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Transport macro accessibility at the Metropolitan Region of São Paulo (MRSP)

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ABSTRACT

This study aims to analyze the macro accessibility of the Metropolitan Region of São Paulo (MRSP) in 2017. Based on data from the Metro Origin and Destination Survey (2017), a descriptive analysis was carried out and a Generalized Linear Model (GLM) was developed. The sample received treatment for the selection of trips departing from the residence and with territorial disaggregation levels that allow verifying the effect of centrality in the regional analysis of RMSP. The results show that the road transport infrastructure has vast territorial coverage, while rail transport infrastructure is concentrated in the center of RMSP. It was found that the closer to the center, the greater the use of individual transport and, the further away, the greater the use of public transport. Statistical modeling showed that Euclidean distance (4.3 min/km), the number of modes used in travel (8.1 min/mode), and the first mode chosen are statistically significant and relevant predictors (with bus having the longest average duration, followed by rail transport). Individual modes obtained the greatest advantage in macro accessibility since less time is used for vehicle access and less time for displacement after transport use (micro accessibility). Also, they do not depend on vehicle transfers and are faster during travel. It is concluded that investment in rail transport will allow better environmental conditions for captive users of public transport, with a decrease in micro accessibility time and a decrease in travel duration, with potential competition with individual modes.

KEYWORDS: GLM. Micro accessibility. Sustainable transport. São Paulo.

1. INTRODUCTION

Between 1950 and 2010, the Metropolitan Region of São Paulo (MRSP) had an absolute increase of 17.3 million inhabitants. Among the main Brazilian metropolitan regions, MRSP had the largest population and territorial increase (ANTP, 2017). In 2017, the municipality of São Paulo concentrated 64.1% of regional jobs (METRÔ, 2019). On the other hand, approximately 45% of the population did not reside in the capital, which generated a population contingent traveling long daily displacements to access services and jobs (LOPES, 2016), with a destination strongly concentrated in the central region of São Paulo (VASCONCELLOS, 2013). In the context of large urban centers, transport infrastructure offers less travel time to motorized individual modes, which consumes a high amount of road space and generates pressure on investment in disproportionate expansion of high-cost implementation infrastructure (ANTP, 2017). In most Brazilian cities, vehicles represent the main source of atmospheric pollutants (SALVIDA, 2018). In the State of São Paulo, the São Paulo Metropolitan Region stands out as a critical area in terms of air pollution, being impacted by industrial poles and mainly by vehicular emissions (CETESB, 2020).

The need to circulate is linked to the realization of cultural, social, political, and economic activities. Circulation depends on people's availability of time, alignment with activity schedules at destinations and on the supply of means of transport (VASCONCELLOS, 2001). The individual decision about which mode of transport is used to move around the city is made considering objective and subjective factors such as: time, cost, comfort, and reliability (ANTP, 2017). The individual decides which investment to make in travel and then establishes a convenient and possible travel strategy to meet their needs (VASCONCELLOS, 2001), especially in the context of large urban centers and metropolitan regions. Vasconcellos (2001) explains that in addition to fluidity and safety, circulation must consider accessibility, level of service, transport cost and environmental quality (noise and pollution). Cardoso (2008) points out that accessibility can be divided into two complementary concepts: accessibility to the transport system (the ease with which the user accesses the public transport system in their region of residence, work etc.) and accessibility to destinations (after accessing the transport system, how easy it is to get to the desired location).

Vasconcellos (2001) defines the macro accessibility terminology used in this study. This is related to the spatial coverage of transport systems. It can be expressed by the sum of four travel times: i) vehicle access time at the beginning of travel; ii) waiting time (public transport); iii) walking time (walking trips) or inside the vehicle - reflecting travel fluidity; iv) time to access the destination after leaving the vehicle. Also, on public transport trips with vehicle transfers, there is transfer time, which can be walking and waiting for a second vehicle for example. Micro accessibility refers to relative ease in having direct access to desired vehicles or destinations (parking condition, access to bus stops or stations for example). The first and last times represent complete micro accessibility which is a component of macro accessibility (VASCONCELLOS, 2001).

The general objective of this research is to analyze macro accessibility in the São Paulo Metropolitan Region in 2017. The specific objectives are to analyze the production and demand for transport in the MRSP's territory; transport micro accessibility; the time used in the travel route; and the effect of transfers on travel duration. Section 1 introduces the theme, objectives and structuring of the article. Section 2 presents the details of the data and methodology. Section **Erro! Fonte de referência não encontrada.** presents the results synthesized in graphs, tables, and respective analyses. Section 4 indicates the main conclusions and suggestions for future research. It ends with section 5, in which the references used in the research are listed.

2. METHODOLOGY

2.1 The study area

The territorial scope of this research is delimited by the Metropolitan Region of São Paulo (MRSP), which occupies an area of 7,946.96 km² and is made up of 39 municipalities (Figure 1).

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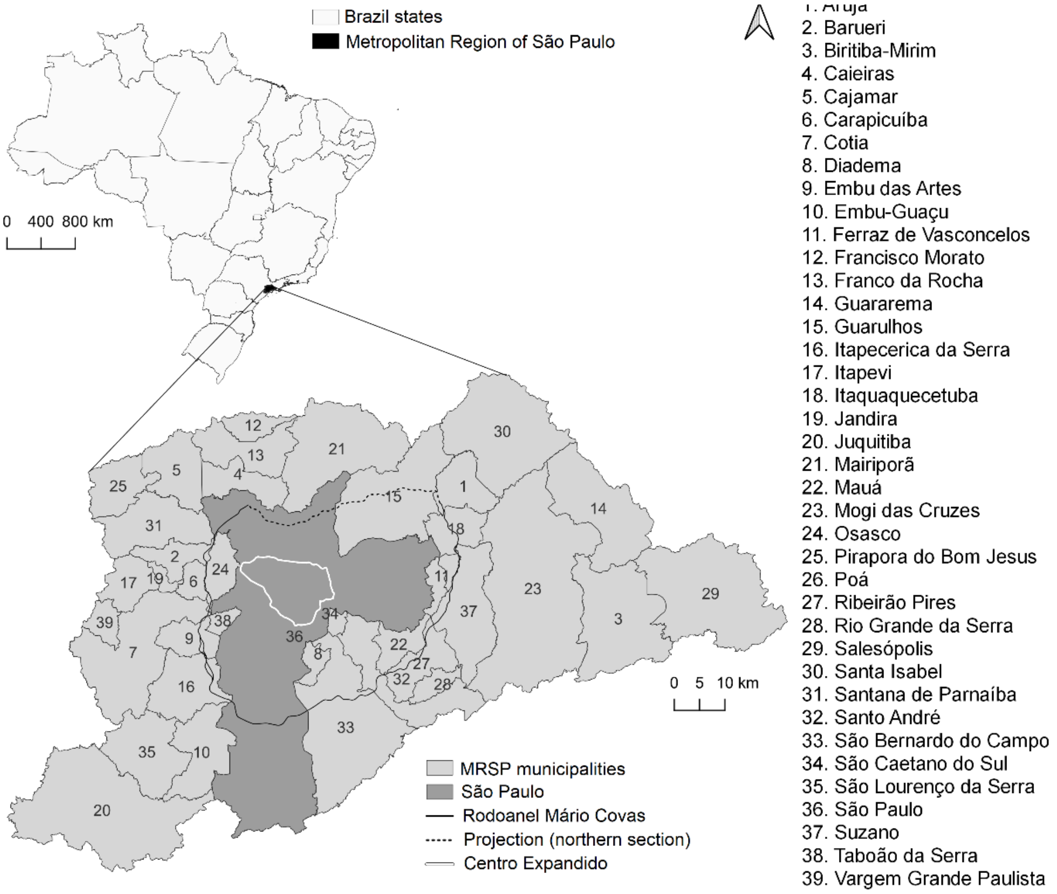
Figure 1 - Municipalities of the São Paulo Metropolitan Region, 2017



Source: authors based on METRÔ (2017).

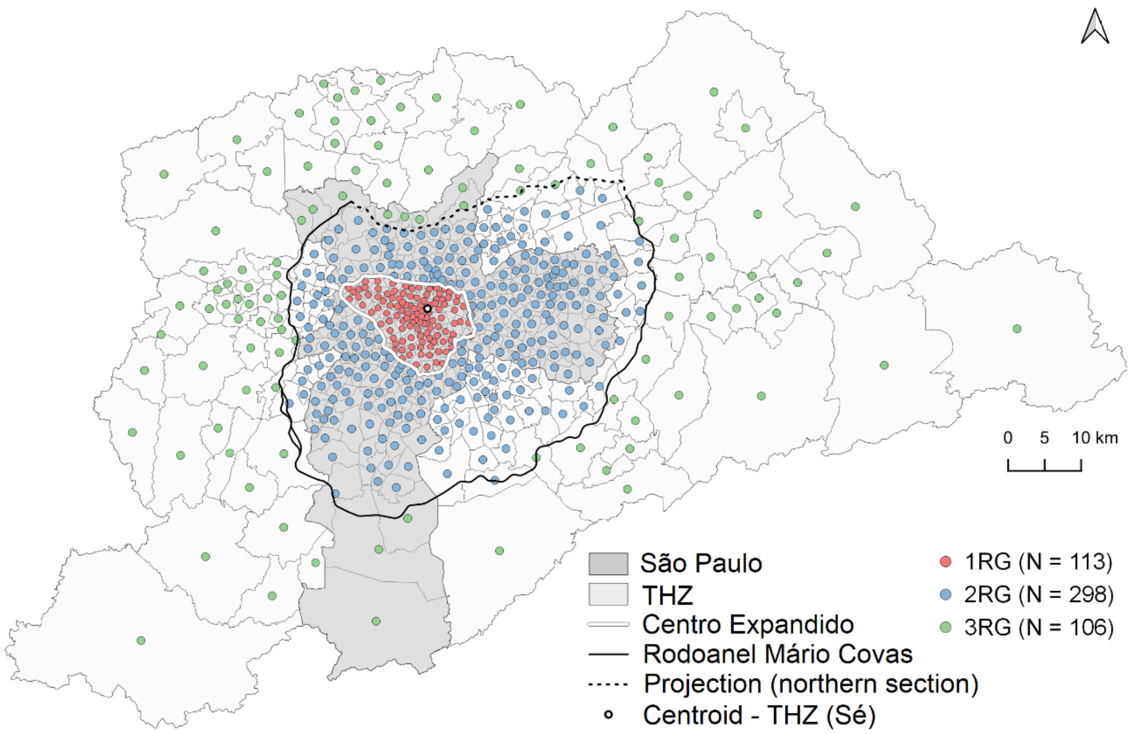
The Metropolitan Region of São Paulo has a population of 21 million inhabitants, which is equivalent to 47.5% of the population of the State of São Paulo. The population density reaches 2,714 inhabitants per square kilometer. MRSP is considered a center of political and economic decisions in the State of São Paulo and represents the largest industrial complex and the main financial center in Brazil (SÃO PAULO, 2019).

2.2 The Origin Destination Survey and Data Processing

This study used the database of the Origin and Destination Survey of the São Paulo Metropolitan Company (METRÔ) realized in 2017. The survey is composed of two parts; the household survey investigates trips made internally in the territory of the Metropolitan Region São Paulo; the contour line survey investigates trips that have origin or destination outside the territory of MRSP, or that simply cross it. The location of household interviews is defined using statistical methods to represent the territory of MRSP. For the year 2017, for example, a sample was totaled with 183.1 thousand records from approximately 32.0 thousand households interviewed. The records contain transport and socioeconomic information of people who have and have not made trips. It should be noted that this information refers to the day before the survey. In this study, trips that start from the residence and are destined for any location, for any reason and by any mode of transport were considered. Thus, out of a total of 183,092 records, 157,992 are travel records. Only trips that start at the residence were selected and other reasons at the origin were eliminated (including the return trip which totaled 71,395 records, 45.2% of total travel records). Return trips were not considered because, in general terms, they are very similar to going there and, therefore, the disregard facilitates the manipulation of data and the interpretation of results.

The travel route can be done with various modes of transport such as bus, train, subway, car, motorcycle, and bicycle or walking. To assist data analysis, these modes were conveniently grouped depending on the analysis. The lowest level of territorial disaggregation used in the Origin and Destination Survey, considered in this research, are the Transport Homogeneous Zones (THZs). These zones are defined based on their urbanistic and socioeconomic homogeneity. In the Origin and Destination Survey in 2017, 517 Homogeneous Transport Zones were established. The highest level of territorial disaggregation used in this research is Regions. The Regions were created with the aim of assisting interpretation and inserting the effect of centrality of the metropolis in regional analysis. The Regions were discriminated into 1st Region (1RG), 2nd Region (2RG) and 3rd Region (3RG). The 1st Region (1RG) is composed by THZs with centroids inscribed within São Paulo's Expanded Center perimeter. The 2nd Region (2RG) is composed by THZs with centroids inscribed between Rodoanel Mário Covas and São Paulo's Expanded Center (considering north section implantation projection). Finally, the 3rd Region (3RG) is composed by THZs with centroids located after Rodoanel Mário Covas. Figure 2 shows the selection of THZs according to each Region for in 2017. 1RG, 2RG and 3RG totaled 113, 298 and 106 THZs, respectively. Also, the centroid of the THZ (Sé) - where Praça da Sé is located - is considered the central point used in the analysis of the distance between centroids of THZs in this study.

Figure 2 - Composition of THZs according to each Region in 2017



Source: authors based on METRÔ (2017).

2.3 Descriptive analysis and statistical modeling

Descriptive analysis is based on the calculation of total values and shares; calculation of centrality measure; preparation of data distribution graphs; calculation of Pearson (linear) and Spearman (non-linear) correlations; and preparation of thematic maps.

Statistical modeling was based on a Generalized Linear Model (GLM). Compared to a Linear Model - which assumes that the data distribution is normal - this type of model allows the choice of the distribution considered for the dependent variable such as Gaussian, Binomial, Poisson, Inverse Gaussian and Gamma, to guarantee the best possible fit of the data. It also allows the choice of the link function, which will establish the form of interpretation of the results: Identity, Logit, Log, Inverse, Inverse square, and square root, for example. The chosen link function is Identity, which allows the interpretation of estimated parameters like a Linear Regression, that is, coefficients on the same scale as the dependent variable. To choose the best type of distribution for GLM, Akaike's information criterion (AIC) was used (the lower the AIC value, the better fit of the data in the chosen distribution).

Considering the objective of analyzing macro accessibility in MRSP, travel duration was used as a dependent variable. For independent variables, Euclidean distance between origin and destination, distance from travel origin to THZ (Sé) centroid, average family income of traveler and the number of trip modes were considered. The first mode of transport used to perform the trip was chosen as independent factor. Thus, GLM estimates the travel duration (in minutes) and the predictor effects, structured as follows:

$$\text{Duration} = \beta_0 + \beta_1.(\text{Dist}) + \beta_2.(\text{Dist\_Sé}) + \beta_3.(\text{AvgInc}) + \beta_4.(\text{NumModes}) + \beta_5.D_1 + \beta_6.D_2 + \beta_7.D_3 + \varepsilon$$

Where:

β_0: intercept;

$\beta_1, \beta_2, \beta_3, \beta_4$: coefficients that determine variation in the dependent variable for each modified unit of the independent variable;

$\beta_5, \beta_6, \beta_7$: coefficients that determine the average value of the dependent variable according to the considered Dummy variable;

Dist: Euclidean distance between origin and destination (in kilometers);

Dist_Sé: Euclidean distance between the centroids of the THZs and the centroid of the THZ at Sé Square (in kilometers);

AvgInc: average family income of passenger (in R$/inhabitant/month);

NumModes: number of modes used on trip generation;

D_1: Dummy variable 1 (Subway/train - Individual);

D_2: Dummy variable 2 (Non-motorized - Individual);

D_3: Dummy variable 3 (Bus - Individual);

ε: model associated error.

Dummy variables are binary (0 or 1) and are used to represent a variable with two or more categories. The number of Dummy variables considered in the model equals the number of categories n minus 1. Dummy variables allow capturing the average differences in the expected values between categories (respective β coefficients). Thus, it is not necessary to create a Dummy variable for the individual mode since the average value of this category is associated to the model intercept (β_0). Therefore, the weights of the 1, 2 and 3 Dummy variables are considered in relation to the referenced mode "Individual". As an example, for a trip made by the Bus mode as main mode, null values are considered for *Dummy1* (D_1) and *Dummy2* (D_2), respectively. Therefore β_0, β_1, β_2, β_3, β_4 e β_7 coefficients remain in the equation. The presentation of the *p-value* was used to flag that the calculations of the modeling parameters are statistically significant. The lower the *p-value*, there is evidence against the null hypothesis (no effect).

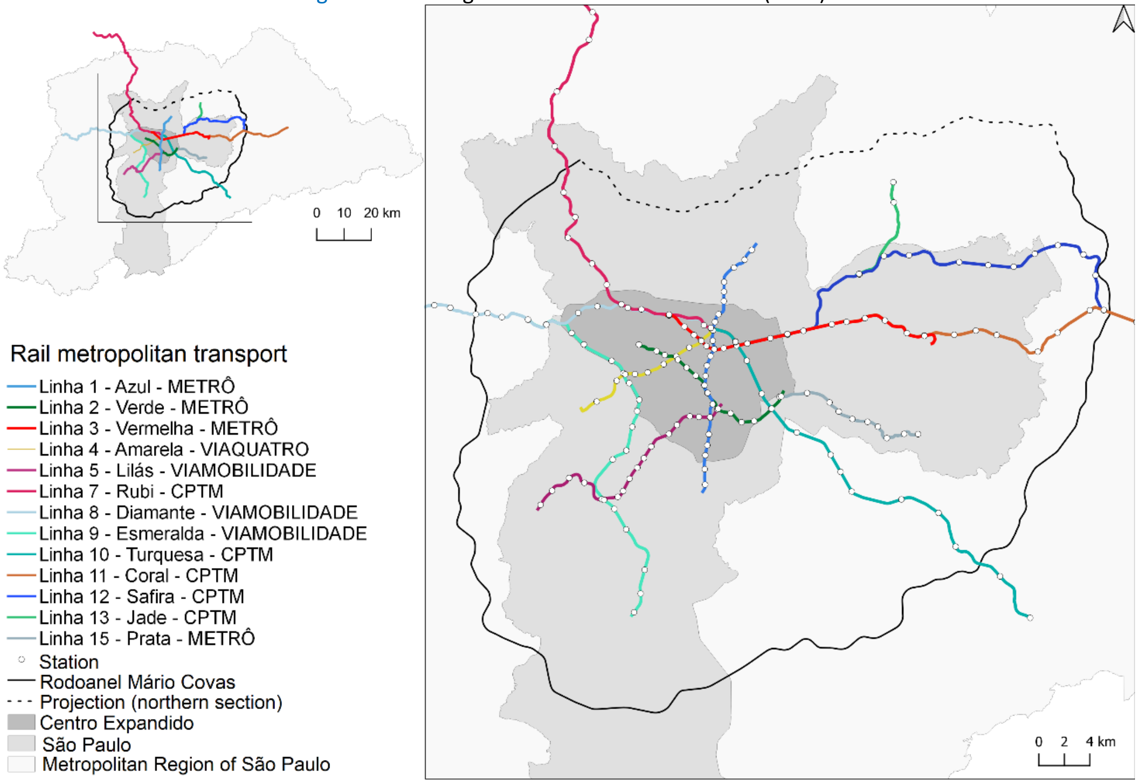
3. RESULTS AND DISCUSSIONS

3.1 Distribution of transport infrastructure in the territory

From the data provided by CEM (2022), it was calculated that the expanded central region has a high density of main urban roads (1RG; 17.5 km/km²), followed by the region circumscribed by the Mário Covas Ring Road (2RG; 16 km/km²). On the other hand, the territory after the Rodoanel Mário Covas has a lower density of main roads (3RG; 5.6 km/km²). A moderate and significant negative linear correlation (-0.65) was found in relation to the distance between centroids of the THZs and the THZ (Sé) and the density of urban roads in the THZs. The further away, the lower the density of main roads. The passenger metropolitan rail transport system is managed by four companies, namely, CPTM, Metrô, ViaQuatro and ViaMobilidade. The Metropolitan Company of São Paulo (Metrô) and Paulista Metropolitan Train Company (CPTM) are state public companies. ViaQuatro operates under a concession contract and ViaMobilidade operates under a Public-Private Partnership (PPP) contract.

Figure 3 shows the passenger rail transport infrastructure in MRSP. According to CEM (2022), there are 198 stations (subway/train) and 378 kilometers of lines.

Figure 3 - Passenger rail infrastructure in MRSP (2020)



Source: authors based on METRÔ (2017) and CEM (2022)

The CPTM train lines reach the central region from the most distant regions of MRSP. In relation to the subway, the lines are concentrated in the central region. It is visible that the organization of the lines prioritizes displacement to central regions, while radial displacement requires other less efficient modes of transport. The 1RG THZs are, on average, 800 meters far away from the metro or train station. The 2RG and 3RG THZs are, on average, 2.5 kilometers and 8.54 kilometers away, respectively. There is a strong and positive linear correlation (r = 0.7) of the average Euclidean distance between the centroids of the THZs and the subway/train stations in relation to the distance from the central spot of MRSP (THZ at Sé square). The further away from the center of MRSP, the greater are the average distances between centroids of THZs and subway/train stations. Therefore, it is observed that the center of MRSP has a more developed transport infrastructure compared to the rest of the territory.

3.2 Analysis of daily trips

The analysis of trip production allows us to verify the patterns of transport demand in the territory. According to Metrô (2017), 42 million daily trips were generated for various reasons and modes in MRSP in 2017. Table 1 shows the production and share of daily trips originating from the residence by main transport mode, which assigns to the trip record only the mode of higher hierarchy among the modes used in the trip.

Table 1 - Production and share (%) of daily trips by main transport modes and regions (2017)

Region	Subway	Train	Bus	Automobile	Motorcycle	Non-Motorized	Total
1RG	264.746	8.987	298.403	663.108	31.154	527.779	1.794.178

2RG	1.153.030	383.040	3.809.729	3.733.957	338.959	4.357.427	13.776.143
3RG	158.052	205.660	1.027.534	979.102	130.005	1.277.851	3.778.202
Total	1.575.828	597.687	5.135.666	5.376.167	500.118	6.163.057	19.348.522
Region	Subway	Train	Bus	Automobile	Motorcycle	Non-Motorized	Total
1RG	14,8%	0,5%	16,6%	37,0%	1,7%	29,4%	100%
2RG	8,4%	2,8%	27,7%	27,1%	2,5%	31,6%	100%
3RG	4,2%	5,4%	27,2%	25,9%	3,4%	33,8%	100%
Total	8,1%	3,1%	26,5%	27,8%	2,6%	31,9%	100%

Source: authors based on METRÔ (2017).

About 19.3 million daily trips were produced in MRSP originating from the residence. It is observed that the types of public, individual, and non-motorized transport modes have close shares: 37.7%, 30.40% and 31.9%. It is noteworthy that 26.5% of the total public trips is carried out by bus, which demonstrates the importance of this mode. The 1RG has the highest share of the subway and automobile modes, due to the availability of metro stations in the region, as well as the higher average family incomes. On the other hand, as a natural consequence of competition between modes, it has a lower participation of bus, train, motorcycle, and non-motorized modes. It was found that there is a strong positive linear correlation (0.85) between the average family income and the motorization index (in terms of number of cars/inhabitant). The higher the average family income of the THZ, the greater the number of cars per resident (and consequently greater share of cars).

The way transport modes are used in urban areas depends on the socioeconomic profile of the population. As family income increases, personal mobility also increases naturally, as well as the cost of travel opportunity in decision making (in parallel with other reasons such as time, safety and comfort prevailing). This mobility is achieved with the use of cars and therefore, the higher the income, the greater the use of a car in relation to other modes of transport (VASCONCELLOS, 2013). The 2RG loses participation of subway and automobile modes and gains participation from other modes in relation to 1RG, due to reduction in average family income and decrease in metro infrastructure. It is worth highlighting the existence of train lines and stations in this territory, which shows an increase in participation of this mode. The 3RG experiences the same process in relation to 2RG (becoming more discrepant in relation to 1RG). An interesting phenomenon to be observed in 3RG is the decrease in the automobile mode use concomitant with an increase in the motorcycle mode use. Motorcycles are financially more accessible and therefore tend to gain shares in regions further from the city center, where there is a trend for the average family income to decrease. Rodrigues (2016) describes that in Brazil part of the solution to mobility problems were motorcycles, especially for low-income population. Vasconcellos (2013) reports that São Paulo was the Brazilian city that had the greatest increase in motorcycle use, high enough to alter traffic conditions on main road systems and therefore traffic accident patterns.

It is worth highlighting the underestimated value of the bus mode use. Due to low coverage of subway system, it is reasonable to say that a significant part of trips considered as metro/train mode (main mode) also use bus mode to access metro stations. These results show that installed infrastructure influences behavior and decision making by transport users. When there is rail transport infrastructure, there is a tendency for an increase participation of this mode. In the absence of rail infrastructure, captive public transport users need bus. On the other hand, users tend to migrate to individual transport when possible.

3.3 Micro accessibility of transport

Table 2 shows the average time spent walking to start the trip and the average time spent after using transport according to each mode and region. It is possible to observe that, on average, the time used to move to a bus stop compared to a subway/train station is approximately the half. These values become more discrepant when compared to individual modes. In fact, individual modes are located mostly at the residence itself or very close, which generates very low values for accessing these modes. Figure 4 shows the distributions of the average time walking at the origin in 2017.

Table 2 - Average duration (in minutes) by walking at origins and destinations by transport region (2017)

	Region	Subway	Train	Bus	Automobile	Motorcycle
Walking (origin)	1RG	7,8	10	4,7	1,2	1,1
	2RG	9,5	11,3	5	1,2	1,2
	3RG	-	13,9	5,2	1,1	1,1
	Total	8,5	12	5,1	1,2	1,1
	Region	Subway	Train	Bus	Automobile	Motorcycle
Walking (destiny)	1RG	6,3	7,8	4,7	1,4	1,3
	2RG	6,9	8	5,4	1,5	1,3
	3RG	-	8,2	5,1	1,3	1,1
	Total	6,5	8,1	5,3	1,4	1,3

Source: authors based on METRÔ (2017).

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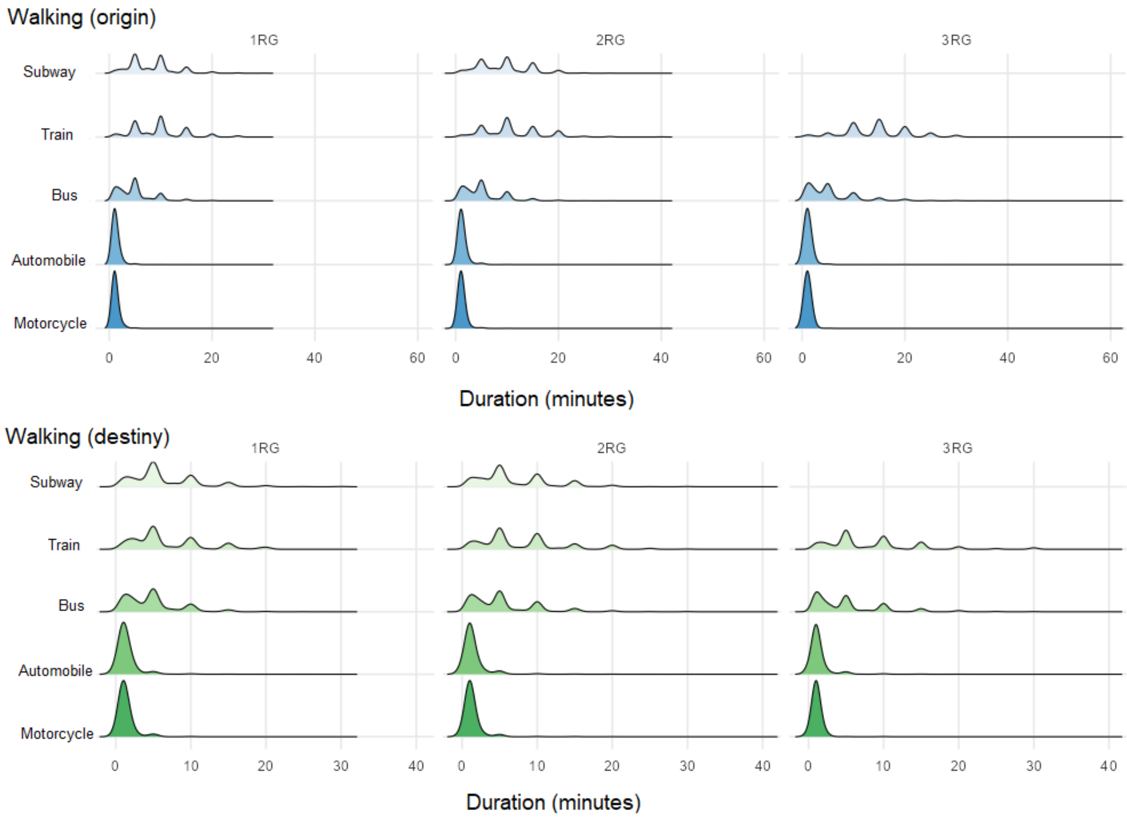
Figure 4 - Distribution of duration (in minutes) by walking at origins and destination by transport region (2017)



Source: authors based on METRÔ (2017).

There is an evident difference between modes both for walking time at origins and destinations. The individual modes have concentration in low values (high positive skewness and high positive kurtosis). The bus mode has concentration in intermediate values and is relatively more dispersed. The subway and train modes have low concentrations and very dispersed values, which generated higher average duration values (low skewness and low kurtosis). As for the regions, there is a difference in the walking times at origin group for the subway and train modes: 10.1, 11.0 and 14 minutes, for the 1RG, 2RG and 3RG, respectively. It takes more time to access locations when using the subway, train and bus transport modes.

A higher number of bus stops allows greater proximity to origins and destinations and consequently shorter walking distances. Individual modes have the lowest values because they generally use parking lots at the locations of origins and destinations (or close to them). The results point to the negative effect of increasing average travel time. Fewer subway and train stations in the territory makes it necessary to disembark at locations further away from the destination. The time used before and after transport gradually decreases from buses to cars and motorcycles. The ideal situation for transport users would be that boarding and disembarking points were next to the origin and destination of the trips (BATISTA JR, SENNE, 2000). Florindo et al. (2019) highlights that there is a higher probability of trips being made by walking to train and metro stations if the distance is less than one kilometer.

3.4 Duration of daily trips and effect of transfers

3.4.1 Average duration and distance

Table 3 shows the average duration of trips and average Euclidean distance between origin and destination according to the first mode and Region.

Table 3 - Average duration (in minutes) and average distance (in kilometers) performed by the first mode by transportation region (2017)

	Region	Subway	Train	Bus	Automobile	Motorcycle	Non-Motorized
Duration (minutes)	1RG	44,6	64,2	40,3	24,0	17,8	13,3
	2RG	57,8	78,3	58,8	26,6	24,8	12,9
	3RG	-	93,4	59,4	27,1	25,0	13,8
	Total	49,7	82,2	57,9	26,3	24,4	13,1
	Region	Subway	Train	Bus	Automobile	Motorcycle	Non-Motorized
Distance (km)	1RG	6,8	11,9	4,4	4,5	4,3	0,8
	2RG	10,7	18,8	8,4	5,7	7,6	0,7
	3RG	-	22,7	10,2	7,7	9,6	0,8
	Total	8,3	19,7	8,5	5,9	7,9	0,7

Source: authors based on METRÔ (2017).

It is noted that trips made by public transport modes have longer average durations compared to individual modes. However, it is emphasized that average distances also follow the same logic, which points to a great influence of this variable on trip duration. The calculation of linear and non-linear correlations between duration and Euclidean distance results in positive and strong values (0.8 and 0.85). The greater the distance between origin and destination, the longer the duration of trips. This phenomenon is also observed in the regions. There is an increase in the distances traveled and, consequently, an increase in average time. It is reasonable to say that this scenario occurs due to the decrease in job and service opportunities in more distant regions in MRSP's territory and therefore, the population of these locations tends to travel greater distances. From the Metrô data, it is possible to verify that the non-linear correlation between job density (jobs/km²) and distance from THZ (Sé) is strong and negative (-0.82). The further away, the lower the territorial concentration of jobs. In fact, the number of jobs per population in the regions has notable differences: 1RG (1.44 employments/inhabitant), 2RG (0.37 emp/inhabitant) and 3RG (0.33 employments/inhabitant).

3.4.2 Number of modes

Table 4 shows the average number of modes used in trips according to transportation mode and region.

Table 4 - Average number of modes, region, first mode, 2017

Region	Subway	Train	Bus	Automobiles	Motorcycle	Non-Motorized
1RG	1,3	1,7	1,3	1,0	1,0	1,0
2RG	1,3	1,8	1,5	1,0	1,0	1,0
3RG	-	1,6	1,4	1,0	1,0	1,0
Total	1,3	1,7	1,5	1,0	1,0	1,0

Source: authors based on METRÔ (2017).

The individual mode does not require transfers during the trip and therefore remains at the value of 1, regardless of the region. Public transport has higher values because users usually need to change vehicles to reach their destination. Although no notable differences are observed between the averages of the regions, the linear correlation between the number of modes and the Euclidean distance are 0.65, 0.53 and 0.22, for bus, subway/train and individual modes, respectively. These results show that there is a moderate positive correlation for public (with greater distances and greater number of modes) and low for individual transport modes (which do not depend on transfers).

3.4.3 Statistical modeling

To estimate the effect of transfers between vehicles, it is possible to use the GLM. The Gamma distribution was chosen because generates the lowest value of the Akaike information criterion (AIC) in relation to other possibilities of distributions. There is a convergence in modeling and therefore is the best option with the objective of generating better adherence of the model. The model provided a coefficient of determination R^2 equal to 0.722 (explains 72.2% of the variance of the dependent variable from the predictors). The model estimates show that:

i. For each additional kilometer traveled on the route, the total duration of the trip increases by 4.34 minutes;
ii. In relation to the origin of the trip, for each kilometer distant in relation to the centroid of the THZ at Sé Square, there is a decrease of 0.02 minutes in the duration of the trips. This value, although statistically significant, is very low;
iii. Average family income is not statistically significant;
iv. For each additional mode used on the route, the total duration of trips increases by 8.12 minutes;
v. Trips that use subway/train as their first mode have an average of 10.72 minutes more than individual transport;
vi. Trips that use non-motorized as their first mode have an average of 3.6 minutes more than individual transport;
vii. Trips that use bus as their first mode have an average of 14.22 minutes more than individual transport;
viii. Post-hoc values show that trips that use subway/train as their first mode have an average of 3.5 minutes less than bus transport.

Table 5 presents the estimated results of the GLM.

Table 5 - Generalized Linear Model estimates (2017)

Nome	Effect	Estimate	SE	p
β_0	Intercept	35,758	0,109	< 0,001
Dist	Distance (km)	4,345	0,020	< 0,001
Dist_Sé	Distance from THZ Sé (km)	-0,020	0,002	< 0,001
AvgInc	Average family income (10^3 R$)	-0,037	0,005	0,032
NumModes	Number of modes	8,126	0,339	< 0,001
D1	Subway/train - Individual	10,723	0,360	< 0,001
D2	Non-Motorized - Individual	3,600	0,061	< 0,001

D3	Bus - Individual	14,222	0,140	< 0,001
R-squared 0,722				
	Individual - Subway/train	-10,723	0,360	< 0,001
	Individual - Non-Motorized	-3,600	0,061	< 0,001
	Individual - Bus	-14,222	0,140	< 0,001
	Subway/train - Non-Motorized	7,123	0,363	< 0,001
	Subway/train - Bus	-3,499	0,375	< 0,001
	Non-Motorized - Bus	-10,622	0,142	< 0,001

Source: authors based on METRÔ (2017).

The model shows that, in addition to variables such as distance and number of modes, which have relevant effects, the use of public transport modes as the first mode generates an increase in the average duration of trips in relation to individual modes. It is verified that public transport modes generate higher coefficient estimates than individual modes, regardless of the chosen referenced transport mode. The bus mode obtained the highest average duration compared to other groups in the model, despite obtaining lower average trip duration values (3.4.1). Buses have lower average values because trip distances are shorter. In fact, subway/train transport is faster. Transfers proved to be a relevant effect on total time and especially affect public transport modes. As shown in Table 4, individual modes have an average of 1 transfer, while other modes reach average values between 1.3 and 1.8 transfers, depending on the public transport mode and region. It should be noted that distance from the center of MRSP itself is not a factor that generates an increase in average trip duration. On the contrary, distance generated a negative and small effect on trip duration. It should be emphasized that the available transport infrastructure significantly alters trip duration and not distance itself. The same applies to average family income.

4. CONCLUSIONS

This research shows that there is a notable difference in the infrastructure installed in the MRSP's territory. Both road infrastructure and rail transport infrastructure are more developed in the center of the metropolis, and this produces different scenarios of macro accessibility at the levels of the territorial disaggregation. In relation to micro accessibility, it was observed that individual modes are more advantageous because they have lower values of duration to access transport and after using it. Individual modes are accessed at the place of residence or very close to it and, in the same way, can be parked closer to destinations. Public transport modes require users to move to stations or bus stops and then move to their destinations. The bus showed lower average duration values for transport access and for travel after using transport, compared to subway/train modes. Bus stops use the road network, which is much more developed in the territory compared to metro stations. The same reasoning applies to the time after using transport.

Statistical modeling shows that the total distance of the trip, the number of modes used on the trip and the first mode chosen are statistically significant and relevant predictors. This scenario demonstrates that these advantages of private transport in relation to public transport modes generate potential for increasing use: greater probability of captive public transport user migrating to individual mode when possible. This effect has greater potential in more distant regions, where trips with greater distances occur. In these regions time savings using individual mode are much more relevant. On the other hand, in these regions there is greater share of public transport.

The results of this study indicate that investment in public transport infrastructure has potential to improve life and social reproduction in the metropolis: increasing rail network and bus lines has potential to reduce micro accessibility time. Expanding the public network allows reducing the number of transfers, which would reduce trip duration. Investment in public transport therefore has potential to reduce impedance generated by lag in macro accessibility, which would cause competition with less efficient modes and reduce average trip duration (factors that are very relevant for quality of life and social reproduction in metropolis). It is recommended that new levels of territorial disaggregation be created and that analyses be extended to entire historical series of the origin and destination survey of the Metropolitan Company Metrô of São Paulo.

5. REFERENCES

ANTP – Associação Nacional de Transportes Públicos. **Mobilidade Humana para um Brasil Urbano**. São Paulo, 2017. Disponível em: http://www.antp.org.br/. Acesso em: 04 set. 2023.

Batista Jr, Edgar Dias. Senne, Edson Luiz França. In: Panorama Nacional da Pesquisa em Transporte 2000. **TRANSIS**: Um Novo Método para Avaliar o Desempenho de Sistemas de Transporte Urbano de Passageiros. Setti, J. R. A. e Cybis, H. B. B. (orgs.). Rio de Janeiro: ANPET, 2000.

CARDOSO, Carlos Eduardo de Paiva. **Análise do Transporte Coletivo Urbano sob a Ótica dos Riscos e Carências Sociais**. 2008. Tese (Doutorado em Serviço Social) - Pontifícia Universidade Católica de São Paulo, São Paulo, 2008. Disponível em: https://tede2.pucsp.br/handle/handle/17901. Acesso em: 4 set. 2023.

CEM – Centro de Estudos da Metrópole. **Base de dados das vias e estações metroferroviárias**. 2022. São Paulo. Disponível em: https://centrodametropole.fflch.usp.br/pt-br. Acesso em: 4 set. 2023.

CETESB – COMPANHIA AMBIENTAL DO ESTADO DE SÃO PAULO. **Qualidade do ar no estado de São Paulo:** 2019. São Paulo: CETESB, 2020. 223 p. Disponível em: https://cetesb.sp.gov.br/. Acesso em: 4 set. 2023.

CINTRA, Marcos. **Os custos dos congestionamentos na cidade de São Paulo**. São Paulo: FGV-EESP, 2014. Disponível em: https://bibliotecadigital.fgv.br/dspace/handle/10438/11576. Acesso em: 4 set. 2023.

FLORINDO, Alex Antonio; BARBOSA, João Paulo dos Anjos Souza; BARROZO, Ligia Vizeu; ANDRADE, Douglas Roque; AGUIAR, Breno Souza de; FAILLA, Marcelo Antunes; GUNN, Lucy; MAVOA, Suzanne; TURRELL, Gavin; GOLDBAUM, Moises. Walking for transportation and built environment in Sao Paulo city, Brazil. **Journal of Transport & Health**, v. 15, 2019. Available in: https://doi.org/10.1016/j.jth.2019.100611. Acesso em: 4 set. 2023.

LIRA, Anneliese Heyden Cabral de; SILVEIRA, José Augusto Ribeiro da; NEGRÃO, Ana Gomes; CASTRO, Alexandre Augusto Bezerra da Cunha. Avaliação da acessibilidade física aos condomínios de alta renda da cidade de João Pessoa – PB. **Brazilian Journal of Development**, Curitiba, v. 6, 2020. Available in: https://ojs.brazilianjournals.com.br/ojs/index.php/BRJD/article/view/5924. Acesso em: 4 set. 2023.

LOPES, Bárbara. In: Mobilidade urbana no Brasil: desafios e alternativas. Marilene de Paula e Dawid Danilo Bartelt (orgs.) **A cidade que não para**: os deslocamentos da vida e do capital em São Paulo. Rio de Janeiro: Fundação Heinrich Böll, 2016. p. 24-39. Disponível em: https://br.boell.org/. Acesso em: 4 set. 2023

METRÔ – Companhia do Metropolitano de São Paulo. **Pesquisa de origem e destino 2017**: Relatório Síntese. São Paulo, 2019. Available in: http://www.metro.sp.gov.br/pesquisa-od/. Acesso em: 4 set. 2023

SALDIVA, Paulo. **Vida urbana e saúde**: os desafios dos habitantes das metrópoles. São Paulo: Contexto, 2018. 128 p. Ebook.

SÃO PAULO. **Região Metropolitana de São Paulo**, 2019. Disponível em: https://rmsp.pdui.sp.gov.br/?page_id=127. Acesso em: 4 set. 2023

VASCONCELLOS, Eduardo Alcântara de. **Mobilidade urbana**: o que você precisa saber. São Paulo: Companhia das Letras, 2013. 58 p.

VASCONCELLOS, Eduardo Alcântara de. **Transporte urbano, espaço e equidade**: análise das políticas públicas. São Paulo: Annablume, 2001. 218 p.