

Analysis of strategies for sustainable transit-oriented development (TOD) used in medium-sized Brazilian cities

Análise das estratégias para o desenvolvimento orientado ao transporte sustentável (DOTS) utilizadas em cidades médias brasileiras

Análisis de estrategias para el desarrollo orientado al transporte sostenible (DOTS) utilizadas en ciudades brasileñas de tamaño medio

Frederico Coli Mendes, master's degree in Environmental Engineering, Federal University of Tocantins Foundation. E-mail: fcolimendes@gmail.com  <http://orcid.org/0000-0001-7329-057X>

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Abstract

Despite the relative gains provided by the population concentration in urban spaces, there are significant challenges for these places to work effectively as facilitators of sustainable development. To overcome these challenges, the concept of Sustainable Transit-Oriented Development (TOD) emerges, focusing on the concentration of



urban strategies aligned with medium and high capacity public transit corridors (TMA), providing access to infrastructure, services and amenities, in addition to the balance between the distribution of jobs and housing in the territory. This work sought to analyze the application of such strategies in medium-sized Brazilian cities, that is, with a population between one hundred and five hundred thousand inhabitants, resulting in the cases of Sobral-CE, Criciúma-SC and Uberaba-MG. Brazilian cities of this size have a lack of studies on the application of sustainable TOD, although they are recognized as providing quality of life and have shown greater economic and population growth than the others. After analyzing its urban legislation, it was found that none of them are in line with TOD concept, although they allow for greater land use intensity and diversity around their TMA corridors and stations, as well as use some urban instruments in a dispersed way in their territory.

Keywords: Sustainable transit-oriented development; TOD; Urban Density; Medium-sized Cities; TMA.

Resumo

Apesar dos ganhos relativos promovidos pela concentração de habitantes em espaços urbanos, apresentam-se desafios significativos para que esses locais sejam, efetivamente, destacados como propiciadores de um desenvolvimento sustentável. Na tentativa de superá-los, surge o conceito de Desenvolvimento Orientado ao Transporte Sustentável (DOTS), com foco na concentração de estratégias urbanas alinhadas a corredores de transporte público coletivo de média e alta capacidade (TMA), propiciando maior acesso a infraestrutura, serviços e amenidades, além do equilíbrio entre a distribuição de empregos e moradias no território. Este trabalho procurou analisar a aplicação de tais estratégias em cidades médias brasileiras, ou seja, com população entre 100 mil e 500 mil habitantes, resultando nos casos de Sobral-CE, Criciúma-SC e Uberaba-MG. Cidades brasileiras desse porte apresentam uma lacuna de estudos de aplicação de DOTS, embora sejam reconhecidas como propiciadoras de qualidade de vida e venham apresentando maior crescimento econômico e populacional que as demais. Após a análise de sua legislação urbanística, constatou-se que nenhuma delas alinha-se ao DOTS, muito embora possibilitem maior intensidade e diversidade de uso e ocupação do solo no entorno de seus corredores e estações TMA, bem como lancem mão de alguns instrumentos urbanísticos de maneira dispersa em seu território.

Palavras-chave: Desenvolvimento orientado ao transporte sustentável; DOTS; Densidade Urbana; Cidades Médias; TMA.

Resumen

A pesar de las ganancias relativas proporcionadas por la concentración de habitantes en espacios urbanos, existen desafíos importantes para que sean efectivamente destacados como facilitadores del desarrollo sostenible. En un intento por superarlos, surge el concepto de Desarrollo Orientado al Transporte Sostenible (DOTS), enfocándose en la concentración de estrategias urbanas alineadas con corredores



de transporte público colectivo de media y alta capacidad (TMA), proporcionando mayor acceso a infraestructura, servicios y equipamientos, además del equilibrio entre empleos y vivienda en el territorio. Este trabajo analizó la aplicación de tales estrategias en ciudades brasileñas de tamaño medio – población entre cien y quinientos mil habitantes – resultando en los casos de Sobral-CE, Criciúma-SC y Uberaba-MG. Ciudades brasileñas de ese tamaño carecen de estudios sobre la aplicación de DOTS, aunque son reconocidas como proveedoras de calidad de vida y han mostrado un mayor crecimiento económico y poblacional que las demás. Después de analizar su legislación urbanística, se encontró que ninguna está en línea con DOTS, aunque permiten una mayor intensidad y diversidad de usos y ocupaciones del suelo en torno a sus corredores y estaciones de TMA, así como hacen uso de algunos instrumentos urbanos de manera dispersa en su territorio.

Palabras clave: Desarrollo orientado al transporte sostenible; DOTS; Densidad Urbana; Ciudades Medianas; TMA

INTRODUCTION

It is common knowledge that the high level of urbanization observed by human settlements in recent decades is a process also experienced in Brazil, with 87.1% of its population living in cities, according to the United Nations (ONU, 2018). However, the UN New Urban Agenda (2019) indicates that, despite the benefits and opportunities provided by the concentration of population and economic activities in urban environments, as well as the understanding that urbanization can represent, with adequate planning and administration, a driving force for sustainable development, this same urbanization challenges the capability to guarantee housing, infrastructure, basic services, health, education, natural resources, among others. The Sustainable Development Goal 11 – Sustainable Cities and Communities, condenses these challenges overcoming (ONU, 2015).

As pointed out by Azeredo and Pacheco (2019), in Brazil, this context results from accelerated urbanization between 1950 and 1980, a period that concentrated the growth of today's medium and large cities. However, the expansion of infrastructure and services necessary to support this contingent of people was not carried out at the same pace. According to Maricato (2015), it is essential to add to this picture a wide use of self-construction in irregular areas, without following any urban legislation, and an urban sprawl provided by the flexibility for accessing different areas of the main transport technology – car and bus – in detriment of rails. These areas, supported by master plans or zoning codes incapable of harmonizing land use and urban transport, resulted in well-known inefficiencies, notably the imbalance between jobs and housing supply in different regions of each city (Maleronka, 2021).



As a planning tool and support instrument for overcoming the cited challenges, the concept of Transit-Oriented Development (TOD) has been highlighted, which constitutes, in a certain way, a rescue of the traditional urbanism practiced before cars were considered the main transport option. Marques (2015) presented this when citing an interview by one of TOD's prominent enthusiasts and researchers, Robert Cervero, in 2012. Although there are minor distinctions between different authors and publications regarding TOD, it can be well understood, especially for this work, by what the Institute for Transportation and Development Policy (ITDP) presents, adding sustainability to this framework, resulting in the following concept of sustainable TOD:

This concept seeks to qualify sustainable transportation (active mobility and public transit), the compact urban development guided by the public transit network (mainly medium and high-capacity ones), a more balanced distribution of urban opportunities in the territory, and the mix of complementary activities (housing, commerce, and services, for example) within neighborhoods. (ITDP, 2017, p. 16, translated by the author)

Although the application of the sustainable TOD concept and its tools might be used in a wide range of cities, with particular attention for them to have a TMA corridor, there is a gap in studies and references of its application in medium-sized cities. According to Motta and da Mata (2009), these cities, in Brazil, which have a population between one hundred thousand and five hundred thousand inhabitants, have shown, population growth rates and gross domestic product higher than large cities, in addition to be privileged places as they have been able to offer qualified services and promote the well-being of their citizens. The cited authors also point to the possibility of strengthening the urban network and, concomitantly, the economic and social development of the country through an urban and regional development policy focused on this type of city, which avoids the diseconomies produced by large cities and metropolises.

In this sense, to strengthen the understanding and possibilities of urban planning aligned to the needs of these types of cities, the present work aims to conduct a survey and an exploratory analysis of urban policies aligned to sustainable Transit Oriented Development (TOD) applied in medium-sized Brazilian cities. Thus, it is intended to contribute so that such human settlements can continue to stand out as places that balance population and economic growth with the quality of life of their inhabitants.

Methods

The study methodology, detailed in the following subtopics, was based on a two-pillar approach: a synthesis of main strategies used to promote sustainable TOD,



carried out through a bibliographical review, and, subsequently, an analysis of the urban legislation of medium-sized cities in the face of such strategies. Thus, it was also necessary to identify which medium-sized cities would meet a minimum criteria to receive sustainable TOD strategies, notably the presence of medium and high-capacity public transit corridors (transporte de média e alta capacidade - TMA).

Delimitation of sustainable TOD strategies

Initially, it is essential to point out that the available materials representing conceptual compendiums, strategies, and cases of good practices in sustainable TOD projects, notably those prepared by Evers *et al.* (2018), ITDP (2017), and Hobbs *et al.* (2021), have different structures in their approach, especially regarding the classification of strategies presented. Despite that, there is an alignment in the synthesis presented by Hobbs *et al.* (2021, pg. 30), emphasizing that “without public transit, there is no TOD.” Along these lines, the existence of medium and high-capacity public transit corridors (TMA) was adopted as an initial criterion for selecting municipalities to be analyzed and later as a guideline for aligning sustainable TOD strategies.

In addition, this study chooses to focus on strategies linked to urban regulation under the competence of city public institutions, which represent the scale of the plan to detriment of the project, in the concept of Evers *et al.* (2018) as well as the level of strategic planning with a lower degree of involvement at the neighborhood scale and unrelated to the implementation of the projects themselves, following the division proposed by ITDP (2017).

The strategies and instruments which served as a research key for reading the urban regulations of selected cities were the following, always highlighting their application in the surroundings of TMA corridor and its stations: transit oriented development; establishment of a basic floor area ratio (FAR) throughout the territory or in the consolidated urban area; establishment of maximum FAR variable throughout territory and higher in the surroundings of the TMA, saled through building rights (Ourtorga Onerosa do Direito de Construir – OODC); minimum number of residential units as a share of the lot size (cota parte máxima); mixed use incentives, mainly through OODC discounts; compulsory building or use of the urban lot through the application of progressive property tax over time (IPTUp); maximum block size suitable for active mobility; definition of coverage areas where sustainable TOD will be structured; zoning that enables or promotes the mixing of uses; establishment of zones for social housing (zonas especiais de interesse social – ZEIS); incentives for urban design that promote active mobility, such as widening the sidewalk, active facade, spaces for public enjoyment on private properties and visual permeability of walls; reduced requirements for parking spaces; establishment of solidarity quota; use of preemption right for acquisition of strategic land for the TMA; establishment of an urban consortium operation (operação urbana consorciada – OUC) or similar instrument.



Definition of analyzed cities

Bearing that TMA is essential for applying sustainable TOD and keeping in line with the study's objective to investigate its application in medium-sized cities, a preliminary survey was carried out for cities that fit both cases. For this, estimates made by the Instituto Brasileiro de Geografia e Estatística (IBGE, 2022) were used for the population residing in Brazilian cities in 2021. Furthermore, cities that are part of metropolitan regions with a population exceeding the limit of five hundred thousand inhabitants were not considered, based on the composition also presented by the IBGE (2021). The exclusion criterion for metropolitan regions was used because it is understood that cities inserted in this context have different dynamics for implementing TMA infrastructure and in the urban regulation itself, highlighting the incidence of integrated urban development plans - Brazilian Federal Law no. 13.089 of 2015.

Regarding the existence of TMA, it was used the ITDP (2020a) consolidated data, which presents all Brazilian cities with operational TMA. According to ITDP criteria, Bus Rapid Transit (BRT), Light Rail Transit (LRT), and Monorail corridors with a minimum classification of Basic according to the BRT Quality Standard can be considered as TMA, as well as ferries, subways, and trains that operate following the criteria established by ITDP (2020b).

Results and discussion

According to IBGE (2022), Brazil contains 277 cities with a population between one hundred and five hundred thousand inhabitants. Of these, 32 have TMA corridors, according to ITDP (2020a), of which only 3 are not part of metropolitan regions also with a population of more than five hundred thousand inhabitants, namely Sobral-CE, Criciúma-SC, and Uberaba-MG. As an initial characterization effort, Table 1 presents the TMA corridors of the analyzed municipalities and their respective populations.

City	Population	TMA type	Start of operation (year)	Length (km)	Number of stations	Average distance between stations (m)
Sobral - CE	212,437	LRT	2016	11.6	12	967
Criciúma - SC	219,393	BRT	1996	6.9	17	406
Uberaba - MG	340,277	BRT	2016	5.0	12	417

Table 1 – General characterization of TMA corridors. Made by the author with data from IBGE (2022) and ITDP (2020a).



There is a significant difference in the distance between the stations of the LRT present in Sobral-CE, in addition to its greater length, compared to other cities with BRT. In this case, sustainable TOD strategies on the LRT could have more significant advantages if linked directly to the stations' surroundings, focusing on the locations with easy access. With reduced station distances, the BRT indicates the possibility of a more linear, sustainable TOD treatment along the entire corridor, making it possible to provide special treatments to specific stations and terminals.

Once the initial characterization of the cities and TMA corridors has been carried out, the study of the urban regulation of each one of them is presented. The legislation consulted is shown in Table 2, which includes all subsequent changes until the production of this paper. As an initial emphasis, it was not possible to find mentions of sustainable TOD or similar terminology, and the established city zoning does not explicitly indicate the relationship with TMA corridors and stations in their descriptions, guidelines, and objectives. Mentions were made aligned to areas in the city provided by infrastructure in general.

City	Legislation and year
Sobral - CE	Plano Diretor – Law no. 028/2008 (Master Plan)
	Parcelamento, uso e ocupação do solo – Law no 006/2000 (land subdivision and use)
Criciúma - SC	Plano Diretor – Law no. 95/2012 (Master Plan)
	Outorga Onerosa e a Transferência do Direito de Construir – Law no. 164/2015 (OODC and TDC)
	Parcelamento do solo – Law no. 7.999/2021 (land subdivision)
Uberaba - MG	Plano Diretor – Law no. 359/2006 (Master Plan)
	Uso e ocupação do solo – Law no. 376/2007 (land use)
	Parcelamento do solo urbano – Law no. 375/2007 (land subdivision)

Table 2 – Cities legislation consulted. Made by the author.

Although no specific zoning is observed along the TMA corridors or its stations, these are aligned with zones that point to greater density and mix of uses. In the case of Sobral, the network serves the zones with preferences to increment population density, priority of lot occupation, and zones assigned for social housing (ZEIS), as well as the CDB or central zones and the ones for economic promotion.



In Sobral, the zones with preferences to increment population density (zonas de adensamento preferencial - ZAP) and occupation priority (zonas de ocupação prioritária - ZOP) have the highest FAR in the city – 2.5 and 3.0, respectively, while in the CDB or central zones (ZEIP, ZCE, and ZCR), this value is 2.0. All these zones are suitable for a wide range of land uses to comply with Article 44, item XVI of its Master Plan, which indicates, as a guideline of the Municipal Urban Mobility Policy, “to promote the integration of urban mobility policies, use and control of land” (Sobral, 2008).

There is no establishment of a basic FAR throughout the territory or, at least, for the zones in which more intensive land occupation is allowed, nor maximum FAR to be reached by building rights (OODC), as the instrument is not even regulated in the city. Figure 1 shows the TMA corridor and zoning of Sobral.

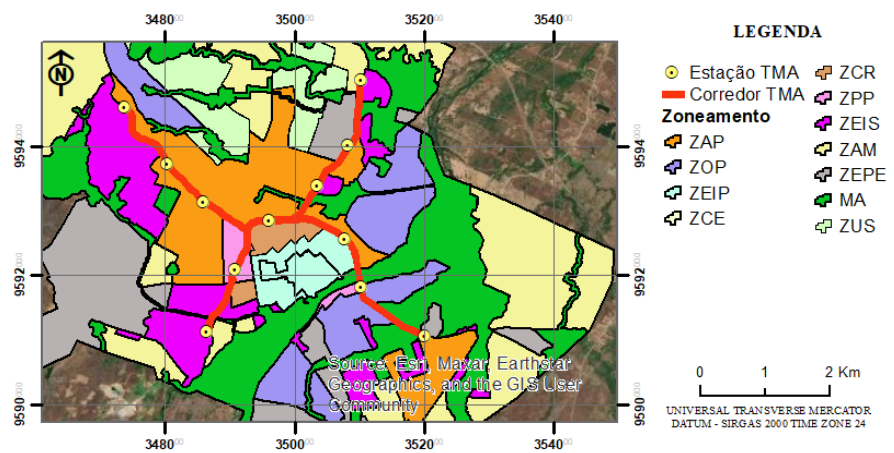


Figure 1 – MCT corridor and zoning of Sobral – CE. Elaborated by the author with data from Sobral (2000).

In Uberaba, most of the BRT corridor is in the Macrozone of Controlled Densification (Macrozona de Adensamento Controlado - MAC), which has a FAR among the highest in the city, with basic values of 3.0, which can reach, in certain zones within the macrozone, to the value of 4.5 on lots adjacent to arterial streets, using the OODC or receiving building rights from transfer of right to build (transferência do direito de construir - TDC). The Urban Consolidation Macrozone (Macrozona de Consolidação Urbana - MCU), which surrounds the MAC, has a basic FAR of 3.5 and a maximum of 4.5 in most of its area, making it possible, according to the urban legislation, to absorb greater density, even if only one of the terminals at the end of the TMA corridor are in this macrozone, as shown in Figure 2.



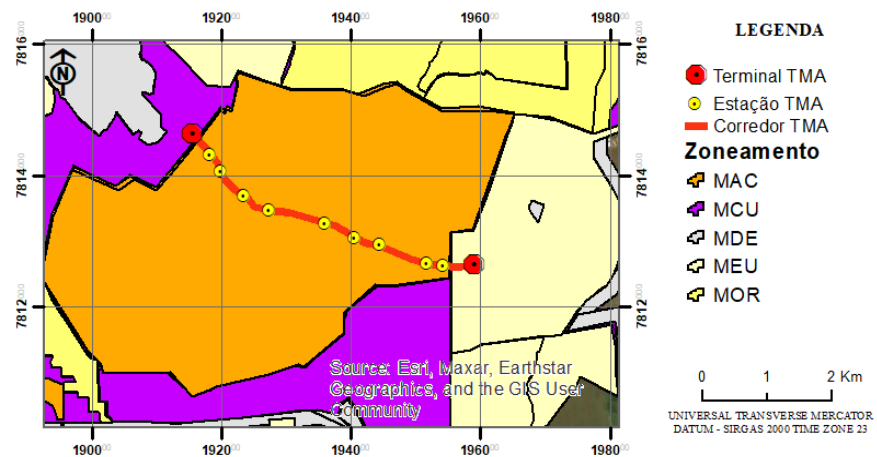


Figure 2 – TMA corridor and zoning of Uberaba. Elaborated by the author with data from Uberaba (2007b).

The FAR distribution, in general, follows the guidelines inserted on its Master Plan for municipal transport system – article 149, item V, and for the use and occupation of urban land, indicating the incremental population density close to the public transit network. Regarding the activities permitted by the land use and occupation law, the diversity of possibilities is perceived to be similar to what was observed in Sobral (Uberaba, 2006 and 2007b).

Among the analyzed cities, Criciúma is the one with the most distinct zoning, as can be seen in Figure 3. It is possible to notice that, along the TMA corridor, the mixed zone 1 (zona mista 1 - ZM1) predominates, which, as described in article 143, item 1, of its Master Plan, is applied only to lots facing the avenue that receives the corridor. In addition, wider zones stand out, the commercial zones 1, 2, and 3 (zonas comerciais 1, 2 e 3 - ZC1, ZC2, and ZC3), which are established around the TMA terminals, except for ZC 3, where the corridor is interrupted outside of a terminal (Criciúma, 2012).

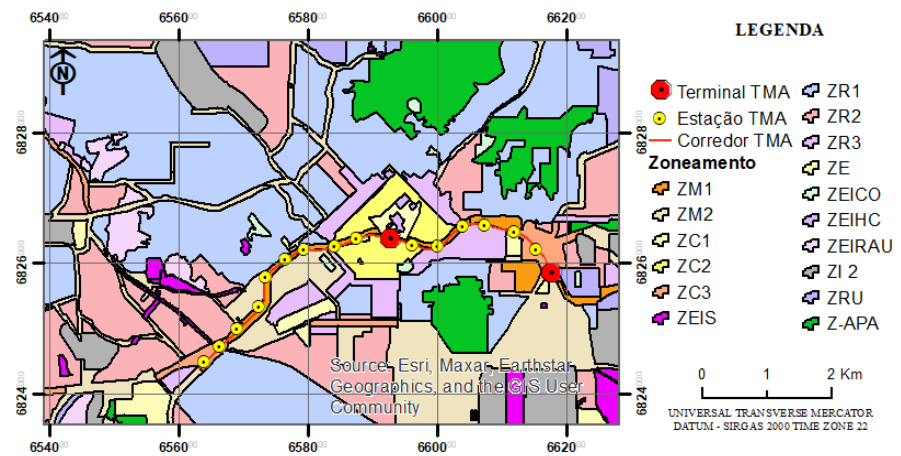


Figure 3 – TMA corridor and zoning of Criciúma-SC. Elaborated by the author with data from Criciúma (2012).



Regarding the FAR, the zones that offer the most significant values in the city are also those mentioned before, with a basic value of 3.0 in ZM 1-8 and 3.5 in ZM1-16 and ZC 2-16. Through OODC (Criciúma, 2015), it is possible to raise the FAR to 4.0 in these zones. In ZC 3-5, the basic FAR is 2.5, and the maximum is 3.0. This is the basic value for the FAR in ZC 3-8, too, where the acquisition of building rights is not possible. For land use, as observed in Sobral and Uberaba, the zones allow for the installation and operation of a wide range of activities.

In addition to the OODC, it is possible to highlight the regulation of compulsory building or use of the urban lot through the application of progressive property tax over time (IPTUp) in the three municipalities analyzed, specifically in the areas served by the corridors. As for the social housing zones (ZEIS), only Sobral has a significant number of them demarcated and served by the TMA corridor.

The application of a minimum number of residential units as a share of the lot size (cota parte máxima), the incentive to allocate spaces for public enjoyment on private properties and active facades, as well as solidarity quota and reduced requirements for parking spaces, were not observed in any of the municipalities analyzed. For visual permeability on facades and walls, only Criciúma indicates, in its Master Plan (Law no. 95/2012), article 229, item II, the use of hollow or translucent elements in walls from a height of 1.5 m (Criciúma, 2012).

Mentions regarding the widening of sidewalks are only observed in Uberaba. However, it is not applied in the zone where most of its TMA corridor was implemented (Zona de Comércio e Serviço 1 – ZCS 1). This is also the only city to identify the areas destined for preemption rights, some of them close to the corridor identified for road improvements, which may include expanding sidewalks and inserting cycle paths. However, this is not explicit in legislation. The preemption right is also applied to buildings listed for historical and cultural preservation, which have no direct relationship with sustainable TOD strategies.

The instrument of Urban Consortium Operation (Operação Urbana Consorciada - OUC) has delimited areas in Criciúma and Uberaba. In the first one, the area mentioned in article 79 of its Master Plan, where the Heriberto Hulse stadium is located, is approximately 300 meters from its TMA corridor, which can enhance the surroundings in a sustainable TOD context. In the case of Uberaba, the areas are located at quite significant distances. However, in both cities, OUCs were not regulated or effectively started, relying only on mentions in respective master plans.

Regarding the mixing of uses around the corridors, although in the three municipalities the zoning allows for a diversity of activities, only Sobral presents a differentiated initiative for its promotion in buildings, considering as non-computable in the calculation of FAR, for this purpose, areas that are destined to commercial and services on the ground floor of buildings that also present residential use above, which was appeased by change in its land use law carried



out in 2018. On the other hand, regarding maximum block sizes for providing more connectivity by active modes, Criciúma stands out with the requirement of a maximum dimension of 180 meters, in line with the recommendations of Evers *et al.* (2018) and ITDP (2017), unlike Uberaba and Sobral, which present values between 250m and 300m (Criciúma, 2021; Sobral, 2000; Uberaba, 2007a).

To facilitate the visualization of the strategies used in the analyzed cities, a summary is shown in Table 3. The presence of the strategy in the table does not necessarily indicate its use linked to a sustainable TOD policy, as previously discussed.

As explained before and through the reading of the summary available in Table 3, it is possible to see that none of the cities broadly adopts, through its urban regulations, a sustainable TOD program of strategies. In general, the consulted legislation explicitly mentions the need for greater intensity and diversity of land use occupation in places where infrastructure is available, although without directly mentioning TMA corridors.

In this sense, it is possible to observe that the strategy used in the three cities, which, in theory, is in line with sustainable TOD, is to provide greater FAR and allow mixed uses in zones that contain the TMA. However, as pointed out by Maleronka (2021), there is a clear distinction between allowing diversity and intensity of land occupation and the effective induction of this behavior, which requires a restriction of unwanted dynamics to the sustainable TOD concept.

As an example, the author cites the need to restrict dispersed urbanization through an adequate definition of the urban perimeter, which it is possible to add the indication by Evers *et al.* (2018) for establishing a basic FAR equal to 1.0 throughout the territory, allowing more significant management of real estate valuation and its use in sustainable TOD strategies. In the analyzed cities, in contrast to these recommendations, it is understood that there is much more a strategy aligned with allowing than with inducting, considering that FAR, like those of the areas surrounding the corridors, and sometimes even higher, are dispersed over large areas of territory.

It is also a lack of use of instruments that allow greater integration of private and public spaces to enhance mobility by active modes, as well as actions that discourage the use of cars, besides the diversification of housing patterns, considering the groups of actions proposed by Evers *et al.* (2018). The use of ZEIS, for example, which can promote demographic and income diversity in the case of areas with a concentration of jobs and public facilities, following what is indicated by ITPD (2017), has an application observed only in the surroundings of Sobral's LRT, and stand out for focusing on occupations with lower incomes that are already consolidated. In any case, this strategy aligns with the cases of informal settlements without infrastructure and low socioeconomic status listed by the same author.



Strategy	City		
	Sobral CE	Criciúma SC	Uberaba MG
Direct guidelines for sustainable TOD	N	N	N
Specific zoning*	N	Y	N
Zoning that allows mixed use*	Y	Y	Y
Basic and equal FAR throughout the territory	N	N	N
Maximum FAR Variable throughout the territory and greater on the surroundings of TMA corridors and its stations, acquired by OODC	N	Y	Y
Minimum number of residential units as a share of lot size*	N	N	N
Incentives for mixed use on buildings through OODC discounts or similar	N	N	N
Compulsory building or use of the urban lot through the application of progressive property tax over time (IPTUp)*	Y	Y	Y
Maximum block size suitable for active mobility	N	Y	N
Establishment of social housing zones (ZEIS)*	Y	N	N
Sidewalk widening*	N	N	Y
Active facade*	N	N	N
Incentives to spaces for public enjoyment on private properties	N	N	N
Visual permeability of walls*	N	Y	N
Reduced requirements for parking spaces *	N	N	N
Solidarity quota*	N	N	N
Preemption right*	N	N	Y
Urban consortium operation (OUC)*	N	N	N

Table 3 – Summary of strategies used in analyzed cities. Elaborated by the author based on legislation mentioned throughout this paper. Y – Yes; N – No. *It refers to applying these strategies in the surrounding TMA corridors and stations.

Still, it is considered that, except for the Master Plan of Criciúma, which received significant changes in 2022, the other regulations had such changes in 2016 and 2018, when the central technical guides published in Brazil concerning sustainable TOD were being prepared or recent released, corroborating the statement that “Transit Oriented Development is still not widespread used in territorial strategies and urban projects in Brazilian cities and metropolitan regions,” carried out by Hobbs *et al.* (2021, pg. 60, translated by the author).

FINAL CONSIDERATIONS

The work was able to fulfill its objective, carrying out the analysis of urban policies aligned with sustainable TOD applied in the three medium-sized Brazilian cities that have TMA corridors and are not part of metropolitan regions with more than



five hundred thousand inhabitants, namely, Sobral- CE, Criciúma-SC, and Uberaba-MG. It was possible to identify that most medium-sized cities with such corridors are inserted in metropolitan regions.

None of the analyzed cities had a straightforward adoption of the sustainable TOD concept and its associated strategies in their urban legislation. Although some strategies are used, such as allowing mixed uses and higher FAR in areas served by TMA, they are not accompanied by a territorial design or zoning with pre-defined distances from these corridors or with inhibition of unwanted dynamics related to sustainable TOD that may be occurring in other areas of the city. Thus, it is possible to identify an attempt to align the availability of urban infrastructure with the intensity of uses and occupation, as explicitly postulated in the master plans and land use laws studied, but without the intention of enhancing gains arising from an alignment with the specific TMA infrastructure that conditions sustainable TOD.

Finally, further studies related to other medium-sized Brazilian cities are recommended, even those integrated into large metropolitan regions, making it possible to identify adopting sustainable TOD or managing land use and occupation in general. In addition, it can also be verified whether sustainable TOD strategies are adopted in any medium-sized city, even outside the country, to identify their potential benefits and real applicability in the context of cities of this size. It would allow conclusions for necessary adaptations concerning what is being done in the examples presented in the technical guides, which emphasize large metropolitan regions.

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