivity was twofold: the islanders were biased against the Project because of the bad image the river transport services enjoy among them and because of their distrust of governmental intentions and policies. In order to overcome their unfavourable opinion of the D-Fluvial Project as a whole, the researchers held meetings with the islanders in their communities to explain it to them, and to explain them the purpose and importance of the survey they had to conduct. In some cases, the assistance of local leaders were of absolute importance during such briefings.

4.2 Methodological problems

As mentioned previously elsewhere, the classical transport survey methodology used in the present research underwent some adjustments in order to meet its needs. These adjustments are going to be described in more detail in this sub-section and in the next three ones. During the planning phase of the study, four issues arose regarding the methodological procedures the research employed. The first issue was related to the OD Survey procedures since the main areas investigated in this research had not been part of previous OD surveys carried out in the region (BMR UTMP 2001). The second one had to do with strategies to update the findings of the OD survey performed in 2001 and to validate new data obtained. The third one regarded developing a stated preference survey instrument that would be adequate to the studied population. The last issue was concerned with developing or adjusting instruments to assess the environmental impacts of the Project.

4.2.1 OD survey: origin-destination survey of fluvial trips

The purposes of the complementary OD survey carried out within the scope of the present research were to quantify and qualify the use the BMR islanders make of the BMR current fluvial transport system. This information was not available then since these areas were not investigated in the 2001 OD survey. The herein reported OD survey was carried out in order to cater to the needs of the D-Fluvial Project. Due to this fact, it did not follow the technical standards of transport research fully.

Household surveys are suitable for home-based daily shifts studies in urban areas. However, the survey herein reported faced some drawbacks. For instance, given the geographical dispersion of the households studied and the accessibility conditions of the islanders, it was expected that the reports on the previous day trips would be scarce or

difficult to obtain, which would reduce the reliability of the survey. Moreover, the OD surveys which are usually performed in transport terminals or with boarded passengers do not assess socioeconomic statuses of the surveyed population, which would make it impossible for the researchers to draw comparisons with the 2001 OD survey data on the issue. Therefore, the researchers developed a survey design to cater to the specific needs of the current research. The new survey design has instruments to observe the flow of the fluvial passengers between the mainland terminals and the new traffic areas, and to collect information on the socioeconomic characteristics of those passengers.

4.2.2 Survey of boarding and alighting of bus lines

The employment of the survey of boarding and alighting of bus lines did no require any major methodological adjustments. The data it generated had a different use within the present research, though. The data collected through this methodology is generally used to build boarding and alighting bus stop matrices. For the purposes of the D-Fluvial Project, the bus boarding and alighting survey data on bus stops were aggregated to macro traffic zones, which resulted in an approximate BMR public transport OD matrix.

4.2.3 Survey of state preference

The previous methodologies only collect data on users' observations about transport system services, if they are to be compared with the scope of State Preference Survey (SP) procedures. Every SP implementation instance poses the researchers a challenge because the transport service users have to quickly analyse, judge and choose one or more statements on different aspects of the service among several hypothetic transport strategies during actual trips. The surveyor has the difficult task of getting the hurried transport service users' attention and collaboration. They also have to clearly present the interviewees the factorial experiment in the hypothetical transport alternatives and their attributes and precisely record their choices. The state preference survey success relies on the interviewees' abilities to judge consistently. In order to improve their analysis abilities, it is essential that the factorial stimuli be as realistic as possible and consider the origin and destination of the transport service of the users, as well as their perceptions and images of these issues. The best procedure is to employ a computer program to customize the scenarios to suit each interviewee.

The computer aided interviews were discarded because of the D-Fluvial Project resource restrictions. The procedure adopted involved a previously conceived factorial experiment for each planning area. This required a set of likely scenarios for each planning area in which the origins and destinations were used to calculate the variations of the attributes of real and hypothetical modal alternatives according to a factorial plan. In each scenario presented, the interviewees had to indicated their order of preferences.

Quality of Service sensitivity for fluvial transport services was implicitly measured by comparing the interviewees' responses to two kinds of stimuli. The interviewees did not know the features of the new fluvial transport service and the surveyors had to present them its amenities. In each planning area, two teams of surveyors carried out the research. A team of surveyors prompted the interviewees' responses by presenting them a service described as *basic* while a second one prompted their responses by the means of a presentation of a service described as *plus*. Then, the stimuli differences were identified and modelled by the means of a dummy variable.

5 FINDINGS

5.1 The new service

BMR fluvial transport pattern is quite different from the urban commuting one due to the natural barriers the former needs to overcome. On mainland, regular trips between passengers' places of residence and places of work or study are the majority of the trips that occur at the peak period daily. The fluvial trips, on the other hand, are motivated by the islanders' needs for health services and shopping as well as by fluvial tours of the islands. These features explain the high demand variability displayed by the routes connecting the islands to the mainland as opposed to the demand stability of the routes connecting mainland fluvial terminals. Figure 3 shows a demand allocation at the morning period of a typical working day during a high tourist season. Cotijuba-Icoaraci route is currently the most important one in operation. However, the simulations of connections between continent terminals display the greatest potential.

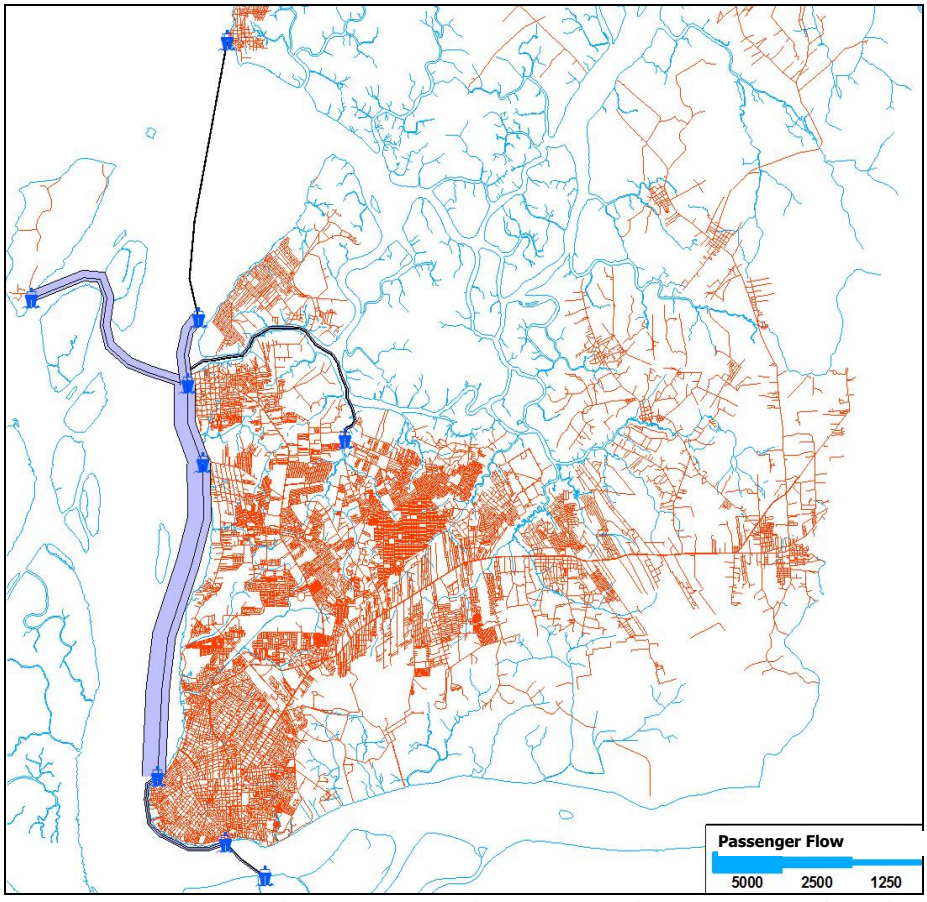

Fig. 3 Passenger Flows – estimated allocation on a typical workday for high tourist season

5.2 The new Boat

The simulations searching for the best technical and economical alternatives to a boat design suggest specific options for each of the studied waterway. For instance, the Cotijuba-Icoaraci route simulation output analysis exhibits demand for a boat with features that include capacity for 96 passengers, speed of 18 knots, two engines of 350 horse-power. See design perspectives in Figure 4.

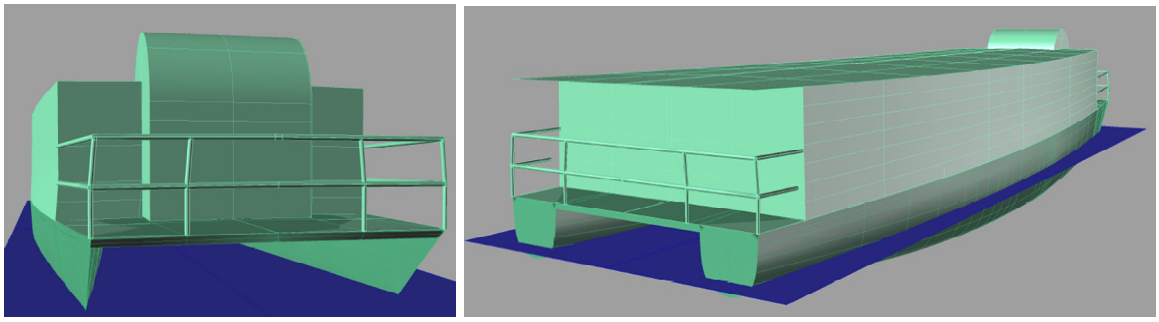

Fig. 4 Boat conceptual design

5.3 Social-economic assessment

According to Tobias *et al* (2009), the river is the current main factor of social inequality and exclusion in BMR. All the areas within BMR with road links, regardless of distance and travel time to downtown Belém, are more developed and have higher market value than the insular ones. Figure 5 illustrates the distribution of the different socioeconomic groups identified in the research. In order, groups 5, 2 and 4 are richer and younger than 1 and 3.

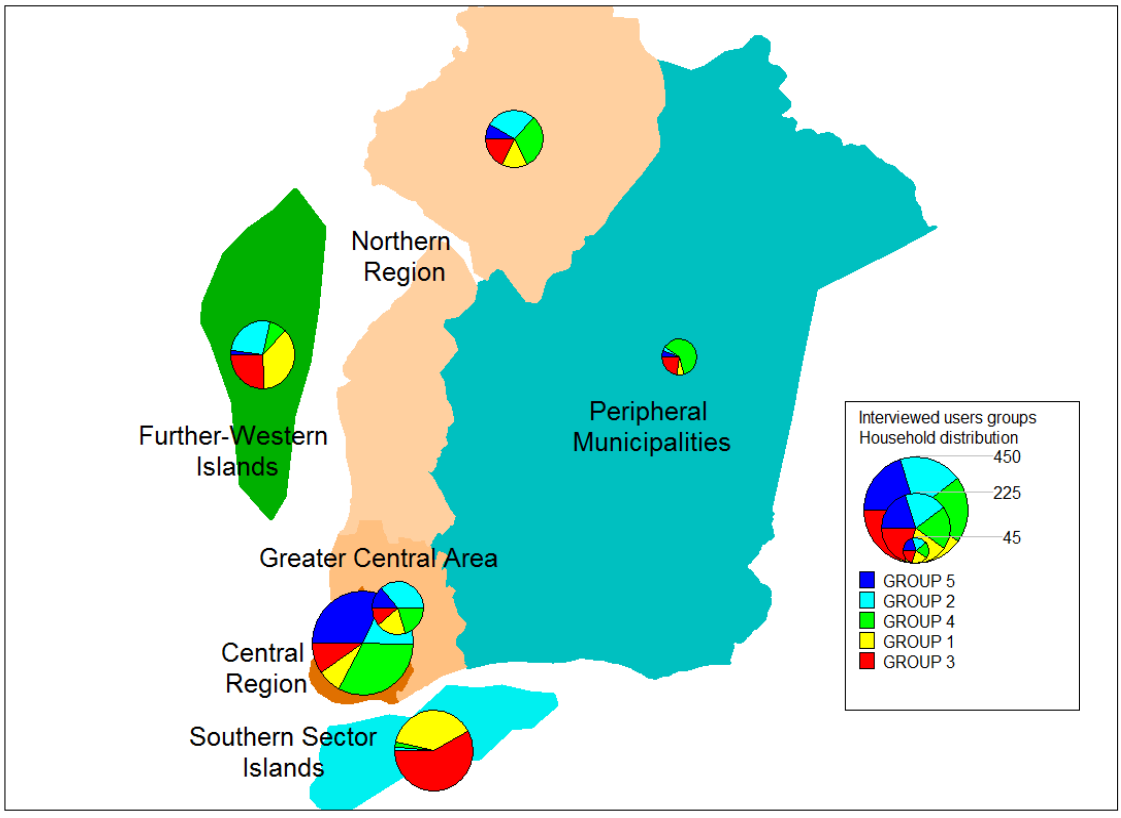

Fig. 5 Spatial distribution of groups of river transport service users identified by the D-Fluvial Project

It is not still possible to assess how and when accessibility improvements might change the life standards of the islanders. Nevertheless, data collected in the research are undeniable evidences of the drawbacks caused by omissions of past BMR strategic projects for transport services.

5.4 Environmental assessment

It is not expected that the new fluvial transport services outlined taking into consideration the estimations made within the herein reported research reduce car trips. However, due to heavy traffic and constant congestions at the studied areas, the envisaged fluvial trips hold a valid alternative to the problem. Thus, besides mitigating the bad traffic conditions, these fluvial trips would contribute to reduce greenhouse gas emissions in the investigated areas by speeding up the traffic. Figure 6 displays simulated reduction estimations of CO_2 emissions from fuel combustion. The simulation instances depicted pre and post fluvial transport service implementation situations and are recorded in the 2009 D-Fluvial Project Research Report.

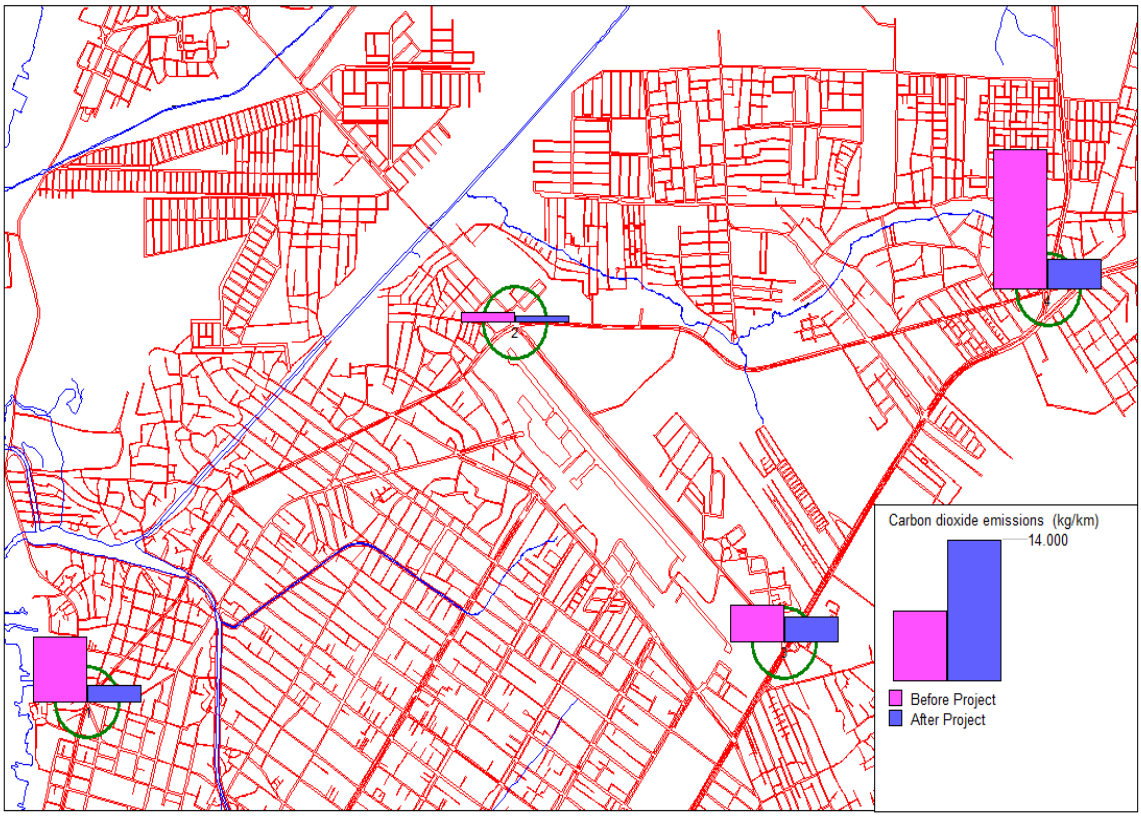

Fig. 6 Variation in the rate of CO2 emissions after the new service (kg/km)

6 CONCLUSION

In recent years, accessibility and mobility of the island population have gained importance within the technical, scientific, political and entrepreneurial communities in BMR. Among the many contributions of the D-Fluvial Project, the main one was bringing into discussion the sustainability of a metropolitan development model that disregards the fluvial transport in a region where it enjoys natural advantage. During the years of 2007 and 2009 researchers of University of Amazonia (UNAMA) and of Federal University of Pará (UFPA) have carried out studies in which information has been gathered and knowledge has been built that is of paramount importance to the future BMR Urban Transportation Master Plan.

D-Fluvial Project produced socioeconomic data, geo-referenced databases, transportation demand models, technological alternatives to fluvial transport services and research methodologies. Moreover, it helped educate a new generation of transportation expert planners for BMR.

The sustainability issue regarding a public fluvial transportation network in BMR cannot be adequately addressed just by considering the infrastructure and boat technology investment returns. The present study found evidences of environmental and social benefits of improved fluvial transport services, but more studies are required to more adequately inform and ground the coming BMR Urban Transportation Master Plan.

Overcoming the methodological challenges of collecting data on fluvial transport service demands required some adjustments of the classical transport surveys. Using discrete choice models proved effective in analyzing demand behaviours. The boat design was in accordance to the parameter specifications obtained in the research. Finally, the intermodal urban transport network was seen as a sustainable transport alternative to the population of the BMR – mainlanders and islanders likewise.

The newly acquired knowledge about the researched population socioeconomic statuses ratified the initial major motivation of this study, which was, we shall recall, help bring the issue of fluvial transport of passengers into the BMR governmental strategic planning agenda as an instrument of social inclusion by the means of the D-Fluvial Project.

Finally, the paper reported the achievements and findings of the D-Fluvial Project, which carried out surveys to assess the transport demands of the islanders and to inform the design of a new boat aiming at implementing viable fluvial public transportation in BMR.

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