Transportation oriented to urban development

Transporte orientado ao desenvolvimento urbano

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Abstract

Transportation networks play a vital role in the development of cities and access to opportunities. Transportation planning, however, has yet to recognize its role in promoting inequalities. This work aims to discuss the concepts of centralization and accessibility and present a paradigm for planning transit networks based on the understanding that transit demand contains an endogenous component: by increasing accessibility, transit systems encourage part of the demand they seek to meet, leading to a circular causation cycle. It is proposed, then, that the planning of transit networks should be strongly associated with the discipline of urban planning, considering the existing demand and the design of the city that one wants to build.

Keywords: transit network design; urban mobility; accessibility; agglomeration; equity.

Resumo

As redes de transporte desempenham um importante papel no desenvolvimento das cidades e no acesso a oportunidades. O planejamento de transportes, contudo, ainda não reconhece seu papel na promoção de desigualdades. Este trabalho busca discutir os conceitos de centralização e acessibilidade e apresentar um paradigma de desenho de redes de transporte coletivo, baseado na compreensão de que sua demanda contém um componente endógeno: ao promover acessibilidade, os sistemas de transporte coletivo incentivam parte da demanda que buscam atender, levando a um ciclo de causação circular. Propõe-se, então, que o planejamento das redes de transporte coletivo deva estar fortemente associado à disciplina de planejamento urbano, considerando não só a demanda existente, mas o desenho de cidade que se deseja construir.

Palavras-chave: *desenho de redes de transporte coletivo; mobilidade urbana; acessibilidade; aglomeração; equidade.*

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Introduction

Transit systems are crucial in promoting access to opportunities in cities that have developed unevenly. The importance of transit is even more significant in developing countries, where inequality levels are more profound and the poorest strata are the most dependent on this system (Vasconcellos, 2015). The adequate functioning of the transit networks is, consequently, an essential condition for the reduction of social inequalities. The opposite, in turn, can result in its deepening.

In recent decades, the concern of researchers with the problems of justice and equity in transportation has grown significantly (Pereira, Schwanen and Banister, 2017). Although many planners do not recognize and do not understand the role of transportation policies in producing and reproducing inequalities (Guimarães and Lucas, 2019), academia has extensively addressed the topic in recent years. A large number of studies have investigated inequalities in urban contexts based on accessibility metrics (e.g., Pereira, 2018; Basso et al., 2020; Smith et al., 2020; Barboza et al., 2021; Giannotti et al., 2021), while others are dedicated to the conceptualization of inequality and distributive justice in transportation (e.g. Lucas, 2012; Pereira, Schwanen and Banister, 2017; Pereira and Karner, 2021).

Historically, the methods of planning and designing transport networks associate the optimal functioning of public transport systems with connecting prominent neighborhoods to the central regions of cities (Brown and Thompson, 2012). This logic produces networks with radial characteristics, in which secondary demands are met only in a subsidiary or complementary way to the main demands (Mello, J. Mello and Orrico, 2016). This type of network, in turn, privileges displacement over ever greater distances and gives rise to a paradoxical scenario: we have been traveling more and more to more places and greater distances, yet this has not converted into access to a more significant number of people of opportunities and activities.

Traditionally, the primary demand – which organizes the planning processes of transit networks – is the demand for commuting between home and work. In addition to reproducing a pendular dynamic of center-periphery connections, it is a model that subordinates the entire dynamic of the city to a single relationship: the relationship between capital and work. As such, traditional planning methods often treat all other natures of displacements as subordinate. The consequences are especially sensitive for people whose travel needs differ from this main route: women, mothers, older adults, the sick, young people, and people with disabilities.

However, even from the perspective of promoting equity, the guidelines for designing transit networks may not be so obvious. Suppose the network design method continues prioritizing links from areas with few opportunities (outskirts, suburbs, or in a more generic classification, 'non-centers') to the area that gathers more opportunities (CBD). In that case, there is a tendency to reproduce a design of a radial network that reinforces the existing displacement pattern and, ultimately, the very concentration of activities in central areas.

The fact that we seek to deepen is the possible evidence that the accessibility gains produced by transit networks result from the approximation of economic agents and, consequently, translate into agglomeration benefits (Credit, 2019). Such benefits, in turn, are relevant for the choice of location of economic agents (Corrêa, 1989; Villaça, 1998). In general, we understand that just as the configuration of the urban environment interferes with the process of defining transit investments, the investment in transit itself affects the urban form (Hickman and Hall, 2008; Kasraian et al., 2016). In this sense, a deeper understanding of these dynamics is essential so that investments in transit and the design of networks can collaborate with the construction of fairer cities in the long term.

In this article, we present a contribution to this discussion, which is being carried out in many literatures with distinct approaches. Our contribution begins with the review of the concepts of centralization and decentralization to characterize transit networks' role in these dynamics. Next, we show how the economic benefits of transit networks result in agglomeration benefits since accessibility gains bring economic agents closer together. Then, we present considerations on transportation planning methods and some approaches that incorporate the interaction between transit and land use in planning practice to discuss their limits and contributions. In the penultimate section, we synthesize the various elements addressed, pointing out interfaces between the concepts that can be explored in network planning. Finally, we point out conclusions and suggest some research paths for future work.

Transit and centralities

The idea of centrality is recurrent in transportation planning. The view that transit networks should privilege connections with central areas prevails in planning (Brown and Thompson, 2012). For example, Nabais and Portugal (2006) point out that in large metropolises, the transit offer should be proportional to the centrality of a location. However, the very definition and identification of centralities can vary greatly depending on the criteria adopted for this classification, often being the object of subjective classifications based on the impression of planners.

Several works have explored, to a greater or lesser extent, the theme of urban centralities (or polycentralities), among which we highlight approaches that use graph theory (e.g., Irwin and Hughes, 1992; Limtanakool, Schwanen and Dijst, 2009), spatial syntax (e.g., Medeiros, 2013) and econometric models (e.g., Pereira et al., 2013). However, these approaches have no consensus on characterizing the centrality phenomenon (ibid.). Thus, before seeking definitions in case studies, we consider it prudent to take a step back and seek, in the literature of history, geography, and urban planning, the roots of centralization processes, its motives, and consequences, particularly in the context of Brazilian cities.

Historically, the formation of centralities is not necessarily associated with the capitalist mode of production but with the very dynamics of life in society (Corrêa, 1989; Villaça, 1998). In this context, the emergence of the center reflects the dispute over control of the time and energy spent on the movement necessary for the production and reproduction of material life (Castells, 1975; Villaça, 1998). It is from the industrial revolution, however, with the intensification of the circulation of people and goods, that the process of centralization gains another dimension and importance in the urban form (Corrêa, 1989). The centralization process, however, is dialectical: at the same time it produces the center, it also produces the non-center (Villaça, 1998). In this way, it is essential to note the relational nature of the process. The center does not exist dissociated from its urban fabric and its activities. The center is only a center in relation to a community, a set of activities, a social fabric.

The relationship between the centralization process and transportation permeates the different interpretations of the concept. For both Corrêa (1989) and Villaça (1998), the centralization process is strongly associated with optimizing the movement of people or goods. In this sense, by providing locational advantages from increased accessibility, transit networks have historically played an influential role in defining central areas. The growing interest of different economic agents in exploiting these locational advantages resulted in rising land prices and, consequently, in the selection of activities (and people) that would occupy the central areas (Corrêa, 1989). The centralization process is, therefore, a search process for agglomeration economies.

The dialectical nature of this process is an essential element to understand: since gathering all people and activities in a single space is impossible, the same process that shapes the central area also expels activities and people whose income cannot keep up with the evolution of land prices (Villaça, 1998). Thus, a process of cumulative circular causation is configured: while the more developed regions attract an increasing number of activities, other regions become less competitive. The result is unequal concentrations of wealth, power, and influence (Santos, 1978; Harvey, 2014).

Although understanding the roots and historical processes of conformation is fundamental, it is still necessary to identify the elements that would define a primary center. In this sense, it is possible to characterize the primary center by the intensive use of land, the complexity of activities, the predominance of activities in the tertiary sector, and for being an area that optimizes movement, having the greatest accessibility among all areas of the city (Corrêa, 1989; Villaça, 1998). Regarding accessibility, Santos (1978) points out that the facilitated movement of people encourages the concentration of commercial activity in the space. This observation is essential for our work since it indicates a strong relationship between our objects of study: transit networks and centralities. Other characteristics, such as verticalization, the concentration of daytime activities, and activities related to the management and decision-making of powerful economic agents, also define primary centers (Corrêa, 1989).

However, since the 1980s, the deconcentration or decentralization of the population and economic activities has drawn the attention of researchers (Fernandez--Maldonado et al., 2014; Lobo et al., 2015). Some have explored and investigated polycentric structures through a functional reading, seeking to identify processes of decentralization or deconcentration based on the pattern of displacements (e.g., Veneri, 2013; Burger and Meijers, 2012; Lobo et al., 2015; Mello et al., 2016; Geaquinto, Paiva Neto and Orrico Filho, 2018). Others adopt a morphological approach, seeking to identify the same patterns based on the concentration of jobs or people in space (e.g., Fernandez--Maldonado et al., 2014; Brezzi and Veneri, 2015; Alidadi and Dadashpoor, 2017).

From a conceptual and dialectical point of view, the decentralization process originates from the diseconomies generated by the centralization process itself. Both are, therefore, the result of the same movement (and not different movements, as one might imagine). Together with the emergence of attraction factors in non-central areas, these diseconomies lead economic agents to seek alternatives to the primary center (Corrêa, 1989; Fernandez-Maldonado et al., 2014). Factors such as the elevated land price, expansion difficulties, legal restrictions, and high congestion, for example, are diseconomies that result in the repulsion of activities from the primary center (Corrêa, 1989). These diseconomies give rise to the formation of subcenters or alternative centralities, which are configured as replicas on a smaller scale of the main center. They compete with it without, however, being able to match it. Their importance, in turn, is associated with the area they serve (Corrêa, 1989; Villaça, 1998; Pacione, 2009). Others point out that subcentralities are characterized by areas that play a structuring role in a metropolitan subsystem (Cladera, Duarte e Moix, 2009) and have a higher density of jobs than the surrounding regions (McMillen, 2001).

It should be noted that the decentralization process takes place differently for different economic sectors. In general, activities that remain in the primary center cannot only pay the price of land but can also convert the locational advantages produced by the central area into economic gains. Corrêa (1989) points out that industrial activities, intensive in land use, tend to move to cheaper areas and closer to labor. In the case of the commercial and services sector, selectivity is processed differently: specialized activities tend to remain in the central area. In contrast, the trade of everyday products or services tends to decentralize. In all cases, what is sought is the optimization of times (Villaça, 1998) or the production of transport economies that can be converted into an increase in consumption (Corrêa, 1989). In this sense, it is essential to note that the decentralization process becomes viable as its gains for economic agents become more significant, representing an advantage in the face of diseconomies generated by excessive agglomeration (Fernandez--Maldonado et al., 2014). For this reason, in the decentralization process, there is a preference, especially in the tertiary sector, for the location in the areas of the city that concentrate the highest income populations (Corrêa, 1989). This process is more significant in Brazilian cities, especially given the relative growth of the tertiary sector's economic participation.

It is important to emphasize that, in our understanding, there is no contradiction or even rupture between the processes of centralization and decentralization. Both are the consequence of the same accumulation mechanism that seeks to obtain ever-greater economic gains. Corrêa (1989), when describing this, points out that small neighborhood stores tend to be replaced by branches of large chains. Although on a different scale, Oliveira (2008) describes a similar process when characterizing the regional development policy for the Brazilian northeast, which, ironically, would focus on expanding oligopolistic markets in the Center-South regions of Brazil. In both cases, similarly, although the location of activities and jobs has changed towards the non-center (or the periphery), the direction of capital accumulation continues to converge towards the central area through structures of financial institutions that end up capturing the productivity gains resulting from the formation of subcenters.

In summary, it is noted that centralization and decentralization are not isolated phenomena: by producing centrality, non-centrality is produced simultaneously. Centralization results from an attempt to optimize travel costs and generate agglomeration economies. Given the spatial concentration process, the dispute for agglomeration economies produces diseconomies. These, in turn, when associated with expulsing the poorest strata from central areas, induce a process of decentralization in a second moment. Therefore, we seek to investigate and better understand the interaction between the urban structure, the formation of centralities, and transit networks. In this sense, it is essential to note the role played by the agglomeration phenomenon, understood as an inverse function of the impedance between economic agents or, directly, as a function of accessibility.

Accessibility and agglomeration economies

The concept of accessibility has been discussed and used by several disciplines and has played a crucial role in the study of transportation and urban and regional development (Páez, Scott and Morency, 2012) and in the definition of public policies (Geurs and Van Wee, 2004). However, even though it is a well-established field in the literature, it is vital to note that the conceptualization of the term and the formulation of various metrics and instruments have resulted from constant debates. At the conceptual level, several definitions of the term are worth highlighting. Hansen (1959, p. 73) defines *accessibility* as the "potential opportunities for interaction." Later interpretations also incorporated elements associated with individual choice (e.g., Burns, 1979) and land use, attributing a relevant spatial dimension to the concept (e.g., Dalvi and Martin, 1976; Ben-Akiva and Lerman, 1979; Geurs and Van Wee, 2004; Páez, Scott and Morency, 2012).

In an attempt to give greater conceptual rigidity to the term, Geurs and Van Wee (2004) identify four essential components for the construction of accessibility metrics: The first component, related to transit systems, concerns the ease of movement between an origin and a destination via a specific mode of transportation. The second component, temporal, is related to the availability of activities at different times of the day or to the users' time constraints. The third component, the individual, represents different individuals' needs, capabilities, and opportunities, relating accessibility to sociodemographic, physical characteristics, or economic conditions of different people (or social groups). Finally, the land use component identifies each destination's quantity, quality, and spatial distribution of opportunities.

Paez, Scott and Morency (2012) draw attention, in turn, to the difference between two ways of implementing accessibility measures, divided into two categories: normative and positive. On the one hand, normative implementations seek to identify acceptable levels of accessibility, establishing maximum or desirable distances to reach certain activities of interest. On the other hand, positive implementations seek to identify how people travel. They are related to the concrete travel pattern, which may or may not respect the normative limits established by planners or researchers.

A last important distinction for the conceptual framework presented concerns how the land use component (the distribution of activities) is treated in accessibility studies. Most studies on accessibility consider the distribution of activities as a given element. That is, they assume a positive attitude concerning this component. There are few exceptions in the literature on accessibility that deal with the distribution of activities from a normative standpoint, that is, what should be the desired or acceptable distribution of activities in space (ibid.). This, however, does not mean that accessibility is not a relevant factor for locating activities in space, just that this discussion has been carried out by other authors and in other literature, especially microeconomic and location-allocation studies (in the field of operational research).

This scenario reveals a critical gap: although the transportation and urban planning literature recognizes the role of accessibility gains produced by transport systems in the production of agglomeration economies and location of economic agents (Corrêa, 1989; Villaça, 1998; Santos, 1978; Kasraian et al., 2016; Credit, 2019), few studies have discussed how transit networks should be planned so that the distribution of activities in space is more balanced. In the same sense, although several studies investigate the impact of the distribution of activities and land use on transit networks, research in the opposite direction – the impact of transit networks on land use – has been much more limited (Kasraian et al., 2016). It is essential, therefore, to recognize the interactions between accessibility gains and agglomeration economies, fields of study that have walked separately (Credit, 2019).

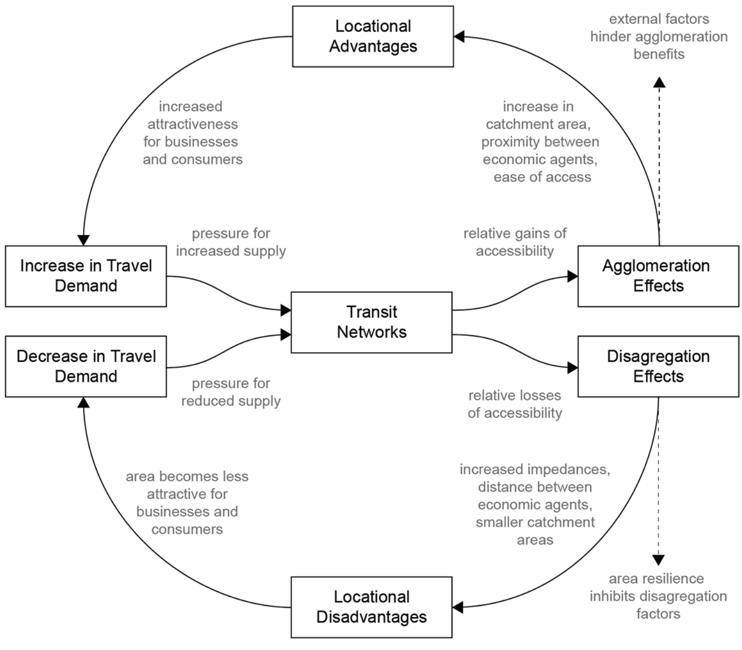
Credit (2019) argues that the economic benefits produced by accessibility gains are, in reality, consequences of the agglomeration economies produced by transit networks, given that the accessibility gain has the same effect as the approximation of economic agents. This approximation, in turn, produces gains in productivity and efficiency, especially for sectors of the economy sensitive to spillover effects, such as activities in the tertiary sector. Analogously, it is possible to argue that the effects of agglomeration are also manifested in the proximity between consumers and sellers (between demand and supply) since proximity to the consumer market is known to be a decisive factor in locating economic agents. Likewise, the effects of agglomeration are present in the relationship between productive activities and the location of labor (Corrêa, 1989).

In this sense, it is essential to note that different modes of transportation produce benefits (or losses) of different intensities for different economic activities (Corrêa, 1989; Orrico, 2005; Lé Nechet et al., 2012; Credit, 2019). For example, implementing an expressway produces urban barrier effects that may hinder the development of commercial activities or services but are attractive for industrial activities that seek to reduce the cost of transporting their production. It should be noted, however, that the accessibility gains produced by transit networks are only potential and may or may not be realized depending on specific locational conditions, the quality of infrastructure projects, and the characteristics of the affected economic activities (Credit, 2019).

The phenomenon of circular causation generated by accessibility gains deserves special attention. As they become more accessible, some regions begin to concentrate economic activities and become the focus of travel, which, in turn, produces the demand for implementation of new infrastructures that produce new gains in accessibility. This paradigm, prevalent among transportation planners (Brown and Thompson, 2012; Brezzi and Veneri, 2015), reinforces a pattern of commuting and the centralization of economic activities. Complementarily, areas that lose importance reduce demand for trips, leading to a reduction in supply and, consequently, a recurring loss of importance. The result is that speed gains, or the possibility of reaching increasingly distant activities, have not been effectively converted into accessibility gains, given that the number of activities reached has remained stable over time (Banister, 2011). Figure 1 conceptually summarizes the dynamics described.

It is not a matter of proposing that activities should be evenly distributed in space. That is impractical and, in many cases, undesirable, as it produces diseconomies due to disaggregation. Instead, it is a matter of discussing what the adequate or tolerable level of centralization is and how transit networks can help the process of decentralization of activities – increasing the accessibility of socially vulnerable segments, for example – not by making longer or faster trips possible, but, from another perspective, by encouraging the diversified location of economic agents in the urban tissue.

Figure 1 – Circular causation dynamics of accessibility gains (and losses).



Source: authors, in 2023.

Thus, we highlight the need to explore accessibility not only from the point of view of individuals but also from the perspective of choosing the location of economic agents. In other words, accessibility can be seen on the one hand as the ease with which people access spatially distributed activities and, on the other hand, as the ease with which spatially distributed activities are accessed by people. Although such differentiation, at first glance, does not reveal its high significance, we emphasize its importance.

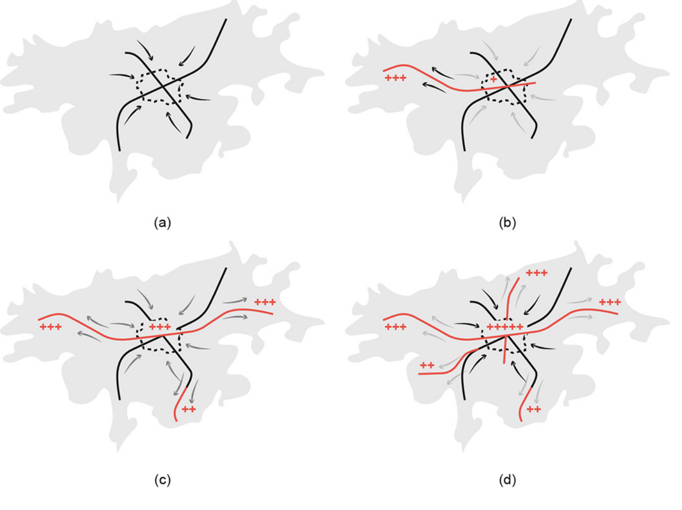
The same project can, for example, produce accessibility gains for those who live in an area (e.g., by facilitating access to the center) and, at the same time, produce zero or negative impacts on economic activities in that same area, either because it does not expand its catchment area (e.g., the consumer market accessible to a given economic activity) or because the characteristics of the project produce externalities and urban barrier effects. The consequence is that, although in the short term such projects produce gains in accessibility for the population in that area, in the long term, they can reinforce travel patterns and centralization that crystallize or intensify the unequal distribution of activities in space.

Despite the undeniable positive effects resulting from an isolated connection of the radial type, projects with these characteristics cannot be, a priori, characterized as decentralizing. Although, when evaluated in isolation, the accessibility gains in peripheral regions are significant, reproducing this planning logic over time can reinforce centralization dynamics. By repeating the process, linking even more peripheral regions to the same centrality, the marginal accessibility gains for the central region accumulate and outweigh the isolated gains for any peripheral regions. Figure 2 conceptually illustrates, in a sequence of steps, this process.

Steps on Figure 2 are: a) Reference frame (time 0): CBD is the region with greatest accessibility; b) Network expansion (time 1): When evaluated on isolation, radial expansion of the network produces greater accessibility gains for non-central areas; c) New network expansions (time 2): The planning logic is repeated, but accessibility gains for the CBD already match those of non-central areas; d) More network expansions (time 3): The reproduction of the planning logic results in a sum of marginal gains for the CBD that surpasses the accessibility gains of non-central areas.

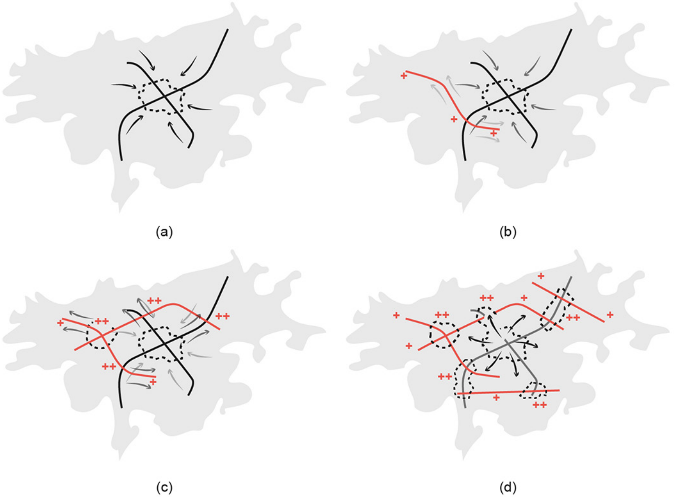
Similarly, it is understood that projects or changes in the transit network that do not produce global gains in accessibility (for example, do not result, in the short term, in greater coverage or the shortest travel times) can have positive effects on the urban development through local accessibility gains (e.g., expansion of catchment areas and increased flow of people in alternative centralities). Such hypotheses are conceptually

Figure 2 – Reproduction of the centralization process through a radial network design



Source: authors, in 2023.

Figure 3 – Decentralization process through transit network design



Source: authors, in 2023.

represented in Figure 3. Incorporating the dimension of land use in planning transit networks is undoubtedly an essential element for decentralized territorial planning

Steps on Figure 3 are: a) Reference frame (time 0): CBD is the region with greatest accessibility; b) Network expansion (time 1): When evaluated in isolation, transversal expansion of the network does not produce optimal accessibility gains; c) New network expansions (time 2): The planning logic is repeated, and cumulative effects start to show up. New destinations are incentivized; d) More network expansions (time 3): The reproduction of the new planning logic results in the emergence of new centralities, producing a fairer distribution of activities in the urban tissue.

Transportation planning strategies

Traditionally, transit network planning strategies follow methods that can be grouped into intuitive or analytical (Orrico, 2013). Orrico (ibid.) points out that intuitive methods are often associated with the logic of road network design. They seek to build transit networks from pragmatic or logical inferences resulting from urban design. Analytical methods, in turn, result from approaches that prioritize the use of mathematical functions in the design of networks, generally seeking to optimize operational parameters such as travel time or cost, frequency of services, or operational restrictions.

Both groups of methods, however, are highly grounded in the dynamics of the existing city: either through the analysis of practical routes or the urban fabric; or through the use of primary data sources based on the behavior of existing displacements, such as origin-destination matrices. Advances in data availability, in turn, have deepened this problem. The transport systems data are increasingly becoming the primary sources of data for constructing origin-destination matrices. Moreover, even the use of more diverse sources, such as mobile phone data, ends up bumping into the same limitation: how to measure the potential of paths that are currently not feasible or possible given the configuration of the existing network.

Although the planning of transit networks continues, to a large extent, to meet the demand of the primary center, in recent decades, other strategies have been gaining strength. In this context, the interaction between transportation and land use has been the object of intense discussion from different approaches. In particular, we highlight Land--Use Transport Interaction (Luti) models and Transit Oriented Development (TOD) strategies. The latter is undoubtedly the most successful in real projects. Although dealing with the same problem fundamentally, they are quite different approaches and deserve a more in-depth evaluation.

Introduced in the literature by Calthorpe (1993), TOD can be understood as a transport and land use planning strategy that makes sustainable modes of transport more convenient and desirable, maximizing the efficiency of these systems by concentrating urban development around transit stations (Ibraeva et al., 2020). It should be noted, however, that the mere densification of transit corridors does not constitute a TOD strategy since this densification will not necessarily convert into a more sustainable travel pattern. There is, therefore, a difference between TOD and what several authors call Transit Adjacent Development (TAD).

Indeed, it is essential to note that TOD focuses on the densification and development of regions close to transit stations (Calthorpe, 1993; Hickman and Hall, 2008; Bertolini, Curtis and Renne, 2012; Thomas and Bertolini, 2017). In this way, TOD strategies are essentially composed of localized projects, resulting in a restricted scale of action. Also noteworthy is that most of the works on TOD are focused on studying travel patterns. Given that one of its main objectives is related to the change in the modal split, development around stations is seen as a means to achieve this. Consequently, there are few studies on the impacts of TOD projects on urban form (Ibraeva et al., 2020).

Furthermore, TOD projects adopt a centralized approach, directing occupation efforts in the intervention region based on coordinating different economic agents. This approach may not be successful, especially when there is no convergence of interests between economic agents and project objectives. Additionally, TOD may encounter additional difficulties in promoting changes in the travel pattern, either because of personal resistance or because the desired destinations remain inaccessible by the transit network, which is often not evaluated in studies on the subject (ibid.). Despite the challenges mentioned, studies on TOD have produced significant advances in understanding the interaction between transport systems and land use, and the benefits considerably outweigh the limitations of the projects.

The Luti models, in turn, deal with the interaction between land use and transport at the urban scale (of the functional urban unit). They understand, in general, the development of cities as a process resulting from the interference of multiple agents whose uncoordinated actions influence several subsystems, and each of these subsystems, in turn, influences the other, producing changes in the balance between supply and demand over time (Stead, Williams and Titheridge, 2000). These models generally incorporate three subsystems: the transportation subsystem, which can be defined as the set of elements and interactions that produce both transport demand and supply (Cascetta, 2009); the land use subsystem, which can be seen as a result of the built environment (Handy, Cao and Mokhtarian, 2005) or the urban form (Rodrigue, Comtois and Slack, 2013); and the subsystem of activities, which is related to participation in activities, understood as the primary motivator of some decisions, such as trips and locational choices (Meurs and Van Wee, 2003). However, there are different approaches regarding the interaction between the different subsystems for the different models, and many fail to incorporate interactions between the activity subsystem and the others (Lopes, Loureiro and Van Wee, 2018). Another aspect of Luti models that deserves to be highlighted and results directly from incorporating dynamic relationships between the subsystems concerns the temporal dimension. Unlike transportation planning models that assume static conditions over time, or linear variations, Luti models incorporate the uncertainties resulting from these complex interactions.

It is possible to group the Luti models into three categories: spatial interaction models, which result, in general, from adaptations of the gravitational model; econometric models, which incorporate both behavioral models and econometric methods; and microsimulation models, which seek to simulate the behavior of various small-scale agents (ibid.). Although Luti models represent a significant advance in trying to model complex interactions, it is essential to note that they also bring with them a set of challenges. The models tend to be complex and difficult to communicate, which makes their adoption by decision-makers, planners, or even acceptance by society difficult. In addition, they tend to be applications that demand much greater volume and availability of data (compared to traditional methods) that are not always available, especially in the context of developing countries.

In general, there is a tradeoff between a more practical approach, albeit limited from a spatial and temporal point of view (TOD), and a more theoretical approach (Luti), which incorporates larger spatial dimensions (the scale of functional urban units), the temporal dimension, and the interrelationships between systems. However, the growing methodological interaction between transit systems and land use has yet to be translated into practical applications in network design. In most cases, the design of public transport networks continues to be motivated by aspects related to the level of service and the economic-financial balance of the systems. There is, therefore, a substantial gap to be filled by instruments capable of incorporating issues related to the interaction between transportation and land use in the design of transit networks.

Urban development-oriented transit

Given the conceptual framework presented, the importance of deepening the studies about transit network design strategies that subvert the current paradigm is proposed. Instead of following current urban development trends and reproducing a pattern of accumulation in primary centers, the design of transit networks would act as a promoter of decentralized territorial planning, encouraging the development of subcenters in less developed regions.

Therefore, Urban Development-Oriented Transit is proposed, as a synthesis of these preexisting debates, as a complementary paradigm to Transit-Oriented Development (TOD). While the TOD promotes urban development initiatives focused around the existing infrastructure, the urban development-oriented paradigm would focus on designing transportation networks – particularly transit – capable of influencing the development of fairer and more sustainable cities.

Therefore, it is crucial to recognize that the movement conditions are decisive in the construction of urban space (Villaça, 1998) and that transportation networks play a fundamental role in the development of cities, especially in the process of centralization of activities (Corrêa, 1989; Villaça, 1998; Santos, 1978). This process, in turn, is motivated by the agglomeration economies produced by accessibility gains, and its nature is dialectical. At the same time that it produces the center, it also produces the non-center. As it approaches some agents, it spreads apart others. By excessively centralizing, it produces the diseconomies that lead to decentralization (Fernandez-Maldonado et al., 2014).

The presented approach proposes that the planning of transit networks should consider not only existing demand but future urban development (Orrico, 2013). It must be an instrument for building the desired city. That is fundamental to achieve, in the long term, a fairer distribution of activities and real gains in accessibility. The direct consequence of this reasoning is that, eventually, the most significant projects to reduce, in the long term, excessive centralization would be precisely the projects that produce transversal connections in the network, especially between and to the peripheral subcenters, meeting a demand that today is considered a subsidiary of the primary demand. This realization, however, is not intuitive since it implies recognizing that to produce optimal gains in accessibility in the long term, it may be necessary to invest in projects that, by definition, do not produce optimal gains in accessibility in the short term. That is, there is a contradiction between short-term and long-term goals.

Recognizing the importance of these transversal links is not, however, enough. In the same sense, it is crucial to note that the accessibility gains produced in the short term can be nullified or reversed in the long run if the network design reinforces existing travel patterns and, therefore, centralization. Even strategies aimed at expanding access to opportunities can result in a concentrated network design, primarily if the evaluation of projects is focused only on gross gains in accessibility for the populations in the area of origin. This paradigm favors connecting areas with few opportunities (generally peripheries) to the area with the greatest number of opportunities (generally the primary center), reproducing a radial design of transit networks.

This set implies a paradigm shift: transit demand, often seen as derived from other activities, would also have an endogenous component. By creating agglomeration economies and the conditions for centralization, transportation infrastructures become, to some extent, drivers of their own demand. That does not mean that transportation is the only element in this equation, but it is undoubtedly significant and that it requires further investigation. In this sense, an essential temporal component has been ignored in network planning. Instead of an excessive focus on long-term demand projections – which are generally unreliable, especially in the context of developing countries (Vasconcellos, 2015) – there should be a greater focus on evaluating the future impacts of projects for the urban form and the spatial distribution of activities. Otherwise, we face the possibility of designing ever larger infrastructures to meet increasing demands for increasingly distant trips in increasingly unequal urban configurations.

The profoundly unequal structure of Brazilian society (and other societies worldwide, especially in the global south) poses short-term challenges. In this sense, concerns about increasing accessibility levels for the poorest populations should not (and cannot) fail to permeate transportation planning. Similarly, concerns about the financial-economic sustainability of the systems are not unjustified and must be solved based on an adequate mobility financing policy. The proposed approach is to add one more element of concern to this complex and delicate planning process. Although the proposed logic may result in connections that, in the short term, do not meet economic--financial optimality criteria, in the long run, they may be a crucial part of building a more sustainable pattern of commuting and a more efficient system.

For this, it is essential that transit network design and planning are closely associated with the urban planning process. Likewise, considering the suggested paradigm, planning must consider functional urban units (metropolitan regions or conurbations), which would result in a second challenge: building the structures of metropolitan governance that will make this practice possible.

In any case, the paradigm presented represents an essential step towards the investigation and formulation of a transit planning practice more integrated with urban development and land use dynamics. Building a sustainable mobility paradigm in Brazilian cities is a multidimensional challenge, and the interaction between transit systems and land use is undoubtedly a vital part of this equation.

Final remarks

Transportation systems played – and will continue to play – a fundamental role in shaping urban centralities. However, they have also been part of a dynamic of circular causation, which reinforces travel patterns and, ultimately, the process of centralization itself. That is, the perspective of maintaining a network design logic based on radial connections may end up neutralizing accessibility gains produced in the short term.

On the other hand, partial alterations in the network, which produce transverse and diametrical connections and which treat the subcenters as focal points – even if they do not envisage optimal gains in accessibility in the short term – may result in an essential incentive for the development of these regions, promoting a fairer distribution of opportunities in space.

However, the planning of transit networks has yet to recognize its role in producing and reproducing urban inequalities. Given this, we emphasize the importance of further investigating the components of transit demand. Since the provision of transit infrastructure interferes with the activities and land-use dynamics, this demand should not be interpreted as derived exclusively from other activities. That implies recognizing transit planning as an essential urban and economic development policy instrument.

Not only do we need to make better use of the infrastructure already built – as transit-oriented development approaches propose – but we also need to investigate in which measure planning for more efficient infrastructure in the future would affect mobility and urban dynamics. Investment in transportation, especially transit, usually results from the collective effort of society through the State and can be coordinated and planned. In contrast, real estate investments and the allocation of activities in urban space are movements of private and diffuse agents driven by diverse interests. Although they share similar demands – which makes it possible to study and analyze the choice of location of economic agents in urban space – the coordination of these agents is significantly more complex than the coordination of public investments.

In summary, what we propose is that the literature deepens research paths that evaluate the hypothesis that transit systems are not only instruments to meet the existing travel demand but also tools to design the city of the future, capable of encouraging (or hindering, when misused) the development of alternative centralities to the primary center, producing a fairer spatial distribution of activities and thus reducing the demand for trips. In our understanding, the planning of transit networks cannot reproduce past mistakes (reinforcing dynamics that produce inequality) and must do whatever is possible to produce fairer cities. To this end, there is evidence that meeting demand is not enough.

It is important to note that a considerable barrier to incorporating more complex approaches in planning transit networks is the unavailability of data and tools. There is still a vast field to be explored on the relationships between transit infrastructure, agglomeration economies, and the locational choice of economic agents, both in empirical studies that seek to measure these impacts and in developing accessibility metrics from the perspective of the various economic agents.

Furthermost, the new production dynamics introduced by incremental or disruptive technological advances – such as changes in the trade and supply logistics chain resulting from the exponential growth of e-commerce activities – as well as changes in work dynamics accelerated and deepened by the Covid-19 pandemic – such as the massive adoption of hybrid and/or remote work in the services sector – greatly influence this discussion. Although this contribution has not addressed them, they are undoubtedly central themes for formulating any contemporary transport planning strategy.

Studies that investigate the behavior of different planning strategies for transportation networks applied to time iteratively, as well as the role of various economic and social agents that influence the spatial allocation process in cities – like the housing market - also format relevant research fields. It is envisaged to understand how different transit network design algorithms behave in the long term and whether they would reproduce or not designs of centralizing networks. These challenges can result in essential quality leaps in mobility planning, accelerating development, and reducing structural inequalities toward building more sustainable and fairer cities in the medium and long term for their inhabitants and visitors.

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