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DISRUPTIVE TECHNOLOGIES IN MOBILITY BUILDING NEW OPPORTUNITIES FOR URBAN PLANNING AND DESIGN

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ABSTRACT
The arrival of driverless vehicles, along with other trends such as ride-sharing and people's greater connection with modes of transportation, will impact vehicle ownership, demand for parking, and consequently urban space. The mainstream of research focuses on the performance of transport systems. Those that address changes in road infrastructure do so qualitatively or empirically, mainly through simulation, with estimates ranging between 15 and 25%. This study aims to investigate changes in urban design and quantify possible changes in road infrastructure, aiming at the qualification of public spaces and more sustainable urban mobility. The method is inductive, through secondary data surveys in the literature and databases, and deductive, through the elaboration of design scenarios and the quantification of changes in road infrastructure. The original contribution is the proposition of a quantitative method, applicable to other urban agglomerations. The quantitative measures are based on concrete proposals for urban redesign, including the integration of transport systems, traffic management and the conversion of spaces for other uses. The results, for a focus area and a broader one, in the expanded center of São Paulo, were 21.8 and 22.8%.

Keywords: Urban mobility. Driverless vehicle. Shared mobility. Road infrastructure. Urban redesign.

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INTRODUCTION

There is significant speculation about how technologies, especially autonomous vehicles and shared mobility, will be adopted and introduced in cities (Fagnant; Kockelman, 2015; Schlossberg et al., 2018; Bala et al., 2023). There has also been disagreement regarding the impacts of such changes on the urban environment, hence the difficulty in making recommendations for the future (Schlossberg et al., 2018; Guerra, 2016). Approaches to technologies have focused mainly on technical aspects, such as algorithms for their operation, predictability and efficiency. To date, there is a lack of studies on the impacts on the urban environment and urban design. However, Schlossberg et al. (2018) and Guerra (2016) mention that this is a unique opportunity to rethink the city.

A century of car-oriented transport policy has left a legacy in urban design focused on prioritizing road infrastructure, where pedestrians have often been neglected.

As a result, public spaces, including sidewalks, have been reduced, street widths widened to accommodate vehicles, and pedestrian movement has become difficult and dangerous (Gehl, 2013; Tsigdinos et al., 2023).

The arrival of autonomous vehicles, along with other initiatives or trends, such as ride-sharing and greater connectivity of people to modes of transport, will have an impact on vehicle ownership, parking demand and, consequently, urban space. This should culminate in less congestion, lower environmental impact, since the new autonomous vehicles are powered by electric and silent motors (OECD, 2015; Staples, 2016; Ratti, 2017).

Others mention that the effect of affordable ride-sharing services, especially autonomous vehicles, will improve mobility and thus increase, rather than decrease, road traffic. In addition, the extinction of types of employment, such as drivers, or the loss of jobs, for example, in the automobile and service industries, and urban sprawl (Kockelman et al., 2016; Arbib; Seba, 2017; Litman, 2018).

However, there are indications that innovative planning is capable of transforming problems into opportunities, in which the cost or lack of accessibility to transport are considered the biggest obstacles for people who do not drive, as well as for people with physical, age or motor limitations. Autonomous vehicles have the potential to provide access to employment, education, health and leisure in an urban environment with fewer road accidents and less pollution.

In the last century, the urban environment has focused on automobiles. Pedestrians were expelled from the roads to make way for the car. Street intersections gave priority to cars over people (Boarnet et al., 2011; DiMento, Cliff, 2013). The more road infrastructure was built to cope with traffic, the more traffic was attracted to them. There have been several attempts to reverse this situation (Downs, 2004; Ladd, 2012). It is thought that the introduction of autonomous vehicles may favor this change (Zakharenko, 2016; Appleyard; Rings, 2017; Bloomberg Philanthropies, 2017; Konig; Neumayr, 2017; Meyer et al., 2017; Ratti, 2017; Schlossberg et al., 2018).

Autonomous vehicles will become a reality and the way cities will change must also be defined in terms of architecture and urbanism (IHS, 2014; Bloomberg Philanthropies, 2017; RPA, 2017; Litman, 2018). Such a definition will be the basis for profound changes in urban design, in the establishment of priorities and practices for future generations, from traditional forms of vehicle ownership, to shared mobility, from product to service, integrated with non-motorized modes and public transport.

The objective of this work is to investigate potential changes in urban design and to estimate, quantitatively, changes in road infrastructure, aiming at the requalification of public spaces. This approach is the original contribution to the discussion of the impact of the autonomous vehicle and shared mobility on urban form and sustainability.

Urban mobility has been severely affected during the COVID-19 crisis, but globally short-distance travel and active transport have increased, with many cities making it permanent (NACTO, 2020; Newman, 2020). Despite the difficulties in converting these areas, due to pressure from drivers against the elimination of parking on public roads and the reduction of lanes, the use of these spaces by pedestrians and cyclists was so popular during the pandemic that many cities converted them to these new uses (NACTO, 2020; Newman, 2020). This action was considered a high priority for the pandemic recovery period in many cities, such as London, Paris, Milan and Oakland.

METHODOLOGY

The proposed research method includes several facets. The approach is both qualitative and quantitative. Qualitative in terms of data from similar studies in some cities, worldwide. Quantitative because the measurements taken in the selected region cover all its streets, and not a sample. It is of an applied nature, insofar as it aims to produce knowledge for practical purposes, directed to the performance of the redesigned city in

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comparison with the existing one. There are previous works on this subject, but they are not based on such measurements.

As for its objectives (and the procedure, described below), it is both exploratory and descriptive. Exploratory because it is based on a review of the literature, with the analysis of the cases described therein. Descriptive in that it conducts a case study of a large portion of a metropolis, including data from a transport origin-destination survey.

The proposed procedure to test plausible urban scenarios, comparing the current state and the expected changes, consists of: 1) the selection of the urban context and the case study area; 2) the analysis of indicators from different urban contexts; 3) the estimate of changes in the road infrastructure for the city of São Paulo; 4) the evaluation of the case study area; 5) the verification of the results against initial estimates based on previous studies; and 6) the proposition of project scenarios resulting from the convergence of the aforementioned disruptive technologies.

CRITERIA FOR THE SELECTION OF THE URBAN CONTEXT AND THE CASE STUDY AREA

The city of São Paulo was chosen to test scenarios and intervention proposals due to its chronic transport problem, despite investments in road infrastructure and mass transport, since the 70s, and other characteristics that justify it as an adequate case study, its complexity, unequal distribution of infrastructures and services, but positive attitude towards change, and visibility.

It is unlikely that such a large and diverse city, with a population of more than 11 million inhabitants and an area of more than 1,500 km2, the center of a metropolitan area, consisting of 39 municipalities, with a total population of more than 21.5 million inhabitants and a total area of almost 8,000 km2, Change your transportation system overnight by deleting conventional vehicles and replacing them with autonomous vehicles.

The transport system of the city of São Paulo is predominantly axial. The central area is crossed by the city's main roads and is home to the main hubs of the subway and urban train systems. This favors initiatives to expand and requalify the different public transport systems, in order to articulate with non-motorized modes and new mobility technologies.

The experimental phase of the method comprises a detailed measurement of the space currently occupied by conventional uses and those that result from the opportunities

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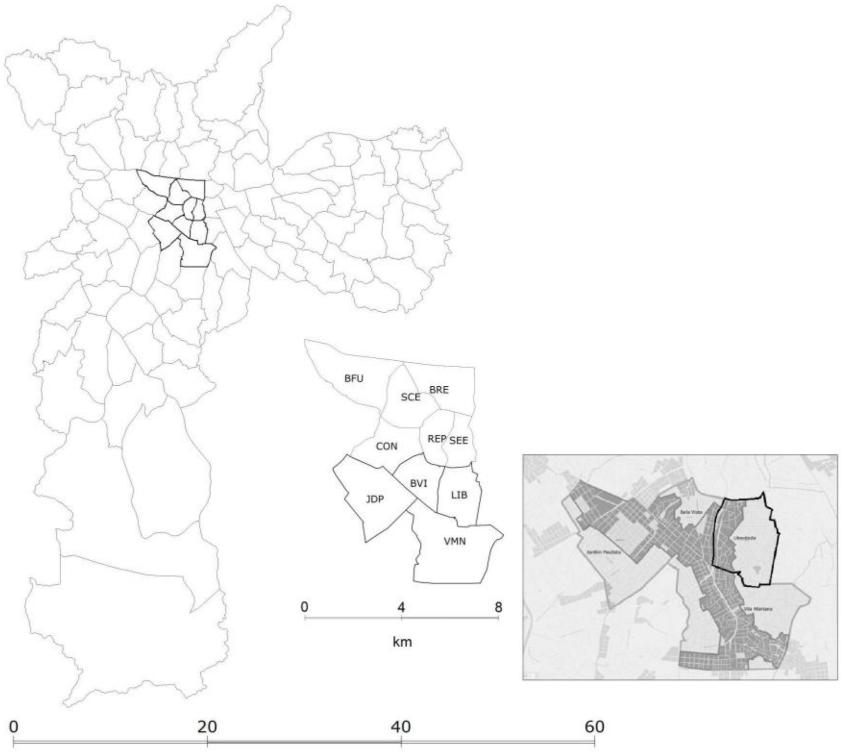
and needs brought by the introduction of disruptive technologies, in this work, mainly, autonomous vehicles and shared mobility. Even considering only the central area, the calculations are unnecessarily time-consuming, so a well-selected sample is sufficient.

A first multi-criteria selection was made, based on an overall score, considering: population density, workplaces/residents, supply of metro-rail transport, available cultural facilities, percentage of elderly people, vehicles/household, distribution of trips by private car, public transport and walking.

The district of Liberdade presented the best combination of the selected criteria and, therefore, was chosen to be the focus area of the detailed study. It presents opportunities for change, due to its greater number of vehicles/household, private car travel and public transport (facilitated by access to the metro-rail network), while having lower walking trips than would be expected, taking into account past initiatives to promote walking travel and social interaction and tourism. Three additional adjacent districts (Figure 1), among the first classified, were selected for the global evaluation: Bela Vista (BVI), Jardim Paulista (JDP), Liberdade (LIB) and Vila Mariana (VMN). Together, they make up a reference area for the study and represent 3.1% of the population, 12% of jobs and 1.4% of the city's territory.

Figure 1 - Districts of the city of São Paulo (left), reference area of the best-ranked districts (scepter), and the district of Liberdade (right), with the structuring axis of urban transformation highlighted (left)



Source: the author

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The design scenarios were tested for the so-called "structuring axes of urban transformation", delimited areas, along the public transport lines, suitable for building and population densification and for the mixed use of the land in Liberdade and also in the other districts of the reference area, although with less detail. In these delimited areas, parameters were defined in the municipality's Strategic Master Plan (São Paulo, 2014), including:

a) Active facades - occupation of the horizontal extension of the façade for non-residential use, with direct access to the street, to promote the dynamization of public sidewalks;
b) Wide sidewalks - minimum of five meters in lots facing the public transport line; minimum of three meters in the others;
c) Disincentive to parking spaces.

ANALYSIS OF MOBILITY INDICATORS IN DIFFERENT URBAN CONTEXTS

In order to qualify and quantify changes in road infrastructure and investigate possible design scenarios, the following indicators were used: distance traveled: most previous studies (Bierstedt et al., 2014; Spieser et al., 2014; Chen, 2015; Fagnant; Kockelman, 2015; Fagnant; Kockelman; Bansal, 2015; OECD, 2015) estimates its increase, which is expected, since it can be driven by the convenience and cost-effectiveness associated with the use of driverless vehicles in shared and individual trips. However, there is a considerable difference between the estimates, possibly related to the particularity of each urban context

Number of private vehicles in use: previous studies (Spieser et al., 2014; OECD, 2015; Bischoff; Maciejewski, 2016; Boesch; Ciari; Axhausen, 2016; Liu et al., 2017; Fagnant; Kockelman, 2018) estimate a reduction ranging from 80% to 90%. This consensus among studies may be related to the expected performance of driverless vehicles, as well as public acceptance.

Changes in road infrastructure: previous studies (OECD, 2015; Zhang et al., 2015; Ambühl; Ciari; Menendez, 2016; WSP; Farrells, 2016) concluded that between 12% and 20% of the space currently occupied by lanes and parking on the public road can be made available for other uses, mainly due to the reduced demand for parking spaces on the public road, suggesting that these be eliminated or partially converted into collection and delivery areas.

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In addition to the qualification and quantification of changes to road infrastructure, in the study of possible design scenarios, some authors (NACTO, 2017; Schlossberg et al., 2018) provide guidance, albeit incipient, on the changes in the urban environment resulting from mobility technologies, the reduction of road space.

One of the expected effects is the conversion of the freed areas into other uses, such as for urban greenery, spaces for pedestrians and cyclists and the expansion or creation of other living spaces. Such actions present opportunities to redesign public spaces and foster urban vitality (WSP; Farrells, 2016; Perkin; Will, 2018).

Chart 1 shows a summary of the main topics of discussion that supported the urban redesign proposals.

Chart 1 - Summary of the main topics of discussion that supported the urban redesign proposals

Selected texts	Key Topics of Discussion										
	Scroll Tracks	traffic lights and signaling	Pedestrian paths	Bike lanes and bike lanes	Urban Green	spaces for social interaction	flexibility of use	Intermodal Stations	Public transport	Street parking	Boarding / disembarking
Future NYC: a city for humans (FUTURENYC, 2015)			√	√	√	√					
Mcity (MIT, 2015)		√	√	√						√	
Envisioning Florida's future: transportation and land use in an automated vehicle world (Chapin et al., 2016)	√	√	√	√						√	√
Making better places: autonomous vehicles and future opportunities (WSP; Farrells, 2016)	√	√	√	√	√	√	√	√	√	√	
Driverless future challenge (BLANKSPACENYC, 2017)			√	√	√	√	√	√	√		√
Blueprint for autonomous urbanism (NACTO, 2017)		√	√	√			√	√	√	√	
Designing for future mobility: developing a framework for the livable future city (PERKIN+WILL, 2018)			√	√	√	√	√	√	√	√	√
Rethinking the street in an era of driverless cars (Schlossberg et al., 2018)	√		√	√	√	√		√	√	√	

Source: the author

It is suggested that estimates for the above indicators can be inferred from other calculated indicators.

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1) For the "percentage change in the distance traveled", the indicators are: number of trips per inhabitant, average distance traveled, average travel time and population density. These indicators demonstrate how consolidated the city is in relation to urban mobility, point to the level of complexity for the adoption of autonomous shared vehicles and express the potential for introducing shared mobility. Chart 2 presents estimated values for these indicators based on previous studies for six cities, and calculated* for São Paulo, based on the latest data from the origin-destination survey (METRÔ, 2019).

Table 2 – Estimates of changes in travel distances

Indicator	London	Lisbon	New York	Austin	Singapore	Berlin	São Paulo*
Trips per inhabitant	2.5[1]	2.6[3]	2.4[6]	-	2.4[13]	3[15]	2.0[16]
Average distance traveled(km/trip)	9.5[1]	10.3[3]	12.4[7]	13.8[7]	9.5[14]	6.9[15]	-
Average travel time (minutes)	46[1]	24[3]	40[8]	23[8]	-	23[15]	48[16]
Population density (inhabitants/km2)	10,800[2]	6,446[4]	10,425[9]	1,455[11]	7,804[13]	11.700[2]	7,598[16]
Change in distance traveled (%)	-	6[5]	-40[10]	8[12]	-	-	-

Source: [1]London (2012b), [2]Berlin (2017), [3]NSI (2017b), [4]Pordata (2011), [5]OECD; ITF (2015), [6]DOT NYC (2017), [7]Goldstein (2015), [8]DATAUSA (2016a), [9]DH NY (2015), [10]MIT (2017), [11]City Data (2016), [12]Fagnant; Kockelman; Bansal (2015), [13]LTA (n.d.), [14]Data Singapore (2015), [15]Berlin (2013a), [16]METRO (2019).

2) For the "percentage reduction in the number of private vehicles in use", the indicators are: number of hours of use of the private vehicle per day, percentage of trips in private vehicles, motorization rate, population and population density. These indicators are indicative of the potential for reducing the total number of vehicles, private vehicle travel and vehicle ownership. In addition, the potential for the introduction of shared mobility underpins the distinction between medium, large and megacities. Chart 3 shows calculated/estimated values for these indicators based on previous studies for six cities and for São Paulo.

Table 3 – Estimates of reductions in the number of vehicles in use

Indicator	London	Lisbon	New York	Austin	Singapore	Berlin	São Paulo
Use by private car (minutes/day)	140[1]	151[1]	131[1]	155[1]	134[1]	125[1]	121[1]
% Congestion	40[1]	36[1]	35[1]	25[1]	34[1]	29[1]	30[1]
% Trips by private vehicle	37[2]	56[6]	32[11]	72[16]	22[20]	32[22]	29[25]

Vehiclesper 1,000 inhabitants	326[3]	388[7]	220[12]	649[16]	98[20]	358[22]	212[25]
Population(x 1,000)	8,800[4]	505[8]	8,623[13]	981[17]	5,600[20]	3,375[23]	11,730[25]
Population density (inhabitants/km2)	10,800[5]	6,446[9]	10,425[14]	1,455[18]	7,804[20]	11.700[5]	7,598[25]
Estimated reduction in the number of vehicles in use (%)	-	65[10]	80[15]	89[19]	62[21]	90[24]	-

Source: [1]TOMTOM (2016), [2]London (2017), [3]London (2012a), [4]London (2016), [5]Berlin (2017), [6]NSI (2017a), [7]EC (2010), [8]NSI (2020), [9]Pordata (2011), [10]OECD; ITF (2015), [11]DATAUSA (2016a), [12]DOT NYC (2016), [13]DCP NYC (2017), [14]DH NY (2015), [15]MIT (2017), [16]DATAUSA (2016b), [17]Austin (2019), [18]City Data (2016), [19]Fagnant; Kockelman (2016), [20]LTA (n.d.), [21]Spieser et al. (2014), [22]Berlin (2013a), [23]Berlin (2013b), [24]Bischoff; Maciejewski (2016), [25]METRO (2019).

3) for the "percentage changes in road infrastructure", the indicators are: percentage of reduction of private vehicles in use (Table 2), percentage of parking area on public roads, percentage of road infrastructure area and variation in distance traveled (Table 3). These are indicators of surplus road space that can be converted to other uses. Chart 4 shows calculated/estimated values for these indicators based on previous studies for six cities and for São Paulo. The indicator 'percentage variation of road infrastructure' for São Paulo was effectively calculated, as described in the Results section of this study.

Table 4 – Estimates / calculation* of changes in road infrastructure

Indicator	London	Lisbon	New York	Austin	Singapore	Berlin	São Paulo
Street parking area (%)	15[1]	5.6[3]	16[4]	15 - 30[6]			
Road infrastructure (%)	9.2[2]	29.9[4]	17.5[5]	-	26[2]	18[8]	22[8]
Estimated / calculated* changes in road infrastructure	15[1]	20[3]	-	15[7]	-	-	22,8*

Source: [1]WSP; Farrells (2016), [2]LTA (n.d.); UN-HABITAT (2014), [3]OECD; ITF (2015), [4]LTA (n.d.); INE (2017a), [4]MIT (2017), [5]LTA (n.d.), [6] Quantumrun (2016a, 2016b); WSP (2016); Perkins+Will (2018), [7]Fagnant; Kockelman; Bansal (2015), [8] UN-HABITAT (2014).

The percentage reduction in the number of private vehicles in use is directly proportional to the release of road space. The fewer vehicles in cities, the greater the flow of traffic and the less the need for road infrastructure for vehicles.

The percentage of parking area on public roads is an indicator of the potential for converting road space to other uses. This is made possible by the impact of autonomous vehicles on urban space, which will need less parking, as they will be in circulation longer than parked, especially during periods of higher demand.

The percentage of area allocated to road infrastructure is an indicator of the potential for conversion to other uses.

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AREA IN FOCUS: URBAN REDESIGN MEASURES AND PROPOSALS

As previously mentioned, among the districts in the central region of São Paulo, the district of Liberdade was selected as the focus area (for detailed project proposals), and the districts of Liberdade, Bela Vista, Jardim Paulista and Vila Mariana, as the reference area (measurements only).

For the area in focus, the 'structuring axis of urban transformation' contained in the district of Liberdade was chosen, as it is fundamental for a more sustainable urban mobility, in addition to advocating the articulation of transport policy with urban planning. This axis has structuring elements of medium and high capacity public transport systems, which determine the areas of influence potentially suitable for construction and population density, as well as for mixed land use (São Paulo, 2014; São Paulo, 2015).

It should be noted that the Liberdade neighborhood is home to several oriental cultures, which can be experienced through its gardens, restaurants, craft fairs and local shops that offer products from the East Asian continent. Liberdade is, therefore, a tourist destination much sought after by São Paulo residents and foreigners.

For all 44 streets in the focus area, measurements were made either locally, through direct observation, and/or the use of remote sensing data. These measurements included: track length; width and use of traffic lanes (including parking for buses and on the street), length of pedestrian crossings and bike lanes, width of sidewalks, afforestation and flowerbeds. Data on the deficiencies and qualities of the area were obtained to support the project proposals.

The potential for changes to the road infrastructure proposed in each case took into account the class of the street and the existing conditions. The percentages of conversion of lanes for vehicles, parking on public roads, in favor of pedestrian or cycling use, and amenities were also calculated.

Among the 44 roads, eight considered good representatives within each class were selected for the elaboration of detailed design proposals: expressway - Avenida 23 de Maio - figures 2 and 6; arterial road - Rua Vergueiro - figures 2, 4 and 7; collector roads (3) - Rua da Glória - figures 8 and 9, also Rua Conselheiro Furtado, and Apeninos Street; local roads (3) - Mituto Mizumoto Street - Figure 10, also Pirapitingui Street and Rodrigo Cláudio Street[4].

[4] Not included in this text

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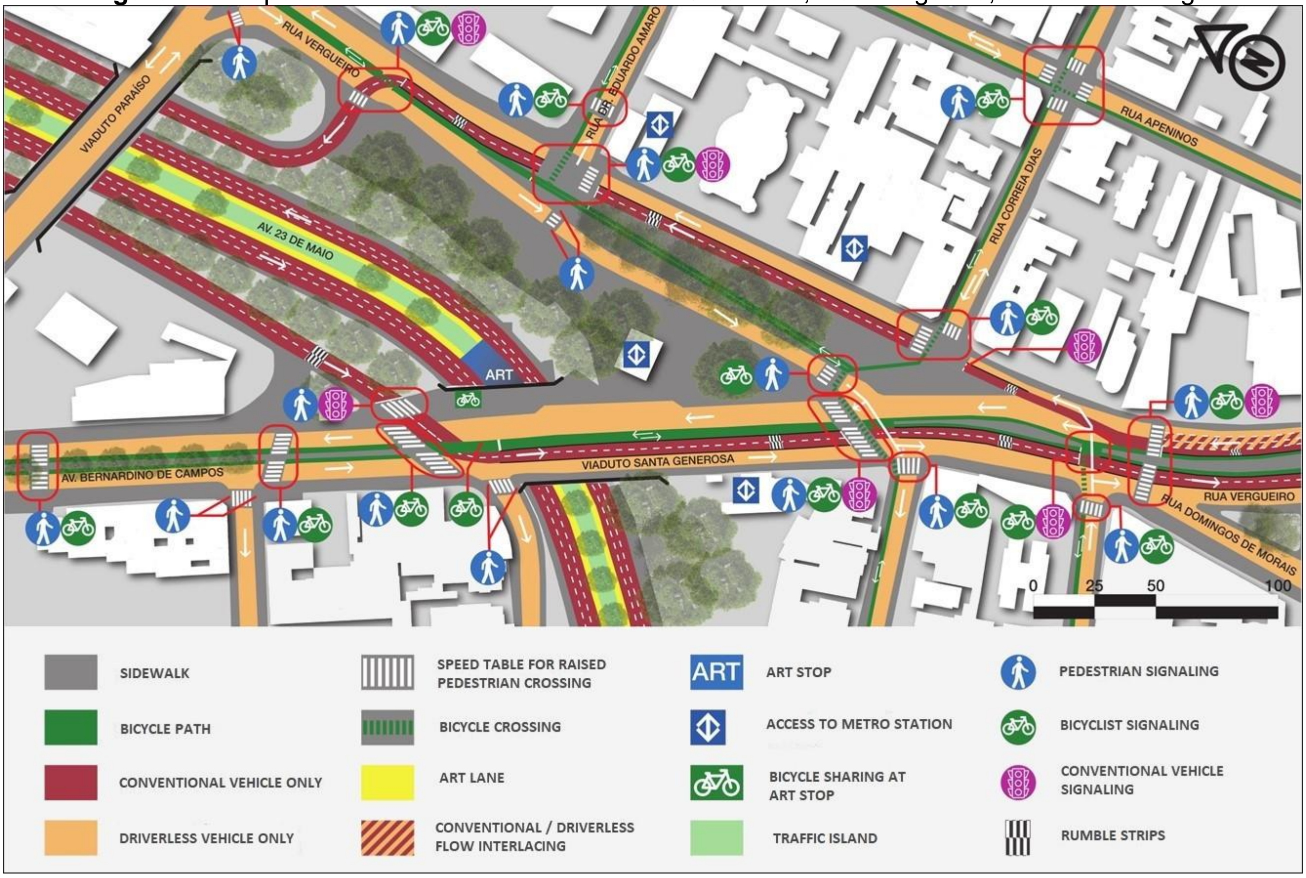
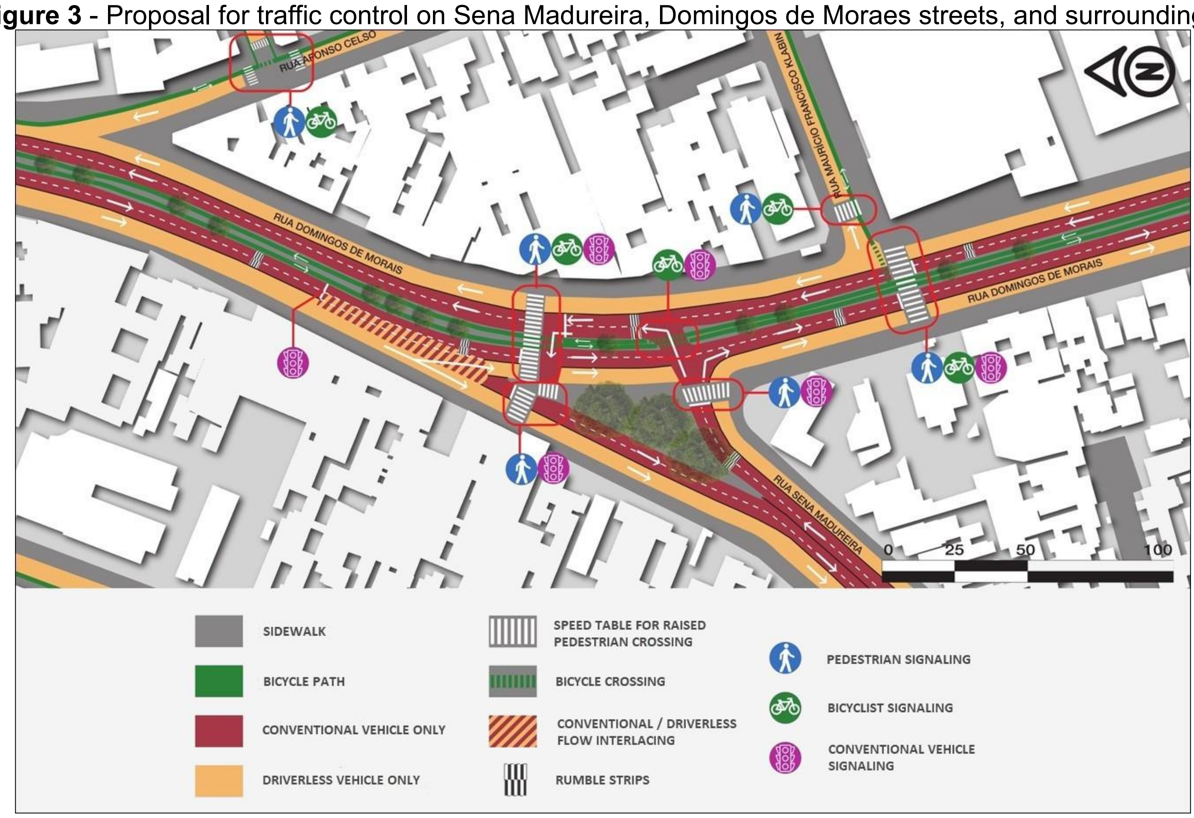
Figure 2 – Proposal for traffic control on Avenida 23 de Maio, Rua Vergueiro, and surroundings



Source: the author

Figure 3 - Proposal for traffic control on Sena Madureira, Domingos de Moraes streets, and surroundings.



Source: the author

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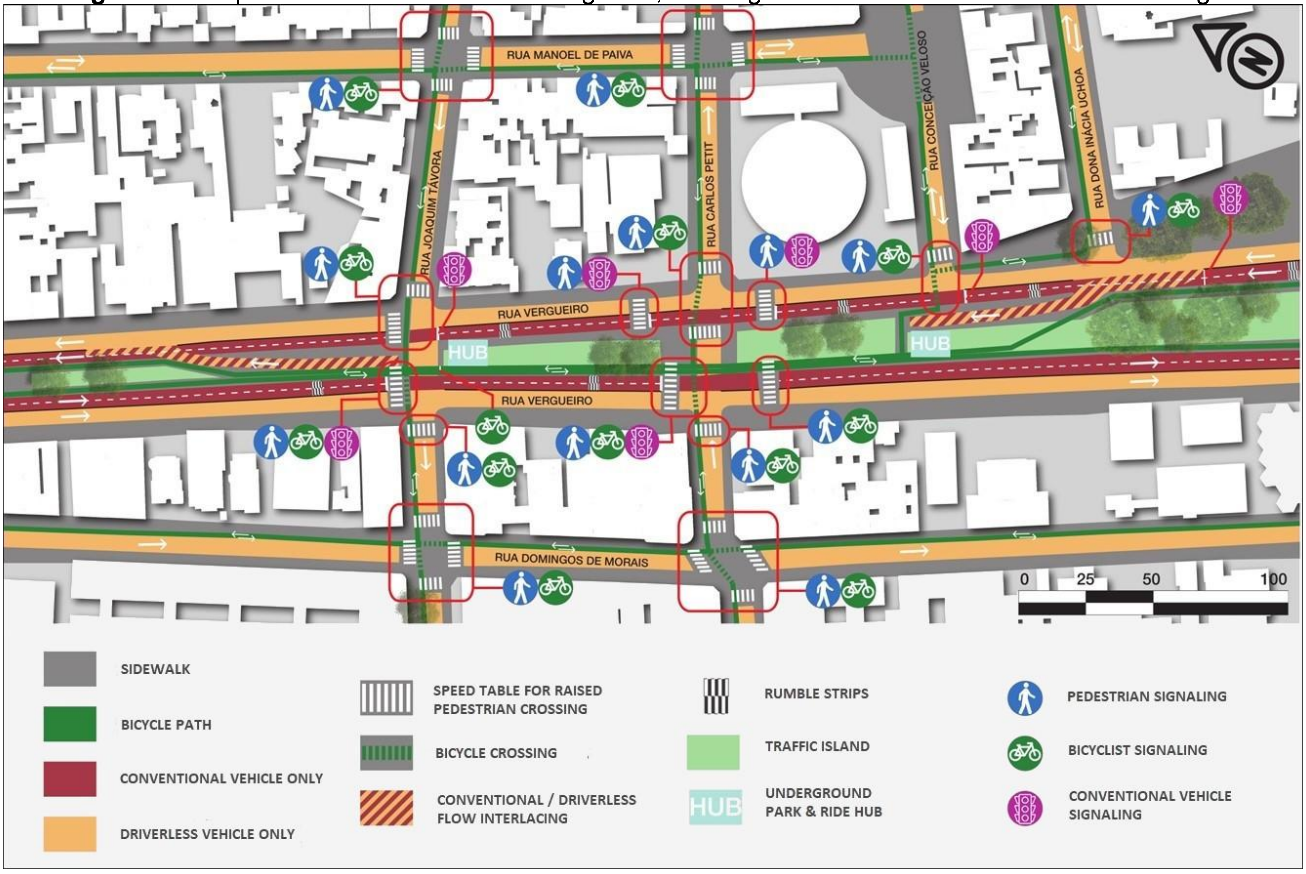
Figure 4 - Proposal for traffic control on Vergueiro, Domingos de Moraes streets and surroundings.



Source: the author

The requirement to control the flows and intersections of conventional and autonomous vehicles, cyclists and pedestrians, included design proposals for the road system, presented in figures 2, 3 and 4, and for the intersection of the collector roads Rua Galvão Bueno and Rua São Joaquim, exclusively for autonomous vehicles. It is proposed that traffic signaling, restricted to pedestrians and cyclists, can transmit information to autonomous vehicles, in order to synchronize their movement for better fluidity and safety of people. The proposal includes pedestrian crossings at sidewalk level to prioritize the circulation of people (Figure 5).

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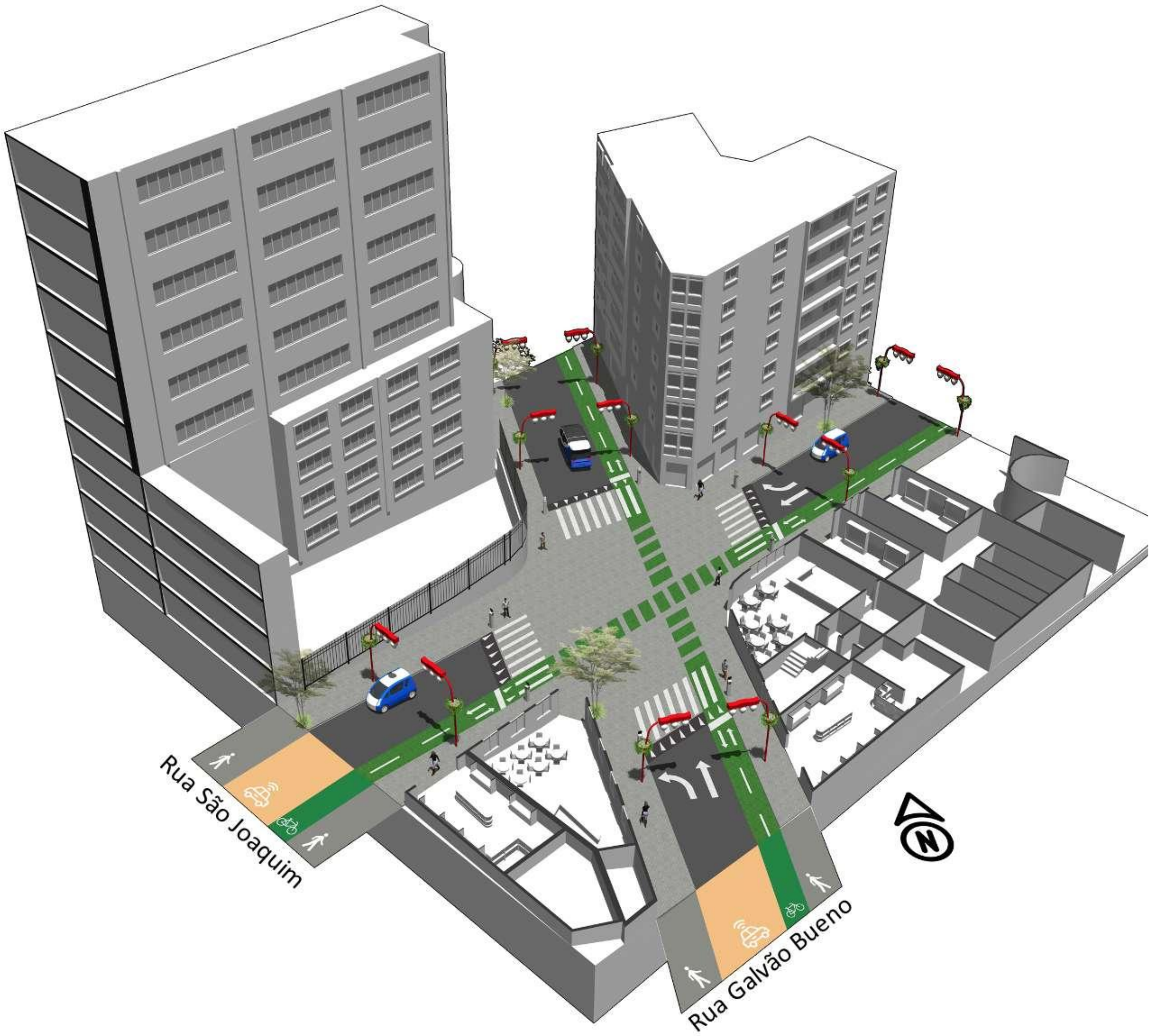
Figure 5 – Illustration of a proposition for the intersection of Galvão Bueno and São Joaquim streets.



Source: the author

REFERENCE AREA: IN-DEPTH STUDY OF THE ROAD SYSTEM

To complement the studies carried out in the area in focus, the on-site survey was expanded to include the structuring axis of urban transformation, also in the neighborhoods of Bela Vista, Jardim Paulista and Vila Mariana, totaling 252 roads, viable to replicate the urban redesign proposed in the area in focus.

In order to deepen the study in relation to the road system of the reference area, especially with regard to traffic signals, pedestrian and cyclist transport routes, it was decided to select the intersections that: 1) cover only autonomous vehicles, pedestrians

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and cyclists; 2) include autonomous vehicles, conventional vehicles, pedestrians and cyclists.

It is proposed that conventional vehicle traffic be allowed on some major roads that cross the reference area. However, where the circulation of autonomous and conventional vehicles coexists, traffic lights and mobile bollards should be used so that these vehicles do not occupy the same road space at the same time (figures 2, 3 and 4). A premise for this evaluation is the assumption that the behavior of the conventional vehicle is unpredictable, from the point of view of the autonomous vehicle, and simultaneous traffic can cause accidents and negatively affect fluidity.

RESULTS

The study sought to be in line with the main plans of the municipal administration for the city of São Paulo, such as those related to bicycle lanes (São Paulo, 2019) and the metro-rail system (São Paulo, 2013).

RESULTS FOR THE FOCUS AREA

By direct measurements or remote sensing, it was found to be possible to reduce 16.4% of the parking area on public roads and change the use of 5.4% of the road infrastructure, reducing the width of the carriageways, by a total of 21.8%.

After the restriction of parking on public roads and the reduction of the width of the lanes, the 44 streets within the incidence area would provide an increase of 14.7% in the pedestrian area and 6.8% in the cycling area.

As for the project proposals, a brief summary follows. The full drawings, which describe the current form, the proposed interventions and the proposed final form, are available in Fortes (2020).

Avenida 23 de Maio (expressway) - The proposal includes a line of autonomous trains without the use of rails (ART), replacing the existing bus lanes. The ART line integrates with the current and planned stations of the metro-rail system. The ART line runs along the North-South corridor (expressway), in a valley, with its stations planned along some existing viaducts (with access by escalators), prioritizing those leading to existing or planned metro-rail stations.

In addition to the inclusion of the ART, the proposal for Avenida 23 de Maio is to maintain it for the exclusive traffic of conventional vehicles, as it is an important

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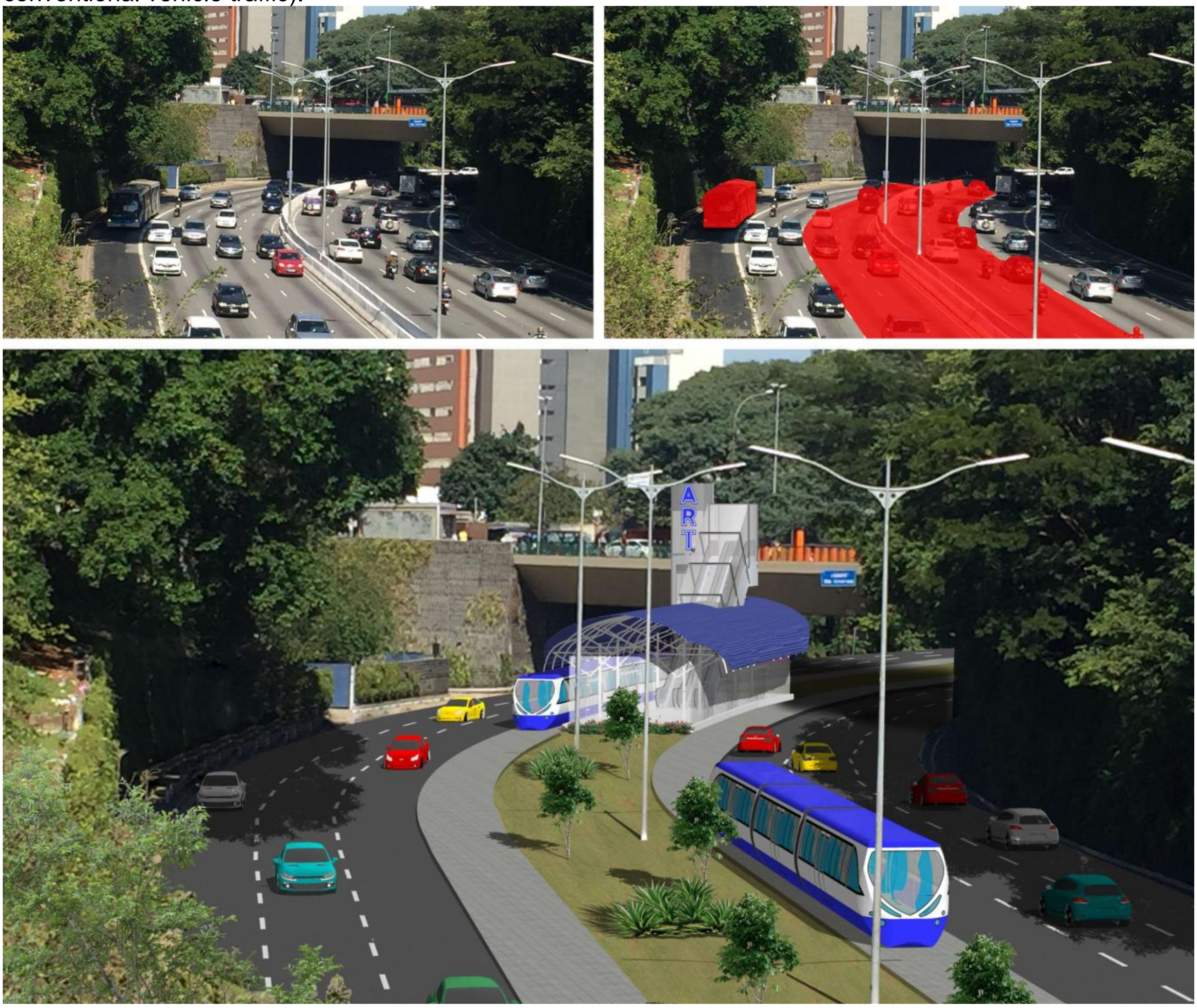
expressway that crosses the intervention region. To access the intervention area, the location of parking poles strategically positioned to promote modal integration was proposed, enabling the migration of conventional vehicles to other modes, such as shared autonomous vehicles, public transport on foot and bicycles (Figure 6).

Figure 6 - Illustration of the project proposal for Avenida 23 de Maio (top, left: current state; top, right: elements to be changed; bottom: proposed changes, elimination of the existing exclusive lane for conventional buses, inclusion of an exclusive lane for ART on the opposite side, remaining lanes still for conventional vehicle traffic).



Source: the author

Vergueiro Street (arterial road) - has an intense flow of people, due to a cultural center located on this street, as well as educational establishments and hospitals. The proposal includes the elimination of street parking, to expand pedestrian space, but with *parklets* (areas adjacent to sidewalks, where structures are built in order to create leisure and social spaces where there were previously car parking spaces) and autonomous

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vehicle boarding and disembarking points. The bike path was maintained, as well as the circulation of buses in both directions (Figure 7).

Figure 7 - Illustration of the proposed design for Rua Vergueiro (top left: current state; top right: elements to be changed; bottom: proposed changes, elimination of parking on public roads, widening of spaces for pedestrians, boarding and disembarking places).

Source: the author

Rua da Glória (collector road) - It is proposed to eliminate parking on the street, freeing up space for other uses, such as wider sidewalks and extension of bike lanes. In addition, the technical galleries will receive the wiring, currently exposed, revealing the typical oriental-style street lighting, and to facilitate its maintenance (Figure 8). It was decided to convert a garage building into a parking center for autonomous vehicles, with charging points for vehicles and electric scooters, maintenance services and bike racks

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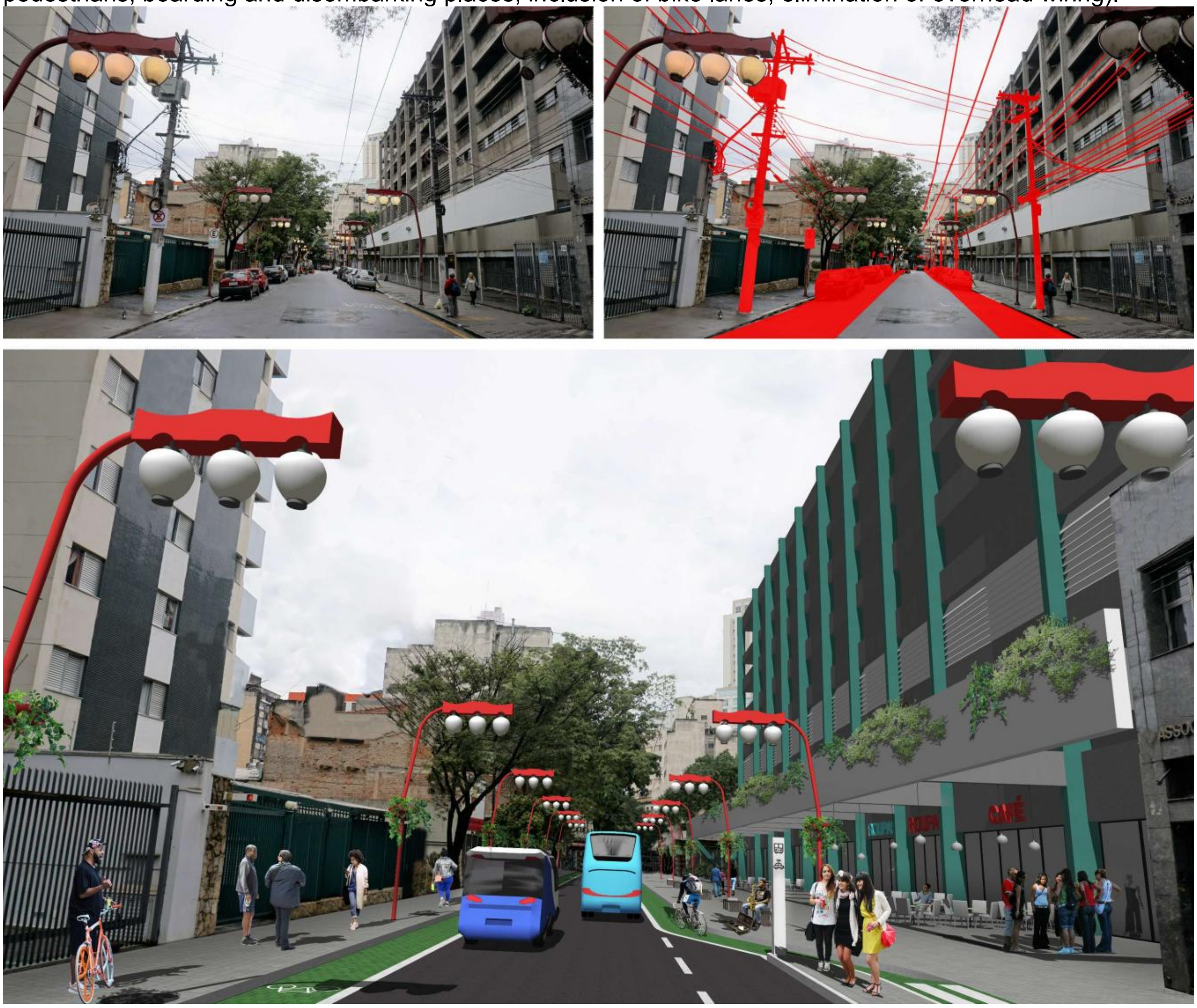
(Figure 9). It should be noted that such construction can also be used as a cargo logistics center for the existing commerce in the region.

Figure 8 - Illustration of the project proposal for Rua da Glória (top left: current state; top right: elements to be changed; bottom: proposed changes, elimination of parking on public roads, widening of spaces for pedestrians, boarding and disembarking places, inclusion of bike lanes, elimination of overhead wiring).



Source: the author

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Figure 9 - Illustration of a service center for autonomous vehicles on Rua da Glória (top left: current state; top right: elements to be changed; bottom: proposed changes, the conversion of a conventional parking building into a parking station and autonomous vehicle service, which can also serve other purposes, such as a collection and delivery point for goods).

Source: the author

Mituto Mizumoto Street (local road) - It is proposed to eliminate street parking, freeing up space for other uses, such as the expansion of pedestrian space and the creation of a bike path. The space previously used for parking on the public road also becomes flexible and, depending on the time of day, can be used by kiosks / *food trucks*, as well as for loading and unloading goods and passengers (Figure 10).

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Figure 10 - Illustration of the proposed design for Mituto Mizumoto Street (top left: current state; top right: elements to be changed; bottom: proposed changes, the elimination of street parking, the widening of pedestrian spaces and the sharing of bicycle/traffic lanes).

Source: the author

Based on the studies carried out, the proposals presented resulted in a 14.7% increase in the pedestrian circulation area, widening the sidewalks from 2.6 m to 4.2 m, representing a 61% increase in pedestrian space. Regarding the circulation of bicycles, there was an increase of 6.8% in the area, representing a fourfold increase, from 2 km to 10 km in length. In addition to the introduction of 3.4 km of cycling routes.

These results are relevant, since 2/3 of the collector roads received bike lanes and, in the local roads, cycling routes were included. In addition, the 14.7% increase in pedestrian area provides safer and more inviting spaces. And the proposed active facades promote attractiveness and permanence in these areas, allowing for social interaction and the vitality of urban spaces.

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RESULTS FOR THE REFERENCE AREA

The measurements for all 252 streets in the reference area gave similar results to those of the area in focus: 17.5% of the parking area on the street and 5.3% of the vehicle circulation area, totaling 22.8%.

CONCLUSION

In order to visualize a broader context, beyond the reference area, a proposal was made for the design of the main roads of the expanded center of the city of São Paulo, contemplating park & ride spaces close to the main access roads to São Paulo and to the stations of the metro-rail system, enabling drivers of conventional vehicles, Coming from other locations, park the vehicles and make the modal transfer to public transport and, with that, access the reference area. The proposal also includes the use of central parking lots so that drivers can park conventional vehicles and have, as one of the options, the modal shift to the shared autonomous vehicle. In this way, it is possible to use the structure of an existing parking lot and reduce the installation costs of the new one.

The propositions demonstrate the potential for transforming the current urban design in favor of more sustainable urban mobility, with the conversion of spaces freed up by the road infrastructure (previously lanes and street parking) to other uses, prioritizing pedestrians and cyclists and qualifying public spaces. With a detailed street-by-street analysis, a transfer of road space to other uses of 21.8% and 22.8%, respectively, was obtained for the area in focus and the reference study area.

In addition to road infrastructure, other hidden spaces for cars in car parks and garages of residential and non-residential buildings can be exploited and converted into urban amenities.

These areas were designed with a view to forming initial nuclei for the adoption of autonomous vehicles. The investments for this change are large and cannot be made overnight. It is proposed that the use of autonomous vehicles spreads from these cores. The infrastructure to segregate conventional and autonomous car traffic should be planned to be reused as the intervention area expands.

It can be inferred that the procedures applied for the calculation of the area within these zones can be applied to other roads of each category, in other areas of the city and, depending on the local context, in other cities.

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In this way, this work contributes to urban studies, especially, but not restricted to large metropolises, which aim to consider the incorporation of disruptive technologies in mobility, seeking opportunities for urban redesign.

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