Transportation Systems and Land Use Planning: The Case of the Metropolitan Region of Rio de Janeiro

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ABSTRACT: Brazilian largest cities growth has been characterized by the expansion of the urban area combined with several vacant urban spaces and unequal infrastructure provision, resulting in socio-spatial segregation and limited access to urban opportunities. Influenced by the rapid industrialization and the modernization pressure in the second half of the twentieth century, the accelerated urban growth along with the adoption of the car as the main mobility solution generated multiple environmental and social externalities. This article aims to identify the main common challenges about the theme of transportation and land use planning integration in Brazilian largest cities, studying more deeply the metropolitan region of Rio de Janeiro (MRRJ). The methodology will be based on literature review about Brazilian urbanization process, the evolution of Rio de Janeiro urbanization as well as the application of land use and transportation integrated approach in developing countries and in Rio de Janeiro. As a result, this article identifies common patterns of the urbanization of Brazilian largest cities, expected benefits of the integration of transportation and land use policies, proposes and tests a simplified framework to assess effective Transit-Oriented Development implementation in the case of the MRRJ.

Keywords *Urban Mobility, Transit Oriented Development, Metropolitan Region of Rio de Janeiro,   Transportation   and   Land   Use   Integration.*

1. INTRODUCTION

Brazil has experienced an accelerated urbanization process during the second half of the 20th century. Although this rapid urbanization process contributed to generate important benefits, such as an overall increase on life expectancy of the population, it also represented several challenges in terms of housing, transportation and equitable access to services and opportunities (Santos 1993, Maricato 2015). These issues are particularly visible in the largest cities where challenges assume greater proportion (Santos 1993, Souza 2003).

More recently, the constant urban mobility crises consolidated itself as one of the major urban issues. In fact, it was one of the main reasons of a significant wave of protest around the country in 2013. These demonstrations occurred in a moment which the country was investing considerable resources in public transit to get structurally ready to receive mega events, such as the FIFA World Cup in 2014 and the Olympics Games in 2016. After decades of low level of investments in public transportation, these new efforts created the expectation of noteworthy improvement in the urban mobility conditions in several cities (ITDP 2016).

However, while the need for investments in infrastructure is unquestionable, it will not alone be sufficient to solve all the challenges and lead Brazilian cities to better mobility conditions. More specifically, there are strong arguments that the promotion of an effective and sustainable solution for the urban mobility issues requires greater integration between transportation and land use planning (Litman 2016, Cervero 2009).

Several authors and institutions are defending that the organization and development of cities should be built upon the transit infrastructure, considering the principles of Transit Oriented Development - TOD (Cervero et al. 2004, ITDP 2013). Regarding this model, the main expected benefits are the improvement of democratic access to transport and opportunities, the reduction of time spent and distance of daily travel as well as the use of the automobile as well and its environmental impacts. However, multiples challenges remain to be addressed to promote an effective implementation in developing countries (Cervero 2013).

In order to set the ground that will guide this article, firstly the authors identified the main patterns of urban development in Brazilian large cities, based on the origin of urban mobility conditions. Then, this article discussed how TOD implementation could be part of the solution to improve these conditions as well as define a simplified framework to assess its effective implementation in the case of Metropolitan Region of Rio de Janeiro (MRRJ).

The second section of this work explores how TOD implementation could support urban planners to address specific common urban mobility issues, discussing what are its main challenges to be implemented and proposing an analytical framework of needed conditions for effective TOD application. The third section characterizes the obstacles faced in the MRRJ. Finally, the last section present a preliminary high level analysis of the case of the MRRJ as a specific example of urban planning and transportation challenges.

2. TRANSIT ORIENTED DEVELOPMENT: EXPECTED BENEFITS AND CHALLENGES

2.1 Relationship between Urban Form and Mobility Patterns

Multiples research conducted in North-America indicated that urban sprawl has significant interconnection with mobility patterns. In fact, the findings show an interconnection between urban sprawl with increasing use of automobile, in contrast to a decrease of walking, biking and use of transit, as well as no substantial improvement in congestion delay (Ewing et al. 2003).

On the other hand, several authors defend the implementation of smart growth policies to promote dense neighbourhoods, organized around major transit stations. In this regard, it would reduce dependency on automobile, increase walking and transit mode share as well as improving transport and housing affordability (Ewing & Hamidi 2014). Smart growth approach advocates for more compact and diverse development, in order to match demographic and economic expansion with environmental protection (Jepson & Edwards 2010). Aligned with these approach, since 1992, the European Community also opted to promote the compact city as the most desirable urban design. Therefore, it contributes to reduce transport needs, establish more favourable conditions for environmental friendly modes and it decreases the energy consumption at city level (Banister 2007).

Promoting sustainable mobility patterns supposes a rupture with traditional isolated urban development and transportation practices and to integrate transportation and land use planning as well as to incorporate the human scale design. By redefining urban space, fostering mixed-use development and common open spaces, promoting pedestrian oriented and friendly development, the new urbanism approach is supposed to decrease the number of drivers as well as increase safety and attractiveness active transportation (Jepson & Edwards 2010, Gehl 2010).

In addition to all these factors several authors defend that complementary travel management measures should be implemented to foment driving reduction. A revision of 26 study cases in the Transland Project (1999) financed by the European Commission reinforced that integrated land-use and transport policies based on increasing urban density around transit and promotion of mixed land-use have limited effects on driving reduction if not accompanied by measures to discourage its use aiming to turn this option more expensive or slower than the use of others modes.

TOD can be defined as dense and mixed-use land, which promotes attractive environment for walking, biking and public transport use. In other words, TOD is presented as an urban development model able to effectively promote sustainable mobility patterns. Moreover, it is also considered to be an effective model to promote revitalization of common spaces, stimulate more human interaction, turning transit surrounding areas more livable and safe (Mu & De Jong, 2012) as well as promoting more efficient use of existing infrastructure.

The research designed to address neighbourhood characteristics and its impact on the number and the means chosen for mobility highlights five main variables to be considered, in the promotion of sustainable mobility called the 5 Ds. They are: (1) net residential density, (2) diversity or land use, (3) urban design oriented to active transportation, (4) accessibility of destinations and (5) the distance to mass transit (Cervero et al. 2009).

Studies conducted in the United States have also shown that the distance to transit is the one of the most influential factor on the choice of transport mode as well as reducing driving (Lee & Cervero 2007). The findings of an analysis of 1449 high-capacity American transit stations in 21 cities pointed that transit ridership is significantly impacted when jobs are concentrated within ¼ mile from transit stations and half within ½ mile (Cervero & Guerra 2011). Thus, promoting sustainable mobility is intrinsically related to putting people and jobs in the surroundings of transit stations.

2.2 Developing a Framework Analysis for TOD Implementation in Brazilian Metropolitan Regions

In the early 2000's TOD projects were already widespread among urban planner practitioners in the United States (Cervero et al. 2004). In Europe, although there is no evidence of urban intervention reclaiming the TOD principles, several initiatives integrating transport and land-use planning have been implemented (Rayle 2008).

However, though Curitiba is frequently cited as a best case of TOD implementation, successful examples in developing countries are more exception than rule. Study cases revealed that one of the main reason for this situation is that planners used to neglect the city-shaping potential of transit system infrastructure; then, leading to cost-minimization and under-investment in TOD multi-scale strategic planning - regions, corridors and station areas and public space improvement (Cervero 2013). Cervero (2013) also conducted a survey with urban planners in twenty-seven countries which found common implantation hurdles; such as, the lack of dedicated fund, the lack of inter-agency coordination, limited experience in TOD planning and implementation as well as weak political support and lack of stakeholder coalition to promote TOD.

According to Hakkaart & Morrissey (2014) there are four main themes that helps to successfully implement TOD: (1) integrated and coordinated governance, (2) supportive policy and legislation, (3) good relationship between the public and private sector and (4) well-planned and accessible mobility infrastructure. Likewise, Mu & de Jong (2012) identified six dimensions for effective TOD implementation: (1) urban design, (2) governance, (3) land use, (4) automobile restrictions, (5) transport service and (6) real estate market conditions.

However, the pattern of Brazilian urban expansion has significant differences comparing to North-American and European cities. The dispersion of the urban area was induced by the peripherization of low and middle income groups (LMI) expelled from valorised areas, either directly by the force of the state or indirectly as they are not able to pay increasing cost of living or the promotion of excluding regulations (Harvey 2014, Maricato 2015, Santos 1993, Abreu 1987). In the meantime, several consolidated areas of the cities were kept empty by public and private owners reinforcing highly unequal and inefficient pattern of land use (Harvey 2014, Maricato 2015, Santos 1993).

The literature review about the effects of smart growth policies and housing affordability suggests that TOD may impact housing affordability economical plans and gentrification threats for LMI populations (Addison et al. 2012). Therefore, a contextualization of TOD measures for local needs to include the concern of promoting equitable urban development as well as preserve access and right to the city for all.

Based on this review and a reflection about Brazil urbanization specificities, the authors propose a simplified framework (Table 1) to analyse the most important aspects to effectively implement TOD in Brazilian metropolitan region. This framework aims to provide a high-level structure, which needs to be customized according to local context with relevant indicators to assess each aspect and their different scale of analysis from regional, to corridor and stations areas level.

Table 1. Analytical framework for effective TOD implementation in Brazil

Category	Aspect	Definition	Sources
Transit infrastructure & operation	Coverage	High coverage of transit system providing urban dwellers access to medium and high-capacity transit station at walking distance.	Mu & de Jong (2012), ITDP (2013), Cervero et al (2009), Hakkaart & Morrissey (2014)
	Intermodal connections	High-level of physical, operational and fare integration between different transit modes to facilitate modal interchange and transfer.	Mu & de Jong (2012), ITDP (2013)
Governance	Planning	Capacity to conduct and implement participatory and multi-disciplinary planning for city-shaping transit infrastructure project considering multi-scale approach – regional, corridor and stations areas.	Cervero (2013), Mu & de Jong (2012)
	Coordination	Establish inter-organizational coordination in the processes of transit design, planning, operation and management, including coordination between land use and transport planning as well as between federal, state and municipal level.	Mu & de Jong (2012), Hakkaart & Morrissey (2014), Cervero (2013)
Land use	Density	High-density of residence and jobs offer around transit stations containing urban expansion characteristics of private vehicle oriented city planning. [1]	Cervero et al (2009), Mu & de Jong (2012), ITDP (2013), Cervero & Guerra (2011)
	Diversity	Mixed land-use areas creating offer of daily commerce and services for diverse needs, reducing necessity for long distance trips.	Cervero et al (2009), Mu & de Jong (2012), ITDP (2013)
	Mix of housing offer	Promote diversity of housing contemplating rich and poor, singles and families, young and old as well as houses for sale and for rent.	Mu & de Jong (2012), Hakkaart & Morrissey (2014), Addison et. al (2012)
Urban design	Active transportation	Interconnected street network linked to transit stations, well equipped with amenities, and scaled to the convenience and safe use of active transportation modes (walking and bike).	Mu & de Jong (2012), ITDP (2013)

3. HOW TOD PLANNING COULD CONTRIBUTE TO CHALLENGES IN THE MRRJ

3.1 The formation of the MRRJ

Rio de Janeiro urban formation was closely linked to the implementation of transport infrastructure (Rodrigues 2015). Since the last decades of the 19th century, the light rail system reinforced a trend of land occupation by high-income groups whereas the train

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[1] Demographic density around transit station has to be aligned with local infrastructure capacity.

serving suburban areas helped to displace the nascent industry and LMI groups evicted from valorized areas or arriving from other part of the country in quest of urban opportunities (Abreu 1987, Rodrigues 2015).

This pattern of social group distribution in the territory was reinforced by successive local and federal public administrations diverse measures strengthening the duality nucleus-periphery (Abreu 1987). The suburb was the destination of LMI extensive migratory flows. The large influx of families coming from several regions of the country started to overflow to other municipalities; resulting in conurbation and the expansion of the urban area towards the constitution of a metropolitan region (Abreu 1987, Ribeiro 2015).

In the last decades the socio-territorial dynamic of the MRRJ introduced more complex pattern of residential segregation with counter-trends such as the auto-segregation of the high-incomes groups in large condominiums as well as the "invasion" of valorized areas occupied by high-income groups by LMI families. Despite of this new trends, the separation of social groups is still dominant in the MRRJ (Rodrigues 2015, Ribeiro 2015).

According to Souza (2003), the residential segregation results from a complex set of factors among which are the urban poverty and the role of the state, mainly through its influence in creating spatial disparities in terms of infrastructure provision. Rodrigues (2015) stresses that residential segregation increases inequalities by reducing the access of some groups to several opportunities, mainly when it comes to jobs and transport network. This unequal access to opportunities is caused by the territorial segmentation which is defined by the separation between residential and jobs offer areas and influenced by the mobility offer in the territory (Ribeiro et al. 2010).

3.2 Overall MRRJ patterns of territorial organization and the mobility challenges

Created in 1974, the MRRJ includes twenty-one municipalities and is the second largest metropolitan region of the country with more than 11 million inhabitants (IBGE 2010). As in many other metropolitan regions, the MRRJ is currently experiencing a relative stabilization of its demographic growth with rates around 1% since the 1990's. Meanwhile its urban area kept increasing, resulting in lower densities (Rodrigues 2015). This expansion of the urban area was boosted by the growth of peripheral areas that since the 1950's which have grown faster than the city historical nucleus (Abreu 1987).

Among several inequalities of the territory, the unequal distribution of jobs offer is one of the most critical factor that impacts the mobility patterns; once the access to job is the reason for 45% of the displacement of the population in the MRRJ (Mihessen 2014). The city of Rio de Janeiro concentrates 53,7% of the total active population and 75% of formal jobs offered by the MRRJ, and only Rio de Janeiro, Niteroi and Itaguai have higher percentage of jobs offer than of active population (Mihessen 2014).

In practice this means that a significant part of the population of the metropolitan region lives in dormitory cities and have to commute out of their places of residence to access jobs opportunities (Ribeiro 2004). Among the main metropolis of the country, MRRJ has the highest proportion of people spending more than one hour to travel to work (29%) and the second highest average commuting time to work (49,9 minutes) (IBGE 2014).

As pointed by Villaça (2012), the differences between social groups results from the spatial distribution of type of jobs and activities as well as the unequal dispute to live in

neighborhoods contemplated with better infrastructure offer. The access to transit infrastructure is one example of this situation. Only 30% of the total occupied households of the MRRJ lives within 1km radius of rapid transit stations and the difference between occupied households receiving more than 3 minimum wage (MW) and those with less than ½ MW is 24 percentage points (46% and 22% of respective groups are included in analyzed radius) (ITDP, 2016).

Table 2: Inequalities in terms of time spent and proximity to rapid transit in the MRRJ

Income bracket	Average time spent in minutes	Occupied households near rapid transit stations	Occupied households near rapid transit stations (in %)
Less than ½ MW	47,5	199.091	22%
Between ½ and 1 MW	50,4	259.658	24%
Between 1 and 3 MW	49,9	400.103	32%
Above 3 MW	49,0	304.298	46%
Total	49,9	1.163.150	30%

Source: ITDP 2014 and IBGE 2014

This inefficient distribution and service provided by transit infrastructure in the MRRJ combined with the strong increase of the motorization rate, which went up more than 70% between 2001 and 2014 (Metropolis Obs. 2015), are important factors to explain the progressive reduction of the use of public transport in the modal division of the MRRJ.

4. EXPLORING THE IMPLEMENTATION OF TOD IN THE MRRJ

4.1 Preliminary assessment of necessary conditions for an effective implementation of TOD in the MRRJ

This section consolidates an initial effort of assessing the case of the MRRJ according to the analytical framework defined in table 1. This assessment intends to provide a first and preliminary overall analysis on: whether the local context provides favorable conditions for TOD implementation at metropolitan level. It also seeks to address identify needs for further research as well as specific analysis at corridors and station area level. See overall summary of the results on Table 2 below.

Table 3: A summary of MRRJ's TOD context assessment.

Category	Aspect	Assessment	Observations
Transit infrastructure & operation	Coverage	Insufficient	Low and unequal coverage of the population by rapid transit.
	Intermodal connections	Insufficient	Confusing rules, lack of infrastructure and information for effective integration between transit modes.
Governance	Planning	Partially	Consistent recent progress of governance structure and planning.
	Coordination	To be researched	Still need more research mainly on sectorial coordination.
Land use	Density	Partially	Discrepancies identified between areas with high density under-served by rapid transit and areas with lower density served by BRTs.
	Diversity	Insufficient	Significant segmentation of territory reducing mixed-use areas.
	Mix of housing offer	Insufficient	There is no identified effort of promoting more social diverse neighborhood.
Urban design	Active transportation	Insufficient	Low micro-accessibility and urban integration on surrounding areas.

4.2 Transit infrastructure and operation

The MRRJ has one of the higher transit coverage among main metropolitan region in Brazil with 28% of its population living in 1km radius from rapid transit stations (ITDP 2016). The recent infrastructure built-up for the mega events contributed to a 6% increase of the population with access to rapid transit in the MRRJ. However, this improvement was exclusively concentrated in the municipality of Rio de Janeiro and no progress of this indicator was registered in the other municipalities.

The integration between the diverse modes operated by diverse level of government; still have to be improved in all its aspects. Fare integration for two trips in an interval of three hours works completely when using conventional buses and BRTs, partially with a discount when the integration involves the metropolitan rail system and there is no integration when it involves the use of the metro. Furthermore, the rules already changed several times since 2010, which contributes to create confusion among users. The physical aspects of the integration are precarious mainly when it involves rail and bus-based modes. The lack of information about frequency and real time information in the system jeopardize the reliability and operational integration for the users.

4.3 Governance

Significant improvements on the metropolitan governance structure were achieved since the creation of the Metropolitan Chamber of Governmental Integration, in 2015. Among its responsibilities, this Chamber has to develop integrated urban development and mobility plans for the MRRJ, contributing to fill a vacant space of regional planning since the 1980's. Next expected step is to develop initiatives over the corridor and station area planning to effectively promote TOD measures.

Besides the challenges of promoting coordination among twenty-one municipalities, the Chamber also has to develop financing mechanism for its activities since Statute of the Metropolis, promulgated in 2015, does not provide specific forms to raise funds to this governance body. Further research is needed on how the coordination of the diverse secretary of each municipality and the state governments are planned by the Chamber.

4.4 Land use

Not all rapid transit station areas are necessarily indicated to be contemplated by TOD measures (Cervero et al. 2004). Further research on existing infrastructure and its strategic characteristics has to be performed at corridor and station area level assessment. However, the analysis of the transit network of the MRRJ allows to identify the needs for improvement between the access of rapid transit and density of stations area. While the city of Rio de Janeiro increased significantly the coverage of its rapid transit network, even in less dense area, areas with higher density in the MRRJ area still under covered; mainly in the municipality of the Baixada and the East Fluminense regions.

On the other hand, as demonstrated by Rodrigues (2015) and Mihessen (2014), the MRRJ is characterized by strong territorial segmentation and some of its municipalities present patterns of dormitory-towns. Further research needs to be conducted regarding the localization of jobs in relation to the rapid transit stations is needed to assess the diversity aspects at corridor and stations area level assessment. Moreover, there is limited example

of the real estate and public administration coordination to promote more socially diverse neighborhood.

4.5 Urban Design

Micro accessibility for pedestrian, bike users and infrastructure integration with surroundings areas was historically neglected in the construction of rapid transit in the MRRJ. This can be evidenced by the low quality of sidewalks, inexistence of safe cycling network, limited bike parking spaces and poor quality of public spaces of station areas of the metropolitan trains where the transit infrastructure often creates barrier effects. Large single-use closed condominium with high number of parking spaces are currently the dominant edification model built by private developers. This model damage the connectivity of pedestrian and bike network, favor the use of car and reduce the attractiveness of active transportation modes use.

5. CONCLUSION

The literature review of Brazilian urbanization process showed that, preserved important specificities, the largest cities in Brazil experimented a urban growth with characteristics similar to the urban sprawl. More specifically, when concerning the expansion of urban area with low-density, creation of vacant spaces, separation of land use and deterioration of cities downtowns. Differently from the sprawl experienced in North-American and some European cities, the expansion of the Brazilian urban area was combined with the increasing peripherization of low and moderate income groups creating need for long and expansive communting trips to access jobs, services and public facilities.

In that context, at the same time the application of TOD arises as a model to tackle a set of challenges caused by the Brazilian urbanization process and with potential to promote more sustainable mobility patterns, it also has to be customized consistently to span its specificities. This article provided a first effort to consolidate an analytical framework able to assess the existing pre-conditions of TOD implementation in Brazilian metropolitan regions. A preliminary assessment of the MRRJ case showed that this framework was useful to proceed a structured analysis of specific situation and identify specific challenges at regional-level.

However, to advance and support effective implementation of TOD more research must be performed to refine this framework. Through these new researches, it will be possible to define, more precisely, indicators for each aspect, differentiate critical and important aspects as well as identify specific methods to assess more detailed conditions at corridors and stations area level.

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