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Experiences on the application of the Sustainable Urban Mobility Index (IMUS) in Brazilian and foreign cities

Leandro Augusto Erba
Master's degree, PPGARQ -UNESP, Brazil
leandro.erba@unesp.br

Jeferson Fernando Corrêa Antonelli
Master's degree, PPGARQ -UNESP, Brazil
j.antonelli@unesp.br

Renata Cardoso Magagnin, PhD
PhD Professor, PPGARQ - UNESP, Brazil
renata.magagnin@unesp.br

ABSTRACT

The lack of effective instruments to control and monitor urban mobility has had a direct impact on the management of municipalities. The Sustainable Urban Mobility Index (IMUS, in Portugese) is an instrument that aims to support urban mobility planning, based on a list of indicators that allow the assessment of different aspects of sustainable urban mobility. However, some indicators are still not easily accessible in the municipalities, either due to the lack of data or the absence of information made available in an aggregated form, a numerical value for example. Given this context, this article presents a comparative analysis of studies that applied the IMUS in different cities in Brazil and abroad, in order to identify which indicators of urban mobility are still difficult to access in the municipalities where the IMUS was applied. Theses and dissertations or other academic works that used the IMUS, developed between 2008 and 2019, with the theme adhering to the title "Index of Sustainable Urban Mobility (IMUS)" were selected. The analysis of the works allowed to identify: (i) which indicators are still difficult to access to assess urban mobility, by municipality size, and (ii) a comparative analysis of the index result for the Domains, Themes and Indicators, in the evaluated cities.

KEYWORDS: Sustainable Urban Mobility. Sustainable Urban Mobility Indicators. Sustainable Urban Mobility Index (IMUS).

1 INTRODUCTION

The main role of cities is to maximize the exchange of goods and services, culture and knowledge among their inhabitants, but this is only possible if there are adequate mobility conditions for their citizens. In this sense, mobility is understood as an attribute associated with the city, and corresponds to the ease of moving people and goods in the urban area. Mobility translates the relationships of individuals with the space in which they live, with the objects and means used for their displacement and with the other individuals that make up society (BRAZIL, 2006).

A fundamental factor for the socioeconomic development of any city has a safe and reliable transport system for people and goods that respects the environment. However, this has been a great challenge for public managers. Problems with the management of urban mobility occur all over the world and it has become a challenge for managers and researchers in the area. Researches on this topic indicates the need to have an instrument capable of evaluating and monitoring the performance of urban mobility in its environmental, social and economic aspects, such an instrument would be useful for the formulation of new public policies (VASCONCELLOS, 2001).

Improving urban mobility policies and applying a vision of sustainability to them has been the great challenge faced by public managers. And for this challenge to be faced, it is important to have a good knowledge of the needs of citizens living in urban centers and a new vision of the concept of urban mobility. This vision must be focused on sustainability (COSTA, 2008).

According to the United Nations World Commission on Environment and Development, sustainability is, in short, meeting the needs of the present without compromising future generations (LITMAN, 2017). This definition is incorporated into the new concept of sustainable urban mobility that improves the quality of life for all, including the three principles of sustainability: social, environmental and economic (COSTA, 2008).

The national urban mobility policy expands this definition by mentioning that sustainable urban mobility is associated with a set of circulation and transport policies that seeks to provide broad and democratic access to urban space, through the prioritization of collective and non-motorized transport modes of an effective, socially inclusive and ecologically sustainable way (SEMOB, 2005).

From this definition, it is necessary, therefore, that the concept associated with urban mobility undergoes changes, mainly by managers, who need to be increasingly trained, not only in the area of transport, but mainly in the area of environmental sustainability, in order to develop a strategic vision increasingly focused on sustainable urban mobility projects.

The practical measures for building sustainable urban mobility are land occupation in a more concentrated and compact manner, allowing a connection to the public transportation network in order to increasingly promote public transportation, restricting the use of private cars, balance and integration between the different modes of transport, efficient use of energy resources, implementing technology for sustainable transport, reducing the need for individual motorized transport, controlling urban growth, encouraging non-motorized modes, integrating people with special needs, improving public transport and apply fairer tariffs, among other actions (BRAZIL, 2006; MAGAGNIN, 2008).

It is important to consider that, although the problems with urban mobility are global, it is impossible to say that they are the same in all cities, as they depend on several factors such as culture, level of development, available resources, infrastructure, etc. Therefore, the study of mobility must be done locally, identifying the problems of each city and based on its characteristics, proposing adequate solutions for each reality (VASCONCELLOS, 2014).

In order to diagnose and monitor urban mobility, some cities in Brazil and abroad have used performance indicators and indices, which help to simplify complex information in order to improve its understanding by decision-makers. Some countries in Europe, the United States and Canada have adopted indicators as a way to assess and monitor mobility at the local level (MAGAGNIN, 2008).

The country's current urban mobility policy defines that in the development of Municipal Transport and Mobility Master Plans, it is necessary to incorporate a list of indicators that allow for the assessment or measurement of transport and mobility problems in the municipality. These indicators are intended to “provide information about problems, support policy development and establish priorities, monitor defined actions and be a tool to disseminate knowledge” (PIRES, 2018).

Costa (2008) defines indicators as parameters or instruments that make it possible to assign some type of measure to a given problem or object of interest, in order to reduce its complexity. Wong (2006) adds that they can be used to justify and rationalize the distribution of resources and help in defining public policy guidelines, by transforming abstract concepts into concrete measures, so they are tools to support decision-making (NICOLAS; POCHET; POIMBOEUF, 2003).

However, in most cases, just one indicator is not enough to assess a particular object, it is necessary to use a set of indicators. According to Litman (2005), to define the best set of indicators, those with the greatest diversity of dimensions evaluated (more comprehensive) should be included, and which can be applied to planning decisions, which are easy to understand, using available data, easy to collect, allowing comparison and goal setting. The author also adds that it is important to note the number of indicators, as a very large set can have high collection costs and difficult interpretation, while a very small set can miss important impacts that should be analyzed (LITMAN, 2005).

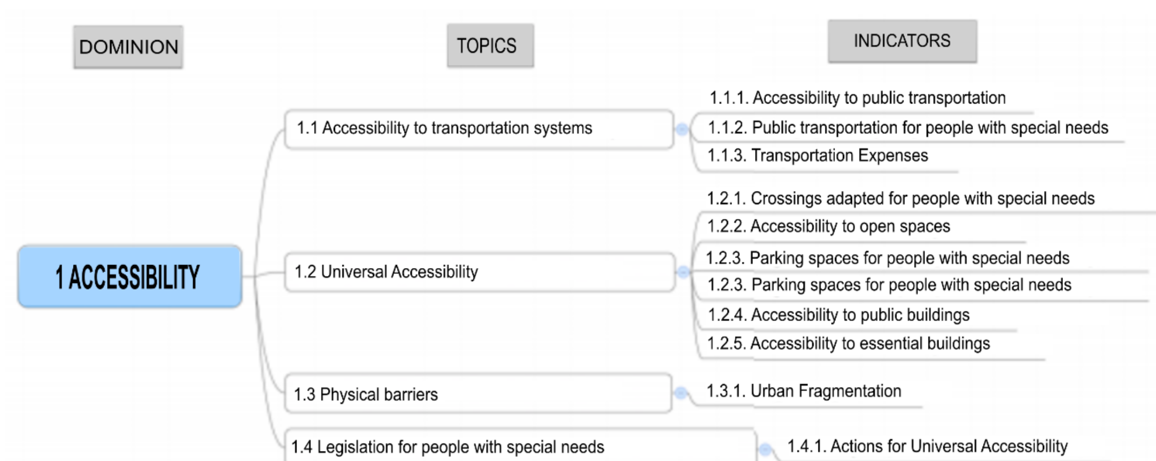
The Sustainable Urban Mobility Index – IMUS, developed by Costa (2008) is a system of indicators that can be adopted in a process of planning and monitoring urban mobility by municipalities.

The hierarchical structure of the index comprises nine domains, thirty-seven themes and eighty-seven indicators. Each theme is associated with a sustainability dimension (social, economic and environmental), so the results obtained can be related to the impacts of each action that may impact one of these 3 dimensions of sustainability (COSTA, 2008).

IMUS adopts a weighting system to assess indicators. It makes it possible to identify the relative importance of each criterion globally and by sustainability dimension. The index also presents assessment scales for each Indicator, allowing verification of performance against pre-established goals and carrying out comparative analysis between different geographic regions.

According to the author, the application of the index allows the identification of critical factors and factors of greater impact for improving of global and sectoral aspects of urban mobility, providing subsidies for the proposition of policies and strategies aimed at improving sustainable urban mobility. The compatibility of the results obtained according to the calculation of indicators and expeditious analysis carried out by an expert suggests that the IMUS provides reliable results for monitoring the conditions of urban mobility in medium and large cities. Figure 1 shows a part of the IMUS hierarchical structure, based on the Accessibility domain.

Figure 1: Detail of the Accessibility domain's hierarchical structure – IMUS.



Source: Costa, 2008.

2 OBJECTIVE

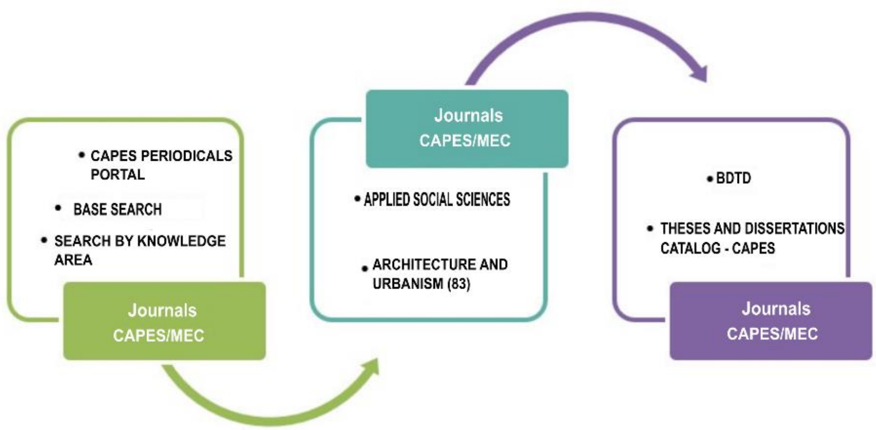
This article presents a comparative analysis of the results of the application of the Sustainable Urban Mobility Index (IMUS) in different cities in Brazil and abroad, to identify which indicators of urban mobility are still difficult to access in the municipalities where the application of the IMUS.

3 METHODOLOGY

The protocol for the review and selection of articles was based on the systematic review works developed by Kitchenham (2004), Gough, Thomas and Oliver (2012) and Muianga, Granja and Ruiz (2015), which incorporate 3 steps (1) identification of electronic databases and definition of search criteria, (2) definition of parameters for data analysis and collection, and (3) analysis and synthesis of results.

In the first stage, it was decided to carry out the search for articles in the platform of the Brazilian Digital Library of Theses and Dissertations – BDTD and in the Theses and Dissertations Catalog (Figure 2). The keywords used were: Sustainable urban mobility index and IMUS (in the database - BDTD), and IMUS (in the database - Theses and dissertations catalog).

Figura 2: Study location path.



Source: The Authors, 2021.

The first selection of articles was carried out after reading the titles of dissertations and theses. 39 studies were identified; however, 26 studies were excluded because (i) they were not adhering to the theme (18 articles), that is, they did not contain the application of the IMUS and (ii) documents in duplicate between the databases, 9 articles (Table 1). Afterward, the abstract and full text of the works were read, three documents were excluded, as they did not assess all domains. In total, 13 works were identified, being 12 applied in municipalities in Brazil, and 1 in Colombia. The

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13 selected works were classified by the size of the cities where the studies were carried out. For this classification, population data in the year of application of the IMUS were adopted.

Table 1: First and second stages of study selection.

Stage	Research database	Keywords	Search Results	Duplicity	Works without adhesion	Inclusion
1ª stage	BDTD	Índice de mobilidade urbana sustentável AND IMUS	15	9	15	8
	Catálogo de teses e dissertações	IMUS	24			7
2ª stage	BDTD / Theses and dissertations catalog	Total of documents	Deleted - Full Text Analysis		Inclusion of TCC	Total of studies
		15	3		1	13

Source: The Authors, 2021.

In stage 2, the parameters to be collected were defined: all the results found by the authors regarding the application of the IMUS. And, the 3rd stage (analysis and synthesis of results) was carried out from the quantification of information regarding the indicators used (Global IMUS, data availability, data quality, analysis of IMUS results by domain), as well as the identification of indicators whose data were not used due to a lack of information in the municipality surveyed.

4 RESULTS AND DISCUSSIONS

In this section, the results are presented on the basis of a general characterization of the works, and then a breakdown of the data by the domain is presented.

Of the 13 cities where the IMUS were applied, it is observed that 53.8% are considered metropolises, and 23.1% are, respectively, large and medium-sized cities (Table 2).

Table 2: Cities evaluated in the study.

Size	City/State and year of IMUS application	Population in the year of IMUS application	Author/Year
Metropolis	Rio de Janeiro, Rio de Janeiro (2018)	6.320.326	Costa (2018)
	Brasília, Distrito Federal (2010)	2.570.160	Pontes (2010)
	Medellín, Colômbia (2017)	2.308.000	Jimenez (2017)
	Curitiba, Paraná (2010)	1.751.907	Miranda (2010)
	Belém, Pará (2012)	1.393.399	Azevedo Filho (2012)
	Goiânia, Goiás (2013)	1.302.001	Abdala (2013)
	Campinas, São Paulo (2017)	1.182.429	Ribeiro (2017)
Large City	Teresina, Piauí (2018)	847.430	Brito Júnior (2018)
	Natal, Rio Grande do Norte (2014)	803.739	Costa (2014)
	Uberlândia, Minas Gerais (2012)	604.013	Assunção (2012)

Medium City	Bauru, São Paulo (2018)	374.271	Erba e Lima (2018)
	Anápolis, Goiás (2012)	334.613	Morais (2012)
	São Carlos, São Paulo (2008)	221.950	Costa (2008)

Source: The authors, based on IBGE, 2020.

All dissertations, theses and other works fully analyzed the domains and themes proposed in the IMUS, however, with regard to indicators, none of them fully evaluated the 87 indicators. The cities of São Carlos, Uberlândia, Natal and Brasília were those that evaluated a greater number of indicators (from 77 to 80), Table 3.

Table 3: Systematization of the parameters evaluated in the different academic works.

SIZE	City	Indicators number evaluated	Number of indicators with missing data	GLOBAL IMUS
Metropolis	Rio de Janeiro	69	18	0.408
	Brasília	78	9	0.486
	Medellín	45	42	0.659
	Curitiba	75	12	0.754
	Belém	64	23	0.380
	Goiânia	85	2	0.658
	Campinas	76	11	0.535
Large City	Teresina	50	37	0.425
	Natal	77	10	0.510
	Uberlândia	80	7	0.717
Medium City	Bauru	66	21	0.435
	Anápolis	70	17	0.419
	São Carlos	80	7	0.578

Source: The Authors, 2021.

It was identified that 13 academic works analyzed the municipality as a whole and the global IMUS ranged from 0.380 (Belém) to 0.754 (Curitiba). This difference in values occurred due to the number of indicators evaluated and the evaluation of indicators in each County. The Brazilian cities whose global IMUS reached the highest values were Campinas (0.754) and Uberlândia (0.717). The Colombian city of Medellín obtained a relatively high index (0.659), however, it is noteworthy that many indicators were not collected due to lack of information, 48% of the indicators was not evaluated.

Regarding the number of indicators without evaluation, the cities that had greater difficulty in obtaining data were Medellín (42 indicators) and Teresina (37 indicators). Table 4 brings this list of indicators with unavailable information by city.

Table 4: List of indicators with unavailability of information in the cities.

Size	City	Indicator with missing data
Metropolis	Rio de Janeiro	Crossings adapted for people with special needs, Accessibility to open spaces, Accessibility to public buildings, Accessibility to essential services, Population exposed to traffic noise, Fundraising, Paved roads, Roads with sidewalks, Vitality of the center, mixed use index, Compliance with urban legislation, Average traffic speed, Violation of traffic laws, Vehicle occupancy rate, Frequency of public transport service, Punctuality, Clandestine transport, Public subsidies.
	Brasília	CO Emissions, CO_2 Emissions, Population exposed to traffic noise, Density and connectivity of the road network, Bicycle fleet, Vitality of the center, Compliance with urban legislation, Prevention of accidents, Violation of traffic laws.
	Medellín	Accessibility to public transport, Accessibility to open spaces, Parking spaces for special needs, Accessibility to public buildings, Accessibility to essential services, Urban fragmentation, Fuel consumption, Vertical equity (income), Participation in decision making, Integration between levels of government, Public-private partnerships, Fundraising, Distribution of resources (collective vs. private), Distribution of resources (motorized vs. non-motorized), Density and connectivity of the road network, Infrastructure maintenance expenses, Roads for public transport, Roads for Pedestrians, Roads with sidewalks, Travel distance, Level of training of technicians and managers, Training of technicians and managers, Vitality of the center, Inter-municipal consortia, Transparency and responsibility, Urban growth, mixed use index, Irregular occupation, Urban, environmental and integrated transport planning, Effectiveness and continuity of actions, Park and green areas, Urban equipment (health clinics), Urban legislation, Compliance with urban legislation, Education for the Traffic, Congestion, Average traffic speed, Violation of traffic laws, Extension of the public transport network, Frequency of public transport service, Punctuality, Public subsidies.
	Curitiba	Accessibility to Public Buildings, CO Emissions, CO_2 Emissions, Vertical Equity (income), Road Signaling, Travel Distance, Travel Time, Trip Number, Accident Prevention, Congestion, Public transport X Individual transport, Non-motorized modes X motorized modes.
	Belém	Accessibility to public transport, Accessibility to public buildings, CO Emissions, CO_2 Emissions, Fundraising, Investments in transport systems, Distribution of resources (collective x private), Density and connectivity of the road network, Expenses with infrastructure maintenance, Bicycle fleet, Travel distance, Travel time, Travel number, Level of training of technicians and managers, Training of technicians and managers, Vitality of the center, Urban voids, Urban growth, Park and green areas, Compliance with urban legislation, Extension of the public transport network, Punctuality, Non-motorized modes X motorized modes.
	Goiânia	Travel distance and travel time.
	Campinas	Accessibility to public buildings, Population exposed to traffic noise, Distribution of resources (collective vs. private), Distribution of resources (motorized vs non-motorized), Road signs, Bicycle fleet, Vitality of the center, Urban growth, Accident prevention, Education for traffic, Violation of traffic laws.
Large City	Teresina	Accessibility to public transport, Transport expenses, Crossings adapted for people with special needs, CO Emissions, CO_2 Emissions, Population exposed to traffic noise, Fuel consumption, Vertical equity (income), Quality of life, Fundraising, Distribution of resources (collective vs. private), Distribution of resources (motorized vs. non-motorized), Density and connectivity of the road network, Paved roads, Infrastructure maintenance expenses, Road signaling, Bicycle fleet, Pedestrian roads, Roads with sidewalks, Trip distance, Trip time, Trip number, Level of training of technicians and managers, Training of technicians and managers, Vitality of the center, Urban voids, Urban growth, index of mixed use, Irregular occupation, Prevention of accidents, Congestion, Violation of traffic laws, Vehicle occupancy rate, Punctuality, User satisfaction with

Size	City	Indicator with missing data
		the public transport service, Public transport X individual transport, Non-motorized modes X motorized modes.
	Natal	Parking spaces for special needs, Accessibility to public buildings, Population exposed to traffic noise, Vertical equity (income), Fundraising, Infrastructure maintenance expenses, Road signaling, Training of technicians and managers, Vitality of the center, Satisfaction of the user with the public transport service.
	Uberlândia	Accessibility to open spaces, Distribution of resources (motorized vs. non-motorized), Density and connectivity of the road network, Bicycle fleet and pedestrian paths, Urban growth and Accident prevention.
Medium City	Bauru	Crossings adapted for people with special needs, Parking spaces for special needs, Accessibility to public buildings, CO Emissions, CO_2 Emissions, Population exposed to traffic noise, Environmental impact studies, Vertical equity (income), Quality of life, Fundraising, Distribution of resources (collective vs. private), Distribution of resources (motorized vs. non-motorized), Infrastructure maintenance expenses, Bicycle fleet, Bicycle parking, Effectiveness and continuity of actions, Park and green areas, Accidents with Pedestrians and Cyclists, Traffic Law Violation, Vehicle Occupancy Rate, Non-Motorized Modes X Motorized Modes.
	Anápolis	Transport expenses, CO emissions, CO_2 emissions, Vertical equity (income), Quality of life, Road signs, Bicycle fleet, Travel distance, Travel time, Travel number, Training of technicians and managers, Congestion, Speed traffic average, Vehicle occupancy rate, Punctuality, Public transport X individual transport, Non-motorized modes X motorized modes.
	São Carlos	Accessibility to public buildings, Quality of life, Fundraising, Road signaling, Bicycle fleet, Effectiveness and continuity of actions, Accident prevention.

Source: The Authors, 2021.

Analyzing the unavailable data by municipalities, it is observed that the domain with the greatest lack of data was “Non-motorized mode”, with the indicators “bicycle fleet” and “travel distance” being those with the greatest lack of data. In general, each city had a lack of data on specific indicators.

Another relevant information in the IMUS refers to the quality of data available in the municipalities. According to Costa (2008), this information refers to the updating, coverage and disaggregation (regions of the city) of the data, in addition to its documentation and knowledge of the methodology used to obtain it. The crossing of information related to the availability and quality of the base data allows the identification of viable indicators to be measured in the short term and with good data quality. The results referring to the analyzed works can be visualized in an aggregated way (each author presents the results individualized by domain), in Table 5.

Table 5: Global data quality and availability.

City	Data availability (%)			Data quality (%)		
	Short-term	Mid-term	Long-term	High	Medium	Low
Rio de Janeiro	79	11	9	37	24	5
Brasília	80	20		56	17	27
Medellín	85	2	13	87	-	13
Curitiba	93	1	6	86	5	9
Belém	79	21		48	26	5
Goiânia	91.9	5.7	2.3	67.8	28.7	3.4
Campinas	83	2	13	87	-	-
Teresina	Not available					
Natal	76	5	19	80	7	13
Uberlândia	92	1	-	61	7	24
Bauru	86	14	39	34	39	24
Anápolis	77	22	1	44	40	16
São Carlos	82	-	8	68	17	7

Source: The Authors, 2021.

Regarding the availability of short-term data, the evaluated municipalities are in the range of 76% to 93%. For long-term data, the difficulty in obtaining available data for IMUS assessment in the municipalities of Bauru (39%), Natal (19%), and Campinas and Medellín (both with 13%) stands out. Regarding the quality of the documents made available by the municipalities, making a comparison regarding the quality of the data, it is observed that the cities of Medellín (87%), Campinas (87%), Curitiba (86%) and Natal (80%) achieved a rate greater than 80% with high quality data.

Table 6 shows the result of the IMUS by domain and by municipality. In summary, the data show that among the domains, the lowest values are related to “Motorized Modes”, in most cities analyzed. The highest values correspond to “Social Aspects”. Next, a breakdown of the data by the domain is presented.

Table 6: Average of results by domain.

City	Accessibility	Environmental aspects	Social aspects	Political aspects	Infrastructure	Non-motorized mode	Integrated Planning	Traffic and urban circulation	Urban transport system
Rio de Janeiro	0.50	0.76	0.54	0.67	0.11	0.35	0.52	0.26	0.45
Brasília	0.42	0.17	0.61	0.61	0.33	0.29	0.48	0.48	0.53
Medellín	0.54	0.56	0.86	1.00	0.68	0.50	0.51	0.77	0.67
Curitiba	0.69	0.83	0.89	0.65	0.95	0.46	0.85	0.65	0.71
Belém	0.46	0.25	0.55	0.38	0.21	0.18	0.41	0.56	0.34
Goiânia	0.62	0.60	0.87	0.69	0.74	0.47	0.74	0.60	0.47
Campinas	0.60	0.82	0.75	0.63	0.63	0.36	0.60	0.58	0.38
Teresina	0.21	0.13	0.80	0.75	0.00	0.08	0.53	0.65	0.57
Natal	0.59	0.42	0.74	0.48	0.61	0.52	0.65	0.43	0.40
Uberlândia	0.74	0.73	0.92	0.71	0.78	0.48	0.64	0.71	0.57
Bauru	0.87	0.27	0.36	0.25	0.54	0.57	0.51	0.43	0.54
Anápolis	0.33	0.38	0.53	0.43	0.59	0.11	0.46	0.66	0.52
São Carlos	0.60	0.60	0.56	0.42	0.88	0.55	0.52	0.81	0.45

Source: The Authors, 2021.

Accessibility domain – Among the cities analyzed, Teresina and Anápolis have a low accessibility index (0.21), while Curitiba and Uberlândia presented the best results, 0.69 and 0.74. The justification given by Teresina was that of the 10 indicators evaluated in this theme, only 4 were calculated due to the unavailability of information in the municipality. Bauru has the best average (0.87), however this does not seem to be in line with the reality observed by the authors Erba and Lima (2018) who emphasized that the quality of data collected in this domain was low, as they came from interviews with managers of the municipality, which is not considered ideal for applying the IMUS (Table 6). The indicator with the lowest evaluation refers to crossings adapted for people with special needs (in the cities of Goiânia, São Carlos, Anápolis, Belém, Teresina, Campinas, Rio de Janeiro and Bauru).

Environmental aspects domain - The data show that Curitiba, Campinas and Rio de Janeiro stand out as the highest values. However, Brasília and Belém had lower indices, a value justified by the lack of data on some indicators in this domain. Among the large cities, Uberlândia had the highest value in this group (0.73) and Teresina had the lowest value, 0.13. Comparing medium-sized cities, the municipality of São Carlos obtained an index of 0.60. Belém and Natal have a greater number of critical indicators, 67% and 50%, which shows that municipal managers must adopt measures in the short, medium and long term to improve these indices. The indicator with the lowest ratings refers to the population exposed to traffic noise. The cities of Bauru, Rio de Janeiro, Natal, Campinas, Teresina and Brasília did not obtain data for this indicator. The cities of Brasília, Teresina and Bauru found it more difficult to obtain data on environmental aspects, 67% of the indicators in this domain were not evaluated in each municipalities. In general, cities had great difficulty in finding documents or data to assess two indicators: i) how much the population is exposed to traffic noise (46% indicators were not assessed) and ii) CO and CO_2 emissions (39% indicators without evaluation).

Social aspects domain - In summary, 92% of the cities had a score above 0.50, especially the city of Uberlândia, with a score of 0.92. It is important to highlight that the municipality has fully evaluated this domain. The indicators: information available to citizens, education for sustainable development and participation in decision-making, achieved a maximum score (1.0), an important result since education, information and citizenship are aspects that act at the base of the society. The municipality of Bauru was the only one with a score below 50% of the assessment, obtaining 0.36. The justification for this value is associated with factors related to data quality and availability, as two indicators were not calculated due to lack of data, Social inclusion and quality of life. The indicators Education, citizenship and availability of information on transport and mobility to citizens received a low rating in this municipality, which contributes to poor performance.

Political aspects domain - The city of Medellín achieved the maximum score of 1.00; however, it had the highest list of unassessed indicators (71%), the highest list of optimal indicators, and no critical indicator. From this assessment, it can be inferred that in a comparative study, it is important to assess the values of each indicator and not just the final score of the domain, as they will not portray the reality of all items involved in this analysis. This is because the authors calculated different numbers of indicators for the cities, between 64 and 85 of the possible 87 (for example, in Teresina, only 50 indicators were analyzed). Such a comparison would be possible considering only the common indicators. According to the scenario of 13 works, it is observed that, for political aspects, the cities with the largest demographic size (metropolises and large cities) 61% of the cities are ranked between good and excellent, however the medium cities show intermediate to bad results. The biggest difficulty for this domain was locating data on the fundraising indicator, 61% of cities did not obtain this information. A positive aspect is associated with the theme Investments in transport systems (77%) and Integration between levels of government (69%), with good and excellent values (Table 6).

Infrastructure domain - Among the cities analyzed, Curitiba has the highest score (0.95), especially for having adopted investments in this area over decades. The city has shown to invest resources in the maintenance of roads, sidewalks and public equipment, and especially in the public transportation system, its great positive highlights. All data evaluated in Curitiba are of high-quality and classified as short term. A negative data refers to the index of road signs that was not calculated, due to lack of data. According to Costa (2008), non-calculated domains can be estimated values, thus performing a simulation of the behavior of the index: through an estimate of possible values for each indicator or maximum values for each indicator. Brasília was evaluated with one of the worst scores (0.33), this is due to the lack of data, such as density and connectivity of the urban road network, which was not calculated because the DF road network is very extensive and according to Pontes (2010) there was no time available for manual counting of connectivity points. Another aspect concerns the value of the calculated indicators that were very low, such as expenditure on infrastructure maintenance with a score of 0.25, which is limited to emergency interventions, with resources of less than 50% of the total municipal resources invested in the transport and mobility system. Another municipality is Rio de Janeiro, which accumulate 60% of the data obtained in a critical situation, and 20% of data unavailable. Regarding the lack of data for the calculation of indicators, Teresina had 80% of indicators without evaluation. Only 1 indicator out of 5 was evaluated, roads for public transportation and its score was 0.0.

Non-motorized modes domain - In all cities where the IMUS was applied, the scores were low (Table 6). This assessment shows how cities are being planned to encourage mobility through individual motorized modes at the expense of more sustainable modes such as infrastructure geared towards cyclists. The bicycle path extension and connectivity indicator in all Brazilian cities had a bad or critical score, below 0.25, only Medellín had a score of 0.50 (intermediate). The bicycle fleet index is the one with the highest number of indicators without evaluation, with 61% of the jobs, in addition to the indicators of travel distance and travel time with indicators without evaluation in 46% of the cities. The city with the highest percentage of indicators without evaluation is Teresina, with 67%. Sidewalk roads had the best results, with good and excellent results in 62% of the studies.

Integrated Planning domain - In general, cities presented a very different result, with values ranging from 0.41 to 0.85 (Table 6). It is noteworthy that Medellín obtained 78% of indicators without evaluation in this domain due to the lack of available data. Brasília and Belém obtained, respectively, 0.48 and 0.41 of score for this domain. These results are a consequence of the lack of municipal information on integrated planning policy in cities, especially in those actions aimed at sustainable urban mobility.

Traffic and urban circulation domain - The traffic accidents indicator achieved the best result among the indicators in this domain, with scores above 0.80. Only Rio de Janeiro had a poor result, with a score of 0.26. The vehicle occupancy rate indicator obtained the worst result in 62% of the jobs (in 7% of the jobs it was evaluated as bad and in 31% this information was absent). São Carlos stands out with excellent scores in this domain, of the 9 indicators, 5 obtained a maximum score (1.00), another 3 indicators obtained a score above 0.65 and only one indicator was not evaluated due to lack of information (accident prevention). Among the cities classified as Metropoles, Medellin had the best average, followed by Curitiba and Goiânia. Another important fact is about education in traffic, Curitiba and Anápolis received maximum marks, however, Rio de Janeiro obtained a critical score of 0.01.

Urban transport system domain - The urban transport system is an important element for sustainable urban mobility. The cities of Rio de Janeiro, Medellín and Teresina had greater difficulty in obtaining data, as 22% of indicators were not evaluated. São Carlos, Uberlândia, Campinas, Brasília and Goiânia obtained data for all indicators. Among the cities evaluated, those that obtained the lowest scores were Belém and Campinas with 39%, followed by São Carlos and Anápolis with 33%. Among the cities studied, Belém (0.34) is the worst, along with Campinas (0.38) and Natal (0.40). The cities with the best score are Curitiba and Medellín in Colombia (Table 6).

In summary, among the domains analyzed, "non-motorized modes" was the one with the greatest lack of available data. Within this domain, the indicator related to the bicycle fleet was the one where most authors did not obtain data for its evaluation, with the exception of the cities of Goiânia, Curitiba, Natal and Rio de Janeiro. The Social aspects domain obtained the highest scores, with emphasis on Uberlândia, which obtained the highest score (0.92). A pattern of result (score) was not observed in cities of the same size, which indicates that Brazil still does not have a guideline on which information municipalities must have data to carry out urban mobility planning. The results of the applications also provided effective information to assess mobility in the evaluated cities.

5 CONCLUSION

This academic paper presents a comparative analysis of studies that applied the IMUS in different cities in Brazil and abroad, in order to identify which indicators of urban mobility are still difficult to access, in the municipalities where the IMUS was applied. In total, 13 studies were identified that evaluated 12 Brazilian cities and 1 foreign one. The study allowed us to identify which themes or indicators whose information was not obtained in the evaluated municipalities, during the period of analysis of each survey, especially in Brazil. And those that still need to be improved to expand sustainable urban mobility in our country.

It was observed that no Brazilian city evaluated includes a database as varied as that necessary for the full application of the IMUS. Many data indicated in the methodology are not collected regularly or officially, as there is no constant monitoring practice. The lack of a series of data also hinders the possibility of periodically applying the methodology in order to monitor the evolution of mobility in municipalities. The adoption of the IMUS by public institutions related to urban transport could structure in Brazilian cities a systematic and continuous process of data collection for periodic evaluation of the Sustainable Urban Mobility Index.

The comparative analysis of the application of the IMUS in different cities made it possible to identify i) the positive and negative aspects of urban mobility in the city, as it is composed of a significant and diverse number of indicators related to sustainable urban mobility, and ii) which indicators are still of difficult access to information in the evaluated municipalities, either due to lack of data systematization or lack of information. It is noteworthy that the result of applying the IMUS in the 13 cities allows for further analysis, which were not carried out in this article, but which can identify other aspects that may be an extension for future work.

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