Extended Abstract


In recent years, urban mobility has been a major topic of debate among general public, academics, politicians and urban planners. Despite public policy programmes on mobility kick-started by the City Statute (Estatuto das Cidades), the resources invested in Brazil have not produced significant improvement in the quality of public transport in metropolitan areas, culminating instead in mass public demonstrations in June 2013.

According to calculations made by the Federation of Industries of the State of Rio de Janeiro (FIRJAN), taking into account loss of production and additional expenditure on fuel, among other variables, the cost of traffic congestion in Rio de Janeiro metropolitan area amounted to R$ 29 billion in 2013, the equivalent of 8.2% of the area’s GDP and higher than the GDP of the states of Piauí and Tocantins.

Against this background of increasing “urban immobility”, investment in public transport, as against private transport, has become a priority. The metro system is acknowledged to be the only mode capable of effectively meeting demand by addressing various problems, namely:

- reducing greenhouse gas emissions from both individual and collective vehicles;
- having the capacity to transport a large number of users (high-capacity transport);
- the unpredictability of traffic in Rio de Janeiro, with its high accident rate, often with fatalities, involving motorcycles, cyclists, pedestrians and drivers and passengers themselves (in both individual and collective vehicles).
Transport quality can be measured in terms of various factors, such as journey time, punctuality, fares and density (number of passengers/m²). There have been studies into passenger discomfort on public transport, linking it to falling productivity at work and low self-esteem among transport users, among other things. The level of discomfort on existing lines is such that women-only carriages are provided at peak times, proving that the maximum density quoted in demand studies (6 passengers/m²) is inadequate and consistently exceeded. Another common practice which subverts the system is that many Rio metro users get on trains going in the opposite direction to their destinations during peak times in order to get a seat further up the line, demonstrating that users of Lines 1 and 2 are concerned with their own comfort.

With regard to potential users of Line 4, preference surveys in the metro demand studies drawn up by FGV Projetos indicated that fares were a secondary concern in decision-making compared to journey time, confirming the premise that time is the deciding factor in the choice of transport mode, especially for private car users who need to be absorbed by public transport. This study therefore assumes that the user will always opt for the quickest way.

Drawn up in the 1960s, the Rio de Janeiro metro project only began to be implemented ten years later, by the state government from 1979 to 1982, and from 1998 to 2009 through concession, while Line 4 was put out to tender in 1998, with work starting in 2010. The 1998 call to tender was to extend Line 1 (from Saens Peña to Jóquei) and to build Line 4 (from Jóquei to Jardim Oceânico). The present route is a result of the first contract amendment of 25/02/2010 which located the interchange of Line 4 (Ipanema to Jardim Oceânico) and Line 1 at General Osório station, with intermediate stations at São Conrado, Jóquei, Bartolomeu Mitre, Jardim de Alah and Praça Nossa Senhora da Paz, departing from Jardim Oceânico.

Delays to work on the Rio metro network have been further compounded by changes to the original projects which reveal the failure of public administrators to make use of logistical tools in decision-making. By using decision support systems (DSS) based on quantitative and objective measuring techniques, it is possible to evaluate the different alternatives and to select the most efficient solution (optimum solution) according to the parameters defined. In this case, the parameters are journey time and the optimization of passenger flow.
In this dissertation, the current metro system is assessed in contrast to a system including a new line linking the Uruguai and Gávea/Jóquei stations, as proposed in a project put out to tender in 1998, which would have produced a circular network. Under this proposal, users from the west side of Rio have a choice of routes from São Conrado station onwards, while Line 2 users have a choice from Central station onwards. By way of example, Figure 1 illustrates the number of stations between São Conrado and Carioca depending on the route chosen:

![Figure 1 Route options from São Conrado station](image)

The question to be answered at the end of the dissertation can be summarized as follows: to what extent does the Uruguai-Gávea link contribute to improved passenger flow given the shorter journey time for a certain proportion of users? Is the number of beneficiaries substantial?

To answer the question “Which direction do users choose?”, a simulation will be conducted of the time taken by users of metro Lines 1 and 4 to the various destinations on the system, taking into account the two routes. In the example given, there will be two options:

- via Ipanema, now under construction (current scenario) or
- via the Gávea-Uruguai link (proposed scenario).

For each origin and destination pair, there will be a faster route depending on whether the user travels via Ipanema or the proposed route, with a point at which journey time will be the same.
2 - DEVELOPMENT

The case study consists of comparing two route options, either via Line 4, currently under construction, or via a new link between Uruguai and Gávea stations, which would complete a circular line with the aim of reducing journey time as a result of connecting existing stations and balancing out passenger flows.

The estimated journey and stopping times were based on data from Line 1; that is, a correlation was established from the times taken for journeys and stopping on Line 1 which could be applied to obtain timings for the new stations on the current and proposed lines.

After comparing the time taken on the two routes, a calculation is made of the number of users who would benefit from putting in place this new section of the metro and the monetary value of the unproductive hours spent by these users on a longer route under the current scenario.

CURRENT SCENARIO

Line 4, currently under construction, is an extension of Line 1 towards the west side of Rio (Barra), comprising around 16 km of underground lines and six stations (Nossa Senhora da Paz, Jardim de Alah, Antero de Quental, Gávea, São Conrado and Jardim Oceânico).

PROPOSED SCENARIO

Linking Gávea and Uruguai stations involves 5.3 km of tunnelling, predominantly through rock, and is proposed not only as a means of reducing journey time, but also as an important step towards turning the Rio de Janeiro metro system into a metro network.

In the present study, the viability of the Uruguai-Gávea link derives from the reduction of journey time for a large number of passengers, making this a more attractive route option than the existing one (Line 4 under construction) for a certain proportion of users.
COMPARATIVE STUDY

Measuring the time taken by metro users to get to different destinations on the circular Line 1, considering the two possible routes, may produce two different values.

From São Conrado station, for example, there will be two route options:

- via the Gávea-Uruguai link (option J) or
- via Line 4 (Leblon – Ipanema), currently under construction (option K)

Stopping and journey times between stations were collated in the spreadsheets found in the appendix to the dissertation to produce a measure of travel times.

For each origin and destination pair, there will be a faster route depending on whether the user travels in a clockwise ($T_{ij}$) or anticlockwise ($T_{ik}$) direction, with a point at which the journey time will be approximately the same, i.e. where $T_{ij} = T_{ik}$.

From the tables contained in the appendix, it is possible to identify the station for which $T_{ij} = T_{ik}$ (the geometric centre, that is $T_j$) in order then to ascribe the value 0 (route not chosen) or 1 (preferred route):

If $T_{ij} < T_{ik}$, then $X_{ij}=1$, $X_{kj}=0$;
If $T_{ij} > T_{ik}$, then $X_{ij}=0$, $X_{kj}=1$.

Based on the spreadsheets showing journey times between origin and destination, taking into account the two route options (time matrices for the current and proposed scenarios), a new spreadsheet was drawn up aligning the times taken on the two routes for each station and its various destinations, to facilitate comparison of journey time between the two routes for every station along Lines 1 and 4.

Taking as the parameter the time taken on the journey, there will be a preferred route for each pair of origin and destination stations.
SOCIAL AND MONETARY BENEFITS OF OPTIMIZATION

The calculation of unproductive hours and the number of users to benefit was based on the spreadsheet consolidating and comparing journey times to determine the preferred route.

The total of unproductive hours can be derived from the time difference on each journey combined with the respective load (number of users to benefit from the proposed scenario).

Considering the average monthly wage in the Rio de Janeiro metropolitan area to be R$ 1,491.95 (average actual per capita household income as of March 2014, as quoted by IBGE, the Brazilian Institute of Geography and Statistics) and an average working month of 220 hours, the average hourly amount works out at R$ 6.78.

The total of hours wasted on the metro as a result of not proceeding with the project put out to tender in 1998 amounts to 18,355 hours per day in each direction, which represents a sum of R$ 124,446.90 a day or R$ 2,737,831.80 a month.

Bearing in mind the two-way commute from home to work and back, the sums involved are close to double these amounts.

3 - CONCLUSION

A circular line, as proposed, allows the redistribution of passenger flow leading to a better balance of traffic at peak times and a reduction in travel time between various stations of up to 36 minutes per journey, in the case of a trip from Jardim Oceânico to Uruguai station.

The total of users who will benefit from the new route every day in terms of shorter journey time is in the order of 97,000, based on 2011 figures.

The amount corresponding to the total of unproductive hours resulting from the non-optimization of the route is over R$ 5.4 million a month.

The significantly shorter time for the journey cited (Jardim Oceânico – Uruguai) will certainly lead to a move away from road transport (individual and collective) via Alto da Boa Vista and onto the metro system, increasing the number of those who benefit.

Thus the conclusion drawn is that putting in place the Uruguai-Gávea link is essential to increase the capacity of the Rio de Janeiro metro system and to ensure quality for metro users by reducing travelling times and density (number
of people per square metre) at peak times, both in trains and on platforms.

A secondary objective, though nevertheless a very important one, is to reiterate to public administrators and supervisory bodies the need to consider the social cost when decisions are taken by politicians, by not neglecting the available logistical tools which should be used in the strategic planning of all public policy, not just that concerned with urban mobility.

**Keywords**

Urban Mobility; Rio de Janeiro Metro; Line Planning.