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APPROACHES TO SUSTAINABLE URBAN TRANSPORT PLANNING

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Tatiana Kolodin Ferrari

Approaches to sustainable urban transport planning

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TATIANA KOLODIN FERRARI

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ABSTRACT

Cities face similar concerns that increasingly call to the development of sustainable transportation. Transportation planning went through a paradigm shift, where new solutions have emerged to deal with urban mobility problems. Accessibility improvement became the focus of discussion and in this context, the urban form became an important element for the promotion of sustainable mobility. Furthermore, there is a raising need for policies aimed at changing the behavior of individuals regarding the use of different modes of transportation. The complexity of cities and individuals has shown that there is no single solution to this matter. Understanding their particularities can help design efficient policies. Mindful of that, this thesis proposes a look through the creation of typologies both for the urban form and its population. The city's urban form is crucial for the promotion of sustainable mobility. Researchers have suggested five built-environment characteristics that influence traveling behavior - Density, Diversity, Design, Destination accessibility and Distance to transit. Cities can be quite heterogeneous, both internally and among each other. Here, we characterize 246 Brazilian urban centers based on their direct urban form attributes with the purpose of revealing structural variations that affect sustainable mobility. Toward this goal, we first develop a grid database that divided urban areas into 1km by 1km cells. The avoidance of administrative boundaries can bring benefits to the analysis of territories, mainly by distinguishing characteristics at the local level. Then, we performed the classification using cluster analysis. This resulted in 17 urban typologies with great differences between Brazilian cities. At the same time, it showed that all of them have some kind of dispersed or disconnected areas. Another important goal to achieve more sustainable transportation is to change individuals' travel behavior towards active and public transport options. Studies have shown that tailored communication to different groups of individuals can achieve better results in this change. Thus, we developed a methodological approach for performing market segmentation based on the individual's behavior and attitude. A preliminary test was carried out in the city of São José dos Campos - SP in order to test the methodology and give guidelines for future research. The database and the classifications created can be used to monitor and manage urban areas toward better strategic urban planning with the ultimate goal of creating sustainable communities.

Key-words: Sustainable mobility. Database. Urban Form. Land classification. Behavior Change.

RESUMO

As cidades possuem preocupações semelhantes que estão impondo cada vez mais a necessidade de se desenvolver um transporte sustentável. Com isso, o planejamento de transportes passou por uma mudança de paradigma, onde surgiram novas soluções para lidar com os problemas enfrentados. A melhoria da acessibilidade ganhou foco principal nessa nova visão e, nesse contexto, a forma urbana tornou-se um elemento importante para a promoção da mobilidade sustentável. Além disso, há a necessidade de políticas voltadas para a mudança de comportamento dos indivíduos quanto ao uso dos diferentes modais de transporte. A complexidade das cidades e dos indivíduos tem mostrado que não há uma solução única. Assim, compreender suas particularidades pode ajudar a desenhar políticas mais eficientes. Tendo isso em mente, esta tese propõe um olhar através da criação de tipologias tanto para a forma urbana quanto para sua população. A forma urbana da cidade é crucial para a promoção da mobilidade sustentável. Estudos sugerem cinco características do ambiente construído que pode influenciar o comportamento de viagem - Densidade, Diversidade, Design, Acessibilidade e Distância para o transporte público. Esses atributos foram utilizados nessa tese para caracterizar 246 centros urbanos brasileiros com o objetivo de revelar variações estruturais que afetam a mobilidade sustentável. Para tal, desenvolvemos primeiramente um banco de dados em grade que dividiu as áreas urbanas em células de 1km por 1km. A renúncia aos limites administrativos pode trazer benefícios para a análise dos territórios, principalmente por distinguir características no nível local. A partir disso, realizamos a classificação por meio da análise de cluster. Os resultados apresentaram 17 tipologias urbanas com grandes diferenças entre as cidades brasileiras. Ao mesmo tempo, mostrou que todos eles possuem algum tipo de área dispersa ou desconectada. Outro objetivo importante para alcançar um transporte mais sustentável é mudar o comportamento de viagem dos indivíduos para opções de transporte público e ativo. Estudos têm mostrado que a comunicação personalizada para diferentes grupos de indivíduos pode alcançar melhores resultados nessa mudança. Assim, desenvolvemos uma abordagem metodológica para realizar a segmentação de mercado com base no comportamento e na atitude do indivíduo. Um teste preliminar foi realizado na cidade de São José dos Campos - SP a fim de testar a metodologia e dar diretrizes para pesquisas futuras. O banco de dados e as classificações criadas podem ser usados para monitorar e gerenciar áreas urbanas e para um melhor planejamento urbano com o objetivo final de criar comunidades mais sustentáveis.

Palavras-chaves: Mobilidade sustentável. Base de dados. Forma Urbana. Classificação urbana. Mudança de comportamento.

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1 INTRODUCTION

The promotion of sustainable transportation in cities is key to deal with the current social, economic, environmental and climate issues. Car dependence has been seen as a huge problem and much interest has been placed in the design of urban areas to tackle individual motorized travel growth in cities. The goal is to create communities where transit, bicycling and walking are viable options and where, even if residents continue to drive, at least the distances are shorter (HANDY, 1996b).

For many years, transportation planning strategies in many cities have prioritized cars and traffic performance, usually based on speed. Litman (2013) explains the transportation paradigm shift that is undergoing, where the priority now is the movement of people, putting accessibility as the main goal. It implies a new way to define the problems and consequently, new types of solutions.

Accessibility is defined as the potential of opportunities for interaction (HANSEN, 1959). The level of accessibility in a place will reflect not only how easy it is to reach an opportunity but also the characteristic of the activity found there (HANDY, 1996b). In these terms the urban form is the key element to determine the choices available. So, by focusing on accessibility, the new paradigm establishes a closer relationship between urban form and urban transportation systems.

In a broader use of the term, urban form is defined as the spatial configuration of fixed elements, which include the spatial pattern of land use, density and spatial design of infrastructure (ANDERSON; KANAROGLOU; MILLER, 1996, p. 9). The idea is that some characteristics of certain areas can influence travel behavior since it can, *e.g.*, have shorter distances and make it more advantageous or not to use a particular mode of transportation. Thus, by re-planning cities, it is possible to minimize the need for extended movement and encourage non-motorized mobility.

Most of the literature that investigate the influence of urban form and travel behaviour point out that denser, mixed-use areas and with good street connections have lower levels of driving. However, the relationship and the impact of urban form on travel behavior is still not clear. Li et al. (2010), for example, show that density by itself is not sufficient to control private car growth in some Chinese cities. According to Ding et al. (2017) the empirical results provide mixed evidences, due to differences in empirical contexts, geographical scales, residential self-selection, and methodologies.

Even though the direct relationship between urban form and mobility is not completely clear, there is a consensus that they are intrinsically related. Thus, any city that intends to end its citizens' dependence on private cars needs to follow an urban planning approach that is integrated with the issues of transportation, real estate, urban design and equity considerations. In the end, sustainable urban development needs to pursue more vibrant, connected and equitable neighborhoods.

In order to achieve a sustainable urban form, some urban planning approaches have stood out in recent years advocating for more compact cities with a mixture of land and interlaced with transit-oriented, walkable, bicycle-friendly land use.

However, to be able to plan cities in a sustainable way, it is first necessary to understand how urban forms develop and their spatial pattern. The formation of urban settlements are diverse and complex which makes it a challenge to create systematic knowledge about it. Even within a city the dissimilarities in urban form variables can be huge. Developing data to understand the territory could be expensive and time consuming. An aggravating issue is that data is often available based on administrative boundaries, that do not have a structural similarity and can hide a variety of different situations within.

Bueno (2014) suggests the use of grid database to overcome the problem of data based on political-administrative or operational boundaries. The grid aggregates data into geographic units composed of a set of cells of the same size placed in a regular way.

So, our first goal was to create a grid database based on direct attributes of the urban form. The database includes indicators of population and employment density, job-housing balance, street design, access to jobs, and the number of bus stops for 246 urban centers in Brazil divided into grids of 1km by 1km.

Then to help city planners and policy-makers better understand the territory Stokes e Seto (2018) proposed a classification of urban form characteristics through cluster analysis using data in grid. The authors state that by characterizing urban areas as a collection of smaller units, instead of as a single aggregate, is better to understand the variety and distribution of processes within. Also, comparison could simply be made in micro-level units. The division on grids of 1km by 1km and then the creation of mosaics seems to be a good way to better understand the functioning of cities.

Then, our study explores the methodology developed by Stokes e Seto (2018) in the context of developing countries. These countries face distinct patterns in the development of urban areas which can lead to different relationships in travel behavior. A systematic classification was conducted for characterizing and measuring urban structures. The results created nationwide geographic classification data based on direct urban form variables that can be used to assess and compare neighborhood conditions, as baseline data for scenario planning studies and can guide investments. The goal of this work is to contribute to the understanding of the spatial patterns in Brazilian urban centers and discuss strategies for urban planning related to sustainable mobility with respect to specific types of urban structures.

Brazil, in particular, has witnessed a rather accelerated urbanization that has often occurred on the fringes of urban planning. Santos (2013) shows that with differences in degree and intensity, all Brazilian cities exhibit similar problems; with a dispersed urban form. Santos (2013) puts a series of factors that cause these sprawling cities in Brazil: urban size, road model, lack of infrastructure, land and real estate speculation, transport problems, extroversion and peripheralization of the population. Each of these realities sustain and feed the others. To be able to develop in a sustainable manner, Brazilian cities need to adopt integrated territorial planning, articulating urban mobility and land use. Thus, the first step is to understand the territory, its occupation, context and dynamics. The application of the methodology proposed here seeks to put into perspective the territory in terms of objective measures of urban form.

In order to reduce the use of private transportation in Brazilian cities, a series of joint policies are essential, ranging from urban planning policies to massive investment in technologies and public transport, but more than anything, it is necessary to create an awareness of these problems in the population so that they are willing to carry out these changes. However, a number of studies have shown a gap on individuals' knowledge and as a consequence on their behavior.

Anable, Lane e Kelay (2006) concluded that a deeper understanding of the role of individual and social motivations and barriers is needed to reduce car use. They suggest that the segmentation of the population is necessary. In this way, the development of travel behavior change programs can be more effective than treating the entire population as an average consumer.

To sum up, we can see that the solutions for the development of sustainable mobility involve knowing the processes in their individuality, both at the level of the territory and of the individual. For this to be possible, this thesis proposes analysis methods that look at each of the influences on urban transportation in an individualized way.

1.1 Research aim and objectives

Understanding spatial and behavior patterns that shape processes and functional relationships in cities is not something trivial, although extremely important for a good design of public policies and urban planning. The aim of this thesis was to develop methodological approaches in order to provide data that policies can rely on. The influence of urban form and travel behavior was investigated to ascertain ways to generated useful data that could potentially contribute to the discussion of sustainable transportation in cities.

To this aim this thesis has the following research objectives:

1. Understand key factors of urban form and travel behavior characteristics that influence the use of automobile;
2. Create a grid database with direct aspects of urban form;

3. Use the key urban form aspects to construct a typology in other to better understand, visualized and compare the spatial patterns;

4. Develop a methodological approach to segment population in accordance to their travel behavior, beliefs and attitudes.

1.2 Thesis outline

This thesis is set out in following six chapters:

Chapter 2 introduces the discussion about sustainable transportation and reviews the main approaches to the impact of urban form and travel behavior on mobility patterns. The intention of this chapter is to establish the research context and introduce the main topic of the thesis.

Chapter 3 presents a statistical grid database for Brazilian urban centers based on direct attributes of urban form. Given the lack of existing data in many cities, the proposal is to build a simple database for municipalities of different sizes, so that they can monitor the characteristics of the urban structure.

Chapter 4 conducted an urban form classification using the grid database developed in Chapter 3. The classification intends to differentiate the neighborhoods through their spatial urban form in a way to better understand the variety and distribution processes within.

In Chapter 5 we change the focus to individuals' travel behavior. We present a method to segment the population into groups according to their travel behavior, attitudes and policy acceptance.

The final chapter (Chapter 6) concludes with a discussion of the contributions of the thesis. Limitations of the study and suggestions as to the future development of this research is also covered in this discussion.

2 THEORETICAL FOUNDATION

The concept of sustainable development has emerged in the last decades bringing a new way of thinking urban problems. Urban areas have a fundamental role in the promotion of sustainable development, since more than half of the world's population reside in these areas[1] and they generates intense environmental and social impacts.

Transportation systems have been seen as a key elements in order to achieve sustainable cities. The concept of sustainable development in transportation can be thought of as the desirable combination of government policies, technologies, infrastructure and behaviors that minimize social adversities and environmental impacts, while maintaining or improving economic efficiency (SCHWANEN; BANISTER; ANABLE, 2011).

The current transportation system based on private vehicles is clearly unsustainable, with impacts on environmental, social and economic areas. In the environmental perspective, the IPCC (2014) report shows that 70% of global energy consumption and emission of greenhouse gases is produced in cities, 23% of which comes from the transportation system. According to Ferreira (2011), emissions of greenhouse gases by the transportation sector are growing faster than those of any other sector. The author shows an alarming scenario from this sector and warns of the need for a radical change in the population lifestyle.

The development of cars with clean technology, despite being beneficial from an environmental point of view, is not in itself a sustainable solution, as it does not solve the congestion and social problems arising from the high use of private cars. Meanwhile, Steg e Tertoolen (1999) point out that experience has shown that people in possession of a good that is considered clean tend to increase the use of that good precisely because they think they are not generating any impact now.

There is also a high social cost in the current transportation system, that includes accidents, air pollution, physical inactivity, time spent in daily commuting and accessibility inequalities. Meanwhile, it also has an effect on the economic system. As Litman e Burwell (2006) point out, a system based in motor vehicle travel beyond an optimal level, can have overall negative economic impacts because the marginal productivity of increased travel is declining and vehicle use imposes external costs that can offset direct economic gains. In addition, the need to create parking lots have implications on the use of urban space, especially in the central areas of cities.

In Brazil, Vianna e Young (2015) estimated economic losses by calculating the average production loss as a function of the commuting time. The value found in relation to GDP is 1.8%,

[1] According to the United Nations Report (2016), 54% of the world population lived in urban areas in 2014, and the projection made, indicates a total of 66% of people residing in urban areas in 2050. In Brazil, this picture is even more intense. According to the 2010 Demographic Census, 84% of the Brazilian population already lives in urban areas.

showing that improvements in urban mobility can bring great social returns. Within the analysis of the socioeconomic issue, Stefanelli (2015) found that the major losses from commuting occur among the poorest and also among the richest, placing the issue of urban mobility beyond social problems.

The motorization trend in developing countries is a cause of concern. According to Cervero (2013), in the advanced economies the rate of motorization has reached its saturation. While, in developing countries motorization rates are increasing rapidly due to the experienced rise in income.

All of these facts highlight the importance of shifting paradigms in the way cities work in terms of sustainability.

We believe that the development of a sustainable transportation system starts with the organization of the urban space (UN-HABITAT, 2013). Thus, a better understanding of the territory is needed to help urban designers and planners to redesign neighborhoods and create urban forms that encourage walking, cycling and increased use of public transportation.

The shape of a city can have immense impact on the daily lives of its citizens. It can determine, for instance, our level of accessibility and interactions, the way we move in the city and consequently, the level of emissions. Despite being obvious that mobility has close ties to urban form, this relationship cannot be understood so directly. It depends on a series of other factors,such as historical and cultural contexts, which demand a holistic view to understand how travel behavior is shaped by the urban form.

The urban form can be seen as a first step in promoting sustainable mobility, since it is through the urban form that we manage to create cities that are more alive, connected and that allow individuals to make choices about the modes of transportation. However, in addition to the influence of the urban form, individuals have different behaviors and attitudes when choosing their displacement. The need to develop policies to change travel behavior has been increasingly noticed. Thus, it is also essential to good mobility management to understand residents' travel behaviour and associated factors that may impact their travel choices.

In view of this discussion, this chapter seeks to contextualize the new paradigm in the area of transport planning and how Brazil is inserting itself in this perspective. The focus on improving accessibility demands greater integration between urban planning and transport planning policies. Thus, we also seek to discuss the relationship observed in the literature between urban form and mobility in order to understand the variables and how they should be worked on in each context. Finally, we discuss the relationship between mobility and the attitude of individuals in order to understand ways to manage their choices towards sustainable options.

2.1 Sustainable Mobility

In 1987, the World Commission on Environment and Development (WCED), presented the report: “Our Common Future”, known as the Brundtland-Report (WCED, 1987). This is considered to be one of the most important documents in the discussion of Sustainable Development (SD) and also with important political impacts. The report brought the concept of SD as being: “the development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED, 1987, p. 45).

In this definition, the intergenerational justice is at the core of this new development view. The satisfaction of people’s needs are the major concern, but these needs have limitations that come from the environment. The world’s population has been growing unprecedentedly in the last decades, which put a lot of stress on the physical environment. Since the resources are finite, we need to guarantee that future generations have access to the same basic needs as our generation. So, the WCED (1987), assert that “living standards that go beyond the basic minimum are sustainable only if consumption standards everywhere have regard for long-term sustainability”. Also, the report claims a social equity within each generation. So, social equity has two dimensions in the SD: time and space (HOLDEN; LINNERUD; BANISTER, 2014).

Although, no clear framework is made explicit in the Brudtland Report, the discussion about SD claims for an holistic view based on three pillars: environment, economy and society[2]. Over time, these three pillars became the center of attention in the SD discussion (SACHS, 2015). The idea is that any development should pursuit a balance of these factors. These dimensions are interconnected, so it is not possible to achieve sustainability without one of the pillars.

The same ideas of SD could be expressed to discuss Sustainable Transportation (ST). The transportation sector is responsible for the movement of goods and people, which generate economic and social opportunities and is a common tool for development. On the other side, the transportation sector carries an important load, being responsible for environmental degradation and social and economic inequalities. Hence, ST must pursuit improvements in the three pillars, seeking for economic growth, environmental preservation and social equity.

In this study we rely on definitions that encompass these dimensions. Schwanen, Banister e Anable (2011) explain that the concept of sustainability in transportation can be thought of as the desirable combination of government policies, technologies, infrastructure and behaviors that minimize social adversities and environmental impacts, while maintaining or improving economic efficiency.

A definition widely used is given by the University of Winnipeg’s Centre for Sustainable Transportation (CST, 2005). This definition is very clear and consistent with the SD pillars. Thus, according to CST, an ST system is one that:

[2] Over time the dimensions of SD have been expanded, but we are going to limit to discuss this three firsts dimensions.

- Allows the basic access to the needs of individuals and societies to be met safely and in a manner consistent with human and ecosystem health, and with equity within and between generations;
- Is affordable, operates efficiently, offers choice of transport mode and supports a vibrant economy;
- Limits emissions and waste to within the planet's ability to absorb them, minimizes consumption of non-renewable resources, limits consumption of renewable resources to the sustainable yield level, reuses and recycles its components, and minimizes the use of land and the production of noise.

Sachs (2015) reinforces that SD is also a "normative outlook on the world, meaning that it recommends a set of goals to which the world should aspire". Indeed, a set of goals and principles have been created, as general guidelines. In the transportation field there is a common view that any ST path should pursuit: - an improvement in transportation system diversity, stimulating the public transportation and active modes; - a reduction of the emissions and energy use, which include technology improvements to shift to alternative fuels, but also, reduce the motor vehicle travels; - a development in land use, to promote compact, mixed and connected cities, with good accessibility, affordable housing and multi-modal options; and - a promotion of more inclusive, accessible and efficient transportation systems.

Goldman e Gorham (2006) argue that such definitions emphasize a desired end-state but do not provide a meaningful way of approaching the problem that is useful to policymakers.

Nowadays cities are seeking sustainable transport strategies, although developing an efficient transport system is a complex task. In addition to the need for a new understanding of ongoing issues, many cities are struggling with challenges that range from the lack of an overall capacity for planning, execution and monitoring; difficulty of policy integration; absence of data and a comprehensive information system; lack of funding; and so on. So, how a sustainable approach translates into planning and policies for more livable cities is still a challenge.

For many years, transportation planning strategies in a lot of cities have prioritized cars and traffic performance. It was a mobility-based view, in which "the goal was to maximize the distance that people can travel within their time and money budgets and therefore maximized travel speed" (LITMAN, 2013, p.20). This is a reductionist view in terms that the transportation problems are addressed only by considering transportation planning; consequently, the solutions are given through infrastructure improvements, such as roadways expansions, widening avenues, creation of more parking slots, and so on. This approach results in the erosion of cities by automobiles, as described by Jacobs (1961). The strategies adopted have positive feedback, that is, produce a reaction which in turn intensifies the initial problem and intensifies the need for repeating the policy, which in turn intensifies the reaction, and so on.

The self-reinforcing cycle is illustrates on the Figure 1. As we can see, automobile-oriented transport and land use planning can reinforce each other creating dispersed cities and automobile dependency that are also self-reinforcing.

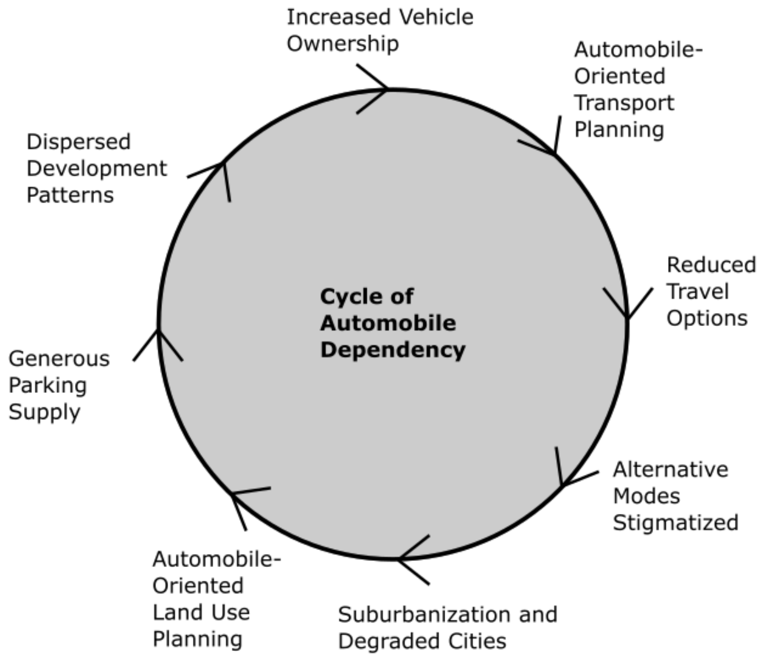

Figure 1 – Cycle of Automobile Dependency and Urban Form. Source: Litman (2015).

In short, by focusing narrowly on mobility, the solutions of this view can cause an adverse effect aggravating traffic congestion and safety, decreasing walkability and also creating isolated land uses and social segregation.

The mobility point of view dominated for many years Brazil's transportation planning. Silva, Costa e Macedo (2008) argues that until the 1970s, Brazil's transport planning was characterized by a preference for road transport, with priority given to private over public transport, low incentives for the use of non-motorized modes and a lack of integrated urban and transport planning. Combined with problems in urban planning, such as the concentration of opportunities and an extensive occupation of the peripheries in a precarious way, this culminated in automobile dependence.

The consequences can be viewed at the current trends of car ownership in Brazil that are not encouraging. From 2008 to 2018 there was a boost of 28.6 million vehicles, while the population increased around 15 million. As a consequence, the motorization rate raised from 19.6 autos per 100 inhabitants in 2008 to 29.7 autos per 100 inhabitants in 2018 (RODRIGUES, 2019). This is still low in comparison to developed countries. However, the trend is going in the opposite direction of sustainable development, and policies and behavior of the population are still based on car dependence. This is the typical case of latent demand, in which income growth is translated in increased motorization rates (CERVERO, 2013). No wonder ANFAVEA 2018 reports Brazil as the 4th largest potential market for the automobile sector in the world.

Automobile dependence is a situation that is commonly associated with an unsustainable urban environment. Brazil in particular has witnessed a very accelerated urbanization that has often occurred on the fringes of urban planning. Santos (2013) shows that with differences in degree and intensity, all Brazilian cities exhibit similar problems; with a dispersed urban form.

According to Ojima e Hogan (2009) Brazilian cities suffer with sprawling problems with different dynamics from the usual sprawl pattern observed in the United States. The unsustainable territorial sprawl, culminates in a city model which Evers et al. (2018) called a 3D city: distant, dispersed and disconnected. “The 3D city presents a distant urban configuration, with peripheral territories far from the center; dispersed, with urban centers spread throughout the territory; and disconnected, that is, these urban centers are not well connected to other centers and to the city center”(EVERS et al., 2018, p. 27).

As we can see, there are several interconnected factors that demand a holistic view of public policies to create sustainable transport system. This goes in line with the paradigm shift undergoing in transport planning. The new paradigm claims for a holistic and integrated approach where transport, land use, environmental objectives and social and economic development planning are integrated. The strategies that arise in this new view give particular attention to the urban form of the cities.

According to Litman (2013) the new paradigm has its focus on accessibility - the most important thing is no longer traffic performance but how easy it is for the population to reach the opportunities.

Hansen (1959) defines accessibility as the potential of opportunities for interaction. It is important to understand that mobility, by improving travel time and efficiency, is a valid way to improve accessibility. Nonetheless, it is not the only means to this end. As UN-HABITAT (2013) states, the ease of reaching destinations in terms of proximity is critical, as well as convenience and positive externalities. As a result, the enhancement of accessibility places the human and spatial dimensions at the core of sustainable mobility.

The accessibility focus demands a combination of high-density settlements, mixed-use functions and appropriate design of streets. So, how urban areas develop is central to whether and how they hinder or help the transition of societies towards sustainability. As UN-HABITAT (2013) states, the development of a sustainable transportation system starts with the organization of the urban space.

As alternatives to urban development problems, principles emerge that conceptualize accessibility and mobility as the focus of urban planning and evaluation of urban development.

Travel demand management, for example, is an approach that promote positive incentives (to attract individuals to sustainable means of transport) and negative incentives (to remove individuals from using car). Positive incentives are usually based on investments in the public transport system, infrastructure for bicycles and pedestrians, development of technologies and by promoting a mixed and compact urban development. While the negative incentives focus on congestion, fuel and parking pricing, vehicle use restrictions.

Other strategies, such as New Urbanism, Smart Growth, Transit-Oriented Development (TOD), arise with the aim of promoting changes in the urban form to reverse the high use of automobiles in cities (KNAAP; TALEN, 2005; CERVERO; KOCKELMAN, 1997). These strategies advocate for the concentration of growth in compact walkable urban centers or around public transport nodes.

Brazil has advanced in its policy vision for ST with the creation of the Urban Mobility Law (Law nº 12.1587), sanctioned by the Federal Government in January 2012. Among its guidelines are: the priority given to the use of non-motorized and public modes of transport; the mitigation of the environmental, social and economic costs of moving people and cargo in cities; and encouraging scientific-technological development and the use of less polluting energy. Thus, this law represented, in the Brazilian case, a starting point for a change in the focus of urban transport policies now concerned with a sustainable development.

The Urban Mobility Law requires municipalities with a population of over 20,000 inhabitants to prepare and present an urban mobility plan, with the intention of planning the growth of cities in an orderly manner. It also establishes a series of guidelines and mechanisms for municipalities to implement policies aligned with the development of sustainable urban mobility.

However, in most cities, the existence of norms, regulations and manuals did not guarantee a practical advance in the improvement of mobility. While cities face many common problems, they also face a diverse range of challenges at the local level.

There is no standard solution and sustainable policies might take different forms. Thus, the understanding of local specificities becomes of paramount importance.

Aware of this problem, WRI Brasil created a specific methodology for Brazilian cities to develop their urban mobility plans. The methodology was officially adopted and consists of seven steps: (i) preparation, (ii) scope definition, (iii) procedure management, (iv) elaboration, (v) approval, (vi) implementation and (vii) evaluation and review.

One of the bottlenecks is in the elaboration stage, in which the use of a database and reliable information is of extreme importance. While larger cities have an information system and trained teams to carry out the necessary analyses, smaller municipalities often do not have the same data support infrastructure.

Once the urban form becomes so important in this new mobility paradigm, understanding the territory in its specifications becomes fundamental for the good alignment of public policies. Without data it is difficult to have a detailed look at the urban environment, and in such cases, public transportation policies may not have the desirable effects.

To our knowledge, there is no database on urban form that Brazilian cities can draw on. In the next session, we will seek to understand the relationship between urban form and mobility, in order to be aware of which variables and what should be observed in the built environment when thinking about public transport policies.

2.2 Mobility and Urban Form

We can understand urban mobility as cause and consequence of the shape of the city, as it is a constituent element of the urban fabric that brings together the movement of people and goods through the city. It reflects a bi-directional relationship that underscore the importance of carefully coordinate mobility and urban planning (UN-HABITAT, 2013).

The term urban form encompasses a variety of physical and nonphysical features, such as size, density, land uses, street designs, green spaces and so on. The literature has pointed seven aspects that can affect individuals' travel behavior. It is common to named these influences beginning with the letter D, due to the work of Cervero e Kockelman (1997) who created the "three Ds": Density, Diversity and Design. The other influences pointed in a review by Ewing e Cervero (2010) are: Destination accessibility, Distance to transit, Demand management, and Demographics. The authors argue that this division is more of a way to divide the literature and provide order-of-magnitude insights, but they can be ambiguous as some dimensions overlap.

The first three D's, destination accessibility and distance to transit are the most commonly cited urban form characteristics that can be significant factors in influencing car usage and ownership. The pioneering work of Newman e Kenworthy (1989) measured the correlation between population density and transport energy consumption by comparing data from 32 cities around the world. The authors concluded that there was a negative relationship, that is, the higher the population density, the lower the energy consumption in transport. Cervero (2002) investigate the influence of density, diversity, and design and also incorporate factors related to generalized cost and socioeconomic attributes in Montgomery County, Maryland. Using the binary logit and MNL models, the analysis reveals a significant influence of density and mixture of land use on travel behavior. The work of Bento et al. (2005) sought to examine the decision on travel mode choice and distance traveled, considering various aspects of urban form and the public transport system. Using data from 114 US urban areas and applying a MNL model, they observed that the major impact for reducing car use came from population centrality. An increase of 10% in the centrality decreases the likelihood of driving by approximately 1 percent.

A variety of other studies report similar results, what establishes the idea that compact, mixed-use, and pedestrian-oriented designs can lead to a sustainable city by reducing trip lengths and making the other modes of transportation more feasible.

It is important to clarify that the relationship between urban form on travel behavior and its magnitude is still debated in the academic community and consists of a vast field for exploration (HANDY, 1996b; HANDY, 1996a). Ewing e Cervero (2010) conducted a meta-analysis over more than 50 studies that analyze the built environment to measures of travel. Then they computed weighted average elasticities for walking and transit use with respect to density, diversity, design, destination accessibility and distance to travel variables. The results should be looked at with caution given the small database used. But, interestingly enough, they reported the variables to be generally inelastic with respect to changes in measures of the built environment. Nonetheless, they find vehicle miles traveled to be strongly correlated to destination accessibility and street network design; walking strongly correlated to diversity, intersection density and accessibility; while densities were weakly associated with travel behavior.

Badoe e Miller (2000) also reported in a literature review many other studies that find the evidence for density to be much less clear. “The role of density as a direct explanatory variable with respect to transit usage, auto VMT, etc., typically declines significantly within the statistical analyses once ‘other factors’ (...) are accounted for” (BADOE; MILLER, 2000, p. 251).

The criticism in the literature pointed as a problem the weaknesses of the methodology and data in many studies (BADOE; MILLER, 2000), the inability to dismantle the influence of socioeconomic and demographics characteristics in the relationship of urban form and travel behavior (BROWNSTONE, 2008; HUMPHREYS; AHERN, 2019), the differences among urban areas and the scale of analysis (CERVERO, 2013; STOKES; SETO, 2018) and the difficulty in translating the results into something useful for policy analysis (BROWNSTONE, 2008).

The failure to clearly understand such relationships limits the ability to produce insights what hinders the promotion of sustainable cities. Even so, it is well establish that the urban form and travel behavior are inextricably related. It’s hard to refute that well-planned, mixed-use, and compact cities offer higher levels of well-being at lower levels of resource use and emissions.

Using the microeconomic perspective, we can view the relationship between travel behaviour and spatial structure by the theory of utilitarian travel demand. In this theory accessibility is the key point in the decision of individuals to travel, since the demand for travel originates in the need to reach the locations where activities take place. So, from the perspective of utility, travel is seen as ‘derived demand’ (WEE et al., 2011).

If travel is derived demand, then demand for travel will depend on the spatial structure of activities and on the determinants of the Generalized Transport Cost (GTC). The basic rationale is that individuals will select a travel mode that could maximize their benefits and minimize their costs. Where the so called GTC includes monetary costs (variable car costs, public transport fares), time and effort (WEE et al., 2011).

The D variables in this perspective can play a significant role.The mechanism behind urban form variables is their ability to reduce trip distances. In doing so, the GTC is reduced and having an adequate infrastructure, the competitiveness of the public transport, cycling and walking mode increases. Table 1 summarizes the D variables effect.

Table 1 – Urban form variables and their channel effect. Source: Adapted from Litman e Steele (2019).

D Factor	Definition	Mechanism
Density	People or jobs per unit of land area	Reduces travel distances. Increases walking and cycling accessibility. Increases sidewalk, path and public transit efficiencies. Increases vehicle congestion and parking costs.
Diversity	Mixed of different land uses	Reduces travel distances between local destinations (homes, services and jobs). Increases the portion of destinations within walking and cycling distances.
Design	Scale, connectivity and design of streets	Reduces travel distances. Increase the portion of destinations. Create vivid streets and improve local environment. Improves walking, cycling and public transit travel.
Destination accessibility	The degree to which destinations are accessible.	Reduces travel distances.
Distance to transit	Access to public transport.	Improves transit access and supports other accessibility improvements.

We would like to comment on a few points about density, the most used factor in urban form studies and also the one that generates the most controversy. So far we verified that density has the ability to increase proximity and also is essential for sustaining cost-effective public transport services. Meanwhile, we need to determine what density means in different cities contexts. Not every city can be as dense as those in big metropolitan centers. So, how dense must a sustainable neighborhood be? Moreover, higher densities suffer unplanned effects and in most cases, those are not always something that is desired.

There are few analysis on density thresholds for the realities of countries in the global south and also that take into account differences in the size of cities. One of the few international studies was conducted by Cerin et al. (2022) with the aim of estimating thresholds for urban design and transportation features. Their results suggest that urban neighborhoods with at least around 5700 people per km^2, 100 intersections per km^2, and 25 public transport stops per km^2 would yield at least 80% of population engagement in walking as transport. They also reported an inverted-U relationship between density and walking probability, where ultra-high density areas suggest negative associations when exceeding 14000 to 14500 people per km^2.

However, much more than a number, density must be considered in relation to other factors and given the local reality. There are other aspects associated with urban density that could either make it beneficial or not for different places. A report from ULI (CLARK; MOIR, 2015) arguments that the most pertinent contemporary density debate is not whether cities should densify but how. The document points out positive and negative aspects in densification (Figure 2).

Characteristics of 'good' density	Characteristics of 'bad' density
Mixed use of land. Combining residential, commercial, retail, transport and green space creates a vibrant urban landscape which is used at all times of day and by different groups.	**Monotonous.** Dense single land use appears to prevent the advantages of density from being leveraged and fosters negative externalities instead.
Connected. Includes high volume reliable public transport and leverages existing infrastructure. 80% of ULI members surveyed identified good infrastructure as an essential component of successful density.	**Isolated.** Without transport infrastructure density is not able to fulfil its key role of facilitating access, and can lead to unmanageable traffic challenges.
Planned in advance and incremental in pace. Good density is the product of an overarching strategic vision about place-making and specific / explicit project choices.	Occurs at a rapid and **unmanaged** pace. Places and people become overwhelmed by rapid density which prevents assimilation and the investment needed to make density work.
Cohesive. Meets social needs as well as economic needs. The aim of good density is not just to create capital assets but to serve people who live and work in the city.	The concentration of single income populations (whether high income or low income) or single ethnic groups. If density is combined with income or ethnic **segregation**, it can have the unintended effect on increasing 'ghettoisation' or spatial inequality.
Liveable. Enhances quality of life and liveability for residents. Good density mitigates the liveability stresses caused by concentration and takes advantage of the opportunities it creates to enhance public services and quality of life.[11]	**Unliveable.** Without good public and private services density can become monolithic, scary, and imprisoning. Bad density can breed crime and insecurity, making dense spaces fearsome and unattractive.
Spacious. Good density provides public and open spaces for citizens to decompress regardless of their income.	Absence of public and open space / connectivity. Without the space to decompress density can become oppressive and feel **crowded.**
Has flexibility. Good density can be increased or added to **incrementally.**	Lack of adaptability to changing economic and social circumstances. Dense buildings that are **inflexible** can prevent a whole district or neighbourhood from adapting. It can have a blighting effect.
Has **design** built into it. High density does not always have to mean high rise, but should always mean high quality urban design.[12]	The absence of good urban design. Density can be created in ways which are perceived to be **ugly.**
Green. Has an environmental benefit and uses energy, waste, water and transport systems more efficiently. Encourages shared facilities and services.	**Polluting.** Traffic congestion and heat island effects stemming from poorly planned density can be detrimental to the environment.
Appropriate. Minimises impact on existing settled neighbourhoods and places. Good density reflects and accentuates the local character of existing neighbourhoods. Planners take measures to accommodate and provide for existing residents.	**Conspicuous** and inappropriate to existing scale of buildings and character of city scape. The blend of buildings in the same neighbourhood is key, each city or district has its own vernacular or narrative that dense buildings need to be in tune with.

Figure 2 – Desired and undesired density. Source: (CLARK; MOIR, 2015)

To sum up, we know that density is an important benchmark for urban planning, but it is not the only one. Its analysis must always be accompanied by other characteristics of urban form. Litman e Steele (2019) show that if one isolates the effect of density from other factors, vehicle travel reductions do not require high urban densities, while relatively modest increases, from low (under 10 residents per hectare) to moderate (over 25 residents per hectare), can significantly reduce vehicle travel if implemented with complementary policies that increase accessibility and transport system diversity.

Bare this in mind, urban planning should pursue to create more compact, well-designed and mixed landscapes respecting local particularities. This is not an easy task, mainly because it demands broad knowledge of the territory, its context and dynamics. Access to data and the characterization of the urban space are devices that need to be available to policy makers in order to allow a detailed look at the different neighborhoods. They are also essential for monitoring, controlling and proposing future urban scenarios.

2.3 Mobility and Travel Behaviour

From the previous discussion we recognize the importance in promoting a shift from car use to alternative forms of transportation. However, the evidence shows that people will not change their travel behavior so readily. First, we assume that not everybody is well informed about the problems with the expansion of motorized traffic. So, first a massive provision of information is required in such a way that people understand the collective costs and risks of car use.

On the other hand, Anable, Lane e Kelay (2006) point out that information is necessary but not sufficient to promote changes in travel behavior. This is recognized as the attitude-behavior gap, where knowledge and attitude fail to be translated into changes.

Although from the stand point of society car use translates to seriously negative effects, from the individual stand point, it can be perceived to have advantages, such as comfort, flexibility and time, over other transportation options. Steg e Tertoolen (1999) state this as a social dilemma, reflecting the conflict between the individual and collective interests. The barriers to change come from the individual's perception that their behavior has no impact on the collective problems and the pessimistic view with respect to other people's willingness to change. So, besides information it is important for people to be aware of their personal contribution in solving the problem.

The economic modeling approach tries to understand the choices among the transport modes based on the microeconomic theories of rational behavior choice. In these models each transport mode has specific characteristics, like comfort, time, cost, flexibility and so on, that the individuals are going to evaluate to make their decision. The mathematical models predict the willingness to change based on the variation of the attributes. The results of this approach are important to service providers and to transport planning to identify the bottlenecks and make improvements to incentivize the use of public transport and active modes by the population.

Meanwhile, car travel also carries subjective or emotional factors. According to Cervero (2013) there are societal values in which the acquisition of a car is viewed as a rite of passage for those entering the middle class. Some studies have shown that the increase in motorization is related to the rising in income (SPERLING; GORDON, 2010). This can happen because of the lack of viable travel options, but also, for emotional factors, expressed in feelings of power or superiority and the enjoyment of driving (STEG; TERTOOLEN, 1999).

Beirão e Cabral (2007) argued that car dependence is not directly related to the objective service level, the ones measured by the economic modeling approach, but is influenced by psychological factors. The authors believe that changing the psychological factors may change travel mode choices, even though the level of service remains the same.

Steg (2005) applied questionnaires to understand the reasons for using cars. The motives were divided into three groups: 1) instrumental motives, which are linked to qualitative and functional aspects; 2) symbolic motives, linked to the feeling of status and privilege; and 3) affective reasons, which refer to the use due to the pleasure it provides. The work showed that affective and symbolic motives play a greater role in determining the use of cars than instrumental factors. However, in general, policies are more focused on the instrumental aspects of different modes.

A theoretical framework used to provide valuable insights into people's intention to engage in certain behavior is the Theory of Planned Behavior (TPB), that was designed to predict and explain human behavior in specific contexts (AJZEN et al., 1991).

The theory asserts that human behavior is preceded by an intention of behavior that is formed by three constructions: Attitude toward the behavior; Subjective norms; and Perceived behavior control. Figure 3 depicts a schematic representation of the theory.

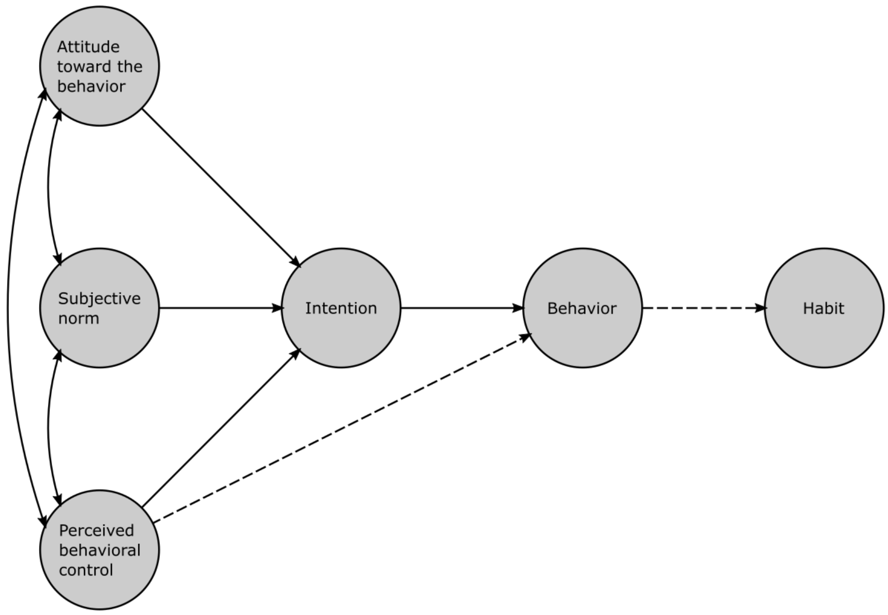

Figure 3 – Theory of Planned Behavior Diagram. Adapted from Ajzen et al. (1991).

The attitude towards behavior represents the opinions of oneself, how we think and feel about certain options. The subjective norm is related to opinion of others, how the others support a given option. The third construction refers to the perceived behavior control, that reflects the capabilities and confidence towards the behavior.

To understand the logic behind the TPB, considere a person that needs to decide how to go to work from their home. The person may begin searching the transportation modes that are available, how they perform and based on that form a opinion about each way of doing this route.

Also, the person may talk to friends and specialists to hear their opinion about the route and their experience with the transportation modes. Finally, the person evaluates their capacity to embrace that choice. For example, a person may find a bicycle trip a good option due to positive attitudes and social norms, however they might fear or not know how to ride a bicycle, which would turn into an impediment to this decision.

These three considerations guide the intention behavior, defined as the probability with which the actor consciously assigns to an engagement in a particular behavior (AJZEN et al., 1991). Furthermore, the repeated performance of a behavior leads to a habit. According to Anable, Lane e Kelay (2006) the habit is when the behavior becomes habitual, so the responses are activated automatically and actions can be instigated without mediation of attitudes or intentions.

Car use seems to have some advantages over alternative means of transports that encourage its use. When a behavior turns into a habit they are more difficult to change, because there is a cost in searching for other alternatives. The repetition of an action makes it easier and less risky, and the expected gains of the alternatives are too uncertain.

This theoretical framework has been applied in some studies to understand different behaviors on people related to transportation choices. The work of Xia et al. (2017) conducted a research in the Adelaide metropolitan region, in Australia, based on the TPB and other sources to investigate travel behavior, attitudes toward transport modes and the intention to reduce car use. One important finding is that individuals have negative attitudes toward pro-environmental travel behavior. They also find that the respondents have different degrees of acceptance for different car reduction measures.

For Anable, Lane e Kelay (2006) a deeper understanding of the role of the individual and social motivations and barriers is needed to reduce the use of cars. They suggest that the segmentation of the population is necessary for the development of travel behavior change programs to be more effective than treating the entire population as an average consumer. In addition, they identify limitations with traditional segmentation approaches, such as age or income, for example, that do not consider the motivation for change.

Using the TPB and the application of a questionnaire to 666 visitors of National Trust properties in the northwest of the UK, Anable (2005) created a market segmentation in six categories based on the intention and use of car by individuals. Each of these groups has a unique psychographic profile, in which the author argues that specific policies must be addressed in each group.

This discussion and previous studies show the importance of identifying the different factors that lead to the choice of travel modes to be used. In addition, it was clear that this choice is much more complex, crossing the sociodemographic characteristics of the population, so that it becomes important to understand different groups of thoughts and work out specific measures for each of these groups.

The specific approach to certain groups of individuals can be addressed by the Mobility Management (MM) framework. The idea of MM is to change travel behavior using communication and the management of the transportation and traffic systems (FUJII; TANIGUCHI, 2006).

Fujii e Taniguchi (2006) reviewed 10 forms of personalized communication applied in Japan and the results are very positive, reducing the emissions by about 19% and car use by about 18%. Meanwhile, they argued that this is a kind of approach that it is effective in different countries and cultures.

Travel demand management is an approach that seeks solutions to the expansion of car use, not by expanding the availability of roads, but by efficiently managing trips and means of transportation available in the city. The idea is to promote positive incentives (to attract individuals to more sustainable means of transportation) and negative incentives (to remove individuals from using car). A successful travel demand management needs to combine both incentives.

Positive incentives are usually based on investments in the public transport system, infrastructure for bicycles and pedestrians, development of technologies and by promoting a mixed and compact urban development. However, the promotion of ST in cities does not depend exclusively on public investment, but also on a change in the habit of citizens to accept this new paradigm. Thus, arises the importance of applying negative incentives on car use in a way that promotes losses (economic, time, well-being) to individuals to force them to reevaluate their transport mode choices.

Some examples of negative measures are: 1) Fuel taxes; 2) Vehicle registration and ownership charges structured in a way to differentiate them by their contribution to emissions, road damage and congestion caused; 3) Reduced car speed; 4) Charges on use of infrastructure and urban tolls; 5) Parking regulations and fees; 6) Land value capture; 7) More space on roads for pedestrians, cyclists and buses instead of cars; 8) Traffic lights that favor walking and cycling; and so on.

Fiscal and market-based measures are seen as important policies to both manage transport demand by economic incentives and also to raise revenue that could be reinvested in ST UN (2016).

In general, negative measures are not well regarded by citizens and end up generating political tension on governments that seek to implement some ST policies. It turns out that one of the problems is how to make ST acknowledged and acceptable by citizens. Do citizens have enough knowledge about transportation problems? And how about the benefits that a ST system can bring to the society? Is this knowledge translated to individual decisions and acceptance of public ST policies?

2.4 Summary

This chapter has presented an overview of the new paradigm in urban mobility and the challenges that it brings to our cities. It has been shown that transport policies should be designed for people and not for cars. Accessibility plays a central role and puts emphasis on a better organization of the urban space. Five elements of the urban form - Density, Diversity, Design, Destination accessibility and Distance to transit - have been discussed in the literature as important factors, mainly by reducing travel distances.

We stated that the urban form is one of the first steps in a ST transition with the aim to promote more vivid and connected cities and that allow modal choices. Therefore, there is also a need to change the population travel behavior. Changing behaviors away from cars is a challenging task due to symbolic and effective reasons. The solution points to a need in group segmentation where specific policies could be addressed in each group.

So, we conclude that there is no standard solution and sustainable policies might take different forms in different places and groups of citizens. So, in order to promote sustainable development, the first step is to understand the territory and population attitudes. In this work we suggest: 1) urban planning sustained through information and characterization of the urban form; and 2) mobility management with personalized communication to different groups of citizens. Topics that will be explore in the next chapters.

3 URBAN FORM STATISTICAL GRID DATABASE

In the previous section, it was perceived that the urban form assumes a crucial role in the search for sustainable cities. There is a functional role between society and the urban form, in which in the daily routine people need to make a series of choices that are strictly related to utilitarian aspects of the urban form. Understanding these utilitarian aspects can be a way to improve performance, comfort and environmental qualities in a city (KRAFTA, 2014). As pointed out in the literature review on Chapter 2, compact, mixed-use, and pedestrian-oriented designs were identified as factors that make cities more accessible, with lower levels of driving and optimization infrastructure and services use.

Filippi (2022) draws attention to the fact that the city as a whole is sustainable only if its parts are sustainable. That is, it is necessary to pay attention and transform each neighborhood, creating places that are built around services, opportunities, and public transport hubs and corridors.

To this end, a good understanding of the city is necessary to plan effective policies and management of the urban environment. Due to urbanization and growing complexity of cities, data availability that makes it feasible to constantly make detailed observations became an essential element for guiding urban planning.

Nowadays, cities became ‘smarter’. Supported by Information and Communication Technologies (ICT) a considerable amount of data is available to address urban problems more effectively. However, access to data is not uniform across cities. While some cities are increasingly being seen through big data, others still rely only on official statistics.

Official statistical data is very important, however, it has some impediments to a detailed understanding of the territory. One of the obstacles to working with this type of data in urban planning is its link to boundaries or administrative units. Researchers need to work with the hypothesis of internal homogeneity of these areas which is not always true. These operational and administrative units have different shapes and sizes that can hide internal variations and make comparison difficult. These unit areas are also not stable over time.

The use of statistical grid data could overcome some of these problems. Statistical grid data is statistics that are geographically referenced to a system of (usually squared) grid cells in a grid net with Cartesian coordinates (EUROSTAT). As described by Bueno (2014) some advantages of its use are: 1) Spatio-temporal stability; 2) Adaptation to spatial cuts; 3) Hierarchy and flexibility; 4) Versatility; 5) Cartographic interpretation; 6) Simple identification; 7) Use in modeling; and 8) Minimizing the effects of Modifiable Areal Unit Problem (MAUP).

In this chapter, we approach the creation of a statistical grid database for Brazilian urban centers. We consider direct aspects of the urban form pointed out by the literature as important factors for the management of mobility and sustainable cities.

To our knowledge, there is no database on urban form that Brazilian cities can draw on. We believe it is very important that different cities, regardless of their size, can access data and observe the territorial structure, both as a way to improve their planning and as a way to observe and compare their structure with other locations and share experiences.

We start the chapter by discussing the importance of urban data and the possibilities of its use in cities. Then we present our proposal to create an urban form database by, first, outlining the study area and after that describing the attributes and data used. Finally, we conclude and discuss ways of using the statistical grid.

3.1 Urban form data in cities

Policy makers are struggling today with a number of pressing mobility and environmental issues, which hinge on changes in the design and form of cities (UN-HABITAT, 2013). Ewing e Cervero (2010) state that the potential to moderate travel demand by changing the built environment is the most heavily researched subject in urban planning. The common urban form variables investigated in this matter are Density, Diversity, Design, Destination accessibility and Distance to transit, reflecting the five dimensions proposed by Ewing e Cervero (2010). The strive for a more compact, connected and coordinated urban growth requires knowledge of these features over the space.

However, the structure of access to information and its monitoring can be very different among Brazilian municipalities. Also, the utilitarian aspects of urban form are spatially different and unevenly distributed in a municipality. In this matter, the availability of consistent, accurate and up-to-date data becomes an essential part of the governance and planning of the city.

The more general data available comes linked with administrative boundaries or census tract. These units can vary substantially in size and shape from one region to another, as well as in time (BUENO, 2014). Also, these units often cover vast areas with large differences within and are represented by an average that does not match reality. This approach leads to the problem that different scales of aggregation can lead to different conclusions, a problem that has been known in the literature as the Modifiable Areal Unit Problem (MAUP) (OPENSHAW, 1984). Furthermore, administrative units pose obstacles to combine different data sets, such as environmental, geographical and demographical data.

Nowadays, advances in Information and Communication Technologies (ICT) have increased the volume, speed, and types of data available. This new urban data has the potential to dramatically change the way we understand and develop our cities.

Arribas-Bel (2014) enthusiastically show the amount and diversity of new data available to the study of cities, which can be classify in three main groups: data coming from individuals carrying location-aware devices, from businesses moving their activity online and from governments releasing an increasing share of their data in open formats. These types of data have the potential to look to urban phenomenons through a more detailed and granular lens.

Nevertheless, development and use of urban data are still complex tasks, specially in smaller cities. Increasing data availability requires computational and programming capacity, as well as teams prepared to extract useful information. Jain e Espey (2022) show that local governments face several issues in acquiring and using urban data appropriately. First, there is a lack of financial resources required to locally generate relevant data, build statistical systems, and foster capacity and skills. Also, there is the absence of spatial data and the fact that most of available data comes linked to boundaries or administrative units, conditions that create difficulties in the examination of inequalities between neighborhoods. In addition, interoperability of data across different sources, formats, and methodologies can be a challenge to the analysis of any subject.

In face of this issue, we would like to highlight the potential that grid data can bring to the analysis of the urban form, as well as, overcome some of the problems associated with traditional data in an easy way and available to all levels of municipalities.

In a statistical grid, geographic units are divided in a set of regular cells and statistical variables are calculated and displayed inside. Grid database can be built in a way that all cells have the same size, which creates comparable territorial statistics. Also, grid cells do not change over time, generating the potential for easy statistical time series. Grid-based data can be easily visualized and manipulated using GIS analysis tools. They are a good solution for the interoperability of different data sources. Using methods such as disaggregation, aggregation or point-based georeferenced data, different sources can be combined in the unit gridded area. Moreover, it has hierarchical flexibility, and the cell can be grouped in different sizes, allowing different views depending on the objective of the analysis (BUENO, 2014).

Leyk et al. (2019) show that the scientific community has increasingly invested in the creation of globally gridded data products that help overcome the inconsistencies in census-derived national population data and facilitate their integration with other spatial datasets. They also describe some of the products created and their qualities and forms of appropriate uses. To our knowledge, few products were produced for Brazil as a whole. The main grid database for Brazil was produced by IBGE - Brazilian Institute of Geography and Statistics, which contains the population density in different cell sizes (from 500km until 1km in rural areas and 200m in urban areas). Data relative to mobility was recently released by the Institute of Economic and Applied Research (IPEA)[1], through the Access to Opportunities project, which has annually publicized accessibility indicators in the 20 largest Brazilian cities in a spatial grid of hexagons with an area of 0.11 km2.

[1] Project information is available at: https://www.ipea.gov.br/acessooportunidades/

It is also important to note that the emphasis has been on producing grids of population counts and density rather than other population attributes and few have joined with data from urban form. Leyk et al. (2019) show examples and the potential of applications of this data format in studies such as: land use and urban planning, measurement of economic development, transportation infrastructure management, resource allocation strategies, disaster risk mitigation, management and reduction, climate change research, sampling design for household surveys, public health campaigns and assessments, and sustainable resource management, among many other applications.

It is important to emphasize that each neighborhood has its on particularities and specific demands, and in order to be able to create less car-dependent urban forms, each of these neighborhoods must be looked at in its individuality. Data in grid format allows more detailed view of the urban space, thus allowing the urban planner to look in detail at each location. In addition, grid format makes it easier to perform simulation processes and observe their effects.

Despite the enormous advantages of a grid system database, Bueno (2014) presents a challenge to its use issues such as confidentiality, international compatibility and data analysis.

Data confidentiality should always be a concern when working with aggregated data in small areas. Researchers want to work with as much detail as possible, but it should go only as far as it does not break confidentiality. In terms of international compatibility, Bueno (2014) argues that there is a lack of international standards and norms that establish good practices to be used in the generation of statistical grids. And last, but very important, is the typical instability derived from the analysis of small numbers. As the analyzed population decreases, the smaller the area and more homogeneous the data becomes in the unit. However, the variables fluctuate a lot along the territory, making it difficult to identify trends or spatial patterns (BUENO, 2014). Thus, the optimal size - the one that combines the advantages of both small and large units - is always a challenge for researchers and it usually depends on the phenomenon under analysis.

3.2 Study Area

This study analyzed Brazilian urban areas. Brazil is a country with interesting features concerning transportation and urban form. It has a population of over 190 million, out of which 87.7% is living in urban areas (IBGE, 2010). The latter are unevenly distributed over the territory with different urban form patterns. In terms of transportation, Brazilian cities still have fewer automobiles per capita than those in high-income countries. However, moving in the opposite direction of sustainability, car ownership has been rapidly increasing in the last decade (RODRIGUES, 2019).

In other to define the urban boundaries to be analyzed, we use the 2007 Regions of Influence of Cities (Regic) made by the Institute of Brazilian Geography and Statistic (IBGE, 2007)[2]. The main purpose of Regic is to identify the hierarchy and influence areas of Brazilian urban centers. Cities were classified according to the influence of both business activities and public management. The classification was based on the definition of a list of goods and services that, measured by the volume and origin of demand, translated the differentiation between the central locations and offered conditions for the hierarchical scale of the centers to be established. Based on this, Regic classifies the cities in 5 levels and the first and second level are subdivided in 3 sub-levels and the third and forth in 2 sub-levels. In total we have 5274 cities classified within some level of centrality.

The degree of centrality is an important measure as it refers to important urban issues, such as patterns of displacement in the city, our object of analysis. For a feasible analysis, we chose to work with the three highest levels of hierarchy, being:

1. **Metropolis** - Also divided in: 1A - Bigger National Metropoly; 1B - National Metropoly and 1C - Metropole
2. **Regional Capital** - Divided in: 2A - Regional Capital A; 2B - Regional Capital B; and 2C - Regional Capital C.
3. **Subregional Center** - Divided in 3A - Subregional Center A; and 3B - Subregional Center B

Furthermore, some of these urban centers are specified as Population Concentration Area (ACP), defined as "large urban areas of continuous occupation, characterized by population size and density, degree of urbanization and internal cohesion of the area, given by population displacements to work or study." (IBGE, 2007, p. 11). However, in the Regic data the ACPs' urban centers are identified by the largest municipality. Thus, we use the IBGE ACP classification to aggregate the counties that are anchored by these areas and considered the whole region in the boundaries delimitation.

At the end, this selection counts with 246 centers based on 530 municipalities represented in the Figure 4[3].

Based on population size (Table 2), this division covers cities with over 20,000 people that, as part of the National Urban Mobility Policy implemented in 2012, needs to develop an Urban Mobility Plan to improve mobility and promote sustainable development.

[2] The last REGIC database available is from 2018, made available by IBGE in 2020. However, the data processing of this thesis was carried out in 2019, therefore being based on the last available version of REGIC 2007. Some cities changed their classification. The big difference is in the inclusion of a large number of cities classified as sub-regional center B. There were 79 cities in 2007 and increased to 256 cities in 2018. However, despite the number of cities included, there is no impact on procedures and analysis presented here.

[3] For a detailed characterization of the cities used, see the Apendice .

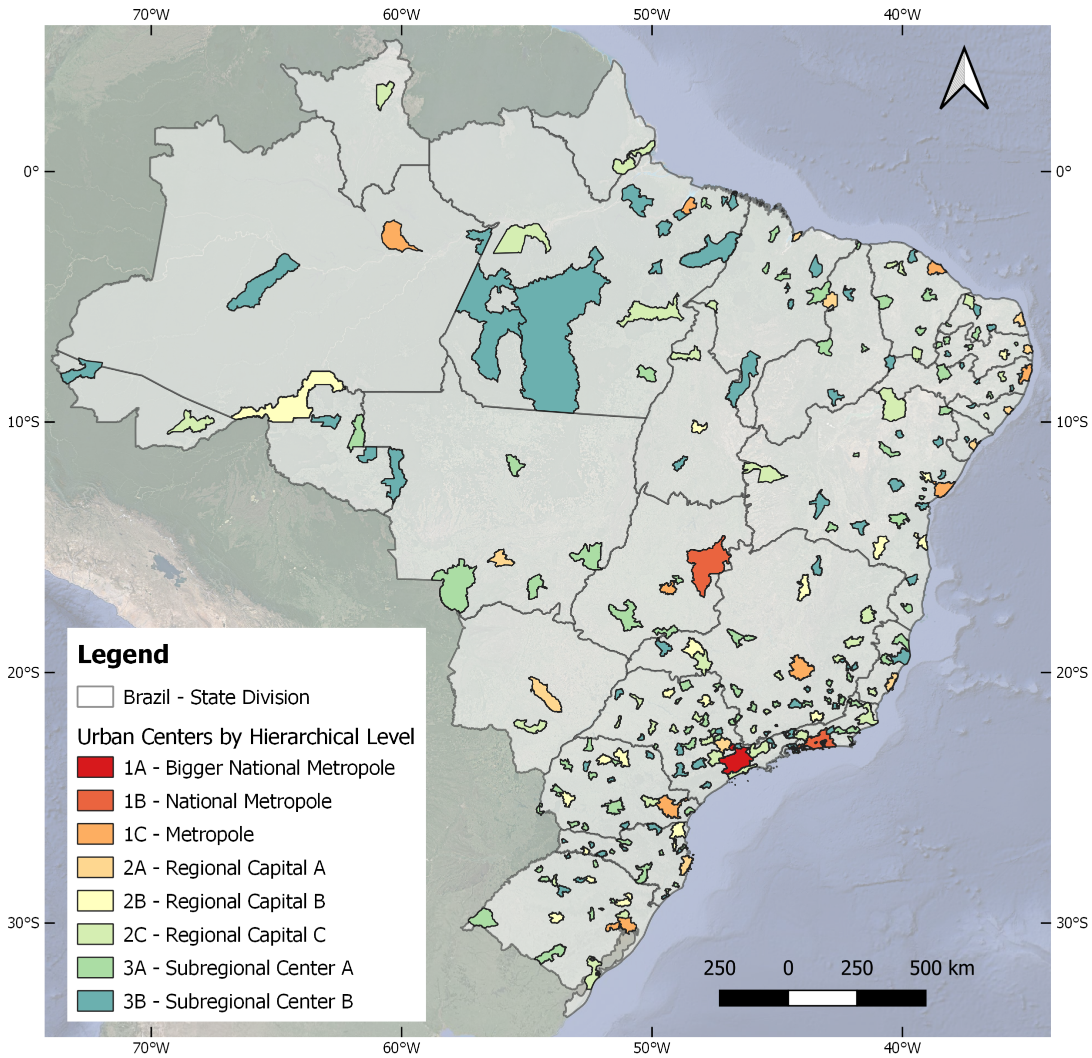

Figure 4 – The Brazil's primary urban areas

Table 2 – Summary of urban centers included in the study.

Center Level	Number of Centers	Max. Population	Min. Population
1A	1	20,096,809	—
1B	2	11,968,973	3,460,637
1C	9	5,039,123	1,802,014
2A	11	2,603,819	786,797
2B	20	791,295	183,530
2C	39	1,604,363	78,915
3A	85	334,613	27,020
3B	79	169,511	23,192

3.3 Measuring the structural attributes in the grid

Grid-based statistics could offer a good source of data for municipalities to get better territorial framework view for urban management and development. Our objective is to create a gridded database with the attributes of urban form pointed out by the literature. To our knowledge, there are no urban form data systematically generated for cities in Brazil as a whole. In addition, despite the great potential of grid data, these have been little used in urban studies.

Ewing e Cervero (2010) separate the urban form variables in five dimensions: Density, Diversity, Design, Destination accessibility, and Distance to transit. These 5 Ds have been widely used in the literature to explain the impacts of urban form on mobility (EWING; CERVERO, 2010; CERVERO; KOCKELMAN, 1997). Thus, the main purpose of our grid database is to estimate these dimensions and make them available for future studies.

We constructed our grid with the cells dimensions of 1km by 1km. The geographical location are based on Sirgas 2000 coordinate reference system (EPS:4674).

We know that some mobility policies need a finer spatial resolution. But this refers to specific infrastructure studies and projects in which an intervention is to be carried out, often requiring data at the block level. However, for the analysis of the urban form as a whole, 1km x 1km grid appears to be a good compromise between data confidentiality, data analysis and suitability for national study. Also, Bueno (2014) carried out a study to evaluate the ideal size for the cells of a statistical grid for Brazil. The study considered the states of São Paulo and Pará, which present very different realities in terms of their territorial occupation patterns. Bueno (2014) concludes that 1km cells would be the best option, with no significant improvements with increasing cell dimensions.

The following subsections explain the selected variables.

3.3.1 Density

Ewing e Cervero (2010) explain that density is always measured as the variable of interest per unit of area. The variable of interest can be population, dwelling units, employment, building floor area, or something else.

Our database contains three variables of density: built-up intensity, population and employment (jobs).

To measure built-up intensity and population we used the Global Human Settlement Layer (GHSL), developed by the European Union's Joint Research Center. We used the built-up area density for epoch 2014, constructed by a supervised classification of Landsat-8 data scenes. The data comes in a resolution of 250 metres, so we vectorized the layer in 1km grid cells, using the nearest-neighbor method to reproject. Thus, each of our cells is ranged in a scale from 0 to 255 measuring the built-up intensity.

Data on the distribution of jobs was obtained from the 2017 Annual Report of Social Information (RAIS), elaborated by the Ministry of Labor and Employment (MTE, 2013). Through ZIP code information, Nadalin (2018) georeferenced the companies. Thus, we take the points and aggregate in the grid of 1km x 1km, in which we have the number of establishments and the number of employments.

3.3.2 Design

Urban design variables measure connectivity or the ability to traverse distances in many directions along a street network. Areas with higher connectivity typically have gridded street networks with shorter block lengths than more disconnected areas with fewer intersections and longer block lengths (EPA). Ewing e Cervero (2010) show that the measures include average block size, proportion of four-way intersections, number of intersections per unit area, average street widths or other physical variables that differentiate pedestrian-oriented environments from vehicle-oriented ones.

In our database we measured the street intersection within the grid area, ie, nodal density.

Brazil's road information was obtained in Geofabrik's server (GEOFRABRIK, 2019) which extracts data from the OpenStreetMap project. The OpenStreetMap is an online open data platform which provides many of the world's geographic data.

To identify the nodal density, we separated the road network into lines and nodes. To the nodes points we assigned a value indicating the number of lines that cross or intersect each node, as reported in Table 3.

Table 3 – Nodes values assigned.

Value	Description
1	End Points
2	Two lines
3	T-intersections
4	4-way stops

Only the nodes of degree 3 and 4 are relevant to our purpose, they are the ones that give the connection of streets in a given area. Thus, the nodal degree values 3 and 4 are aggregated to a 1km grid to match the other data-sets.

3.3.3 Diversity

According to Ewing e Cervero (2010) diversity "measures pertain to the number of different land uses in a given area and the degree to which they are represented in land area, floor area, or employment".

We measure diversity by an indicator of job-housing balance, that acts like a proxy for land use diversity. Job-housing balance is a widely used indicator to express the potential for longer or shorter commutes in a place. In essence the indicator expresses the spatial relationship between workplace and residence. If a balanced spatial distribution between jobs and housing can be reached, the number of vehicle travels will be reduced and it will increase the potential walkability in the area.

We use the same Job-housing balance index presented by Stokes e Seto (2018). First, a spatial filtering algorithm is applied over a kernel of 3km, to represent a walkable distance. Then Equation 1 allow us to calculate the index to each grid cell.

$$B_{(i,j)} = \frac{\sum_{i-1}^{i+j}\sum_{j-1}^{j+1} e(i,j) - \sum_{i-1}^{i+1}\sum_{j-1}^{j+1} p(i,j)}{\sum_{i-1}^{i+1}\sum_{j-1}^{j+1} e(i,j) + \sum_{i-1}^{i+1}\sum_{j-1}^{j+1} p(i,j)} \tag{1}$$

where, $B_{(i,j)}$ is job housing index for residents who live in grid cell (i,j); $e(i,j)$ is the number of employment in grid cell (i,j); and $p(i,j)$ is the population count in grid cell (i,j). The index is a normalized difference, so $B_{(i,j)}$ ranges from -1 to 1, where the extreme values indicate single-use areas: -1 residential areas only and +1 areas with only jobs. Areas close to zero are the desirable ones, meaning areas with a good mix of uses.

3.3.4 Destination accessibility

Destination accessibility measures ease of access to trip attractions (EWING; CERVERO, 2010). There are different ways and methodologies to estimate accessibility.

Following Stokes e Seto (2018) we use the gravity-based measure to calculate the accessibility to jobs in the 1km x 1km grid. The gravity-based measure assumes that accessibility levels are proportional to the attractiveness of an opportunity but have an impedance function representing the cost of reaching the opportunity:

$$A_i = \sum_{j=1}^{J} O_j * f(C_{i,j}) \tag{2}$$

where, A_i is the accessibility index of individuals living in grid cell i; O_j is the number of jobs present in grid cell j; and $f(C_{ij})$ refers to an impedance function that captures the displacement patterns, associated with the travel time cost between areas i and j.

In the literature, impedance functions are modeled by decay functions. The idea is that the representation by these functions show that the interaction between two locations declines as the distance or time of interaction between them increases.

In order to establish the format of the impedance function, we use the observed pattern in the travel times and volume of interactions to jobs reported in the Brazilian Census data of 2010. Based on the functions used in the literature (REGGIANI; BUCCI; RUSSO, 2011), we analyze which line better fits the data, observing the mean square deviation of the residuals. We adopted the negative exponential normal impedance function that best fits data (Equation 3).

$$f(C_{ij}) = \exp(-\beta . t_{i,j}^2) \tag{3}$$

where, $t_{i,j}$ expresses the travel time from i to j; and β is a parameter empirically derived that describes the observed travel time patterns of an urban population. Since the β term varies between urban areas, we derive a β for each individual region separately.

In measurements by gravity accessibility the agglomeration size plays an important role. The number of jobs present in one area could elevate the accessibility index in such a way that the impedance function could not compensate. This indicator is good to show the difference in accessibility within a city. However in the comparison with other cities with huge economic disparities, the difference in the value of accessibility indexes could better represent the disparity in opportunities than the difficulty to reach them. In other words, gravity accessibility may lead to an unattractive feature in which isolated areas close to large cities can have higher outcomes compare to well located areas in small cities. One solution to this problem is to scale the internal accessibility values of cities. As a result, values close to one will indicate places with good accessibility and values close to zero, places with poor accessibility, given its context of city size and economy.

Several databases were used to calculate the accessibility index. Data on the distribution of jobs was obtained from the 2017 Annual Report of Social Information (RAIS), elaborated by the Ministry of Labor and Employment (MTE, 2013). We removed from the analysis the establishments that had no employees, since this kind of enterprise doesn't generate any displacement within the city.

The Origin-Destination (OD) travel time matrix was calculated by the Network Analyst tool available in the ArcGis software, considering displacements made between each grid cell within the areas[4]. The data from OpenStreetMap provided the road configuration with some attributes as type, limit and direction of the street. However, some records have zero speed limit. Before building the network, these records must be updated or deleted. Considering the characteristics of each type of street and based on the Brazilian Traffic Code, we set the speed limits values as described in Table 4:

3.3.5 Distance to Transit

The population's access to public transport is a key element for sustainable mobility. So, in this variable it is important to identify how well the locations are served by public transport services.

We use the data from OpenStreetMap to count the number of bus stops available in each grid cell.

Unfortunately most Brazilian municipalities do not have General Transit Feed Specification (GTFS) data or information of bus routes and timetables. These data are necessary to really

[4] One limitation of this procedure is to considered only the free-flow time-cost to reach the residences to jobs. However, its adoption is due to the limited resources available given the amount of data that need to be processed.

Table 4 – Line feature classes in the layer and the speed limit assigned.

Class	Description	Speed assigned
Major roads		
motorway	Motoway/freeway	110
trunk	Important roads, typically divided	60
primary	Primary roads, typically national	80
secondary	Secondary roads, typically regional	60
tertiary	Tertiary roads, typically local.	40
Minor roads		
unclassified	Smaller local roads	40
residential	Roads in residential areas	30
living street	Streets where pedestrians have priority	30
pedestrian	Pedestrian only streets	0
Highway links		
motorway link	Roads that connect from one road to another of the same of lower category	50
trunk link		40
primary link		40
secondary link		40
Very small roads		
service	Service roads for access to buildings, parking lots, etc.	20
track	For agricultural use, in forests, etc. Often gravel roads.	0
Paths unsuitable for cars		
bridleway	Paths for horse riding	0
cycleway	Paths for cycling	0
footway	Footpaths	0
path	Unspecified paths	0
steps	Flights of steps on footpath	0
Unknown		
unknown	Unknown type of road or path	0

understand the quality of the public transport service. The presence of bus stops can be a proxy for the provision of the service, but often the frequency and route taken by the line can be an impediment to its use.

3.4 Visualization examples

The grid database created let us look within and across cities to explore urban form and and discuss it in urban planning process as a way to improve certain aspects. Here we explore two examples of the data visualization to illustrate the use of data in inform spatial patterns of cities.

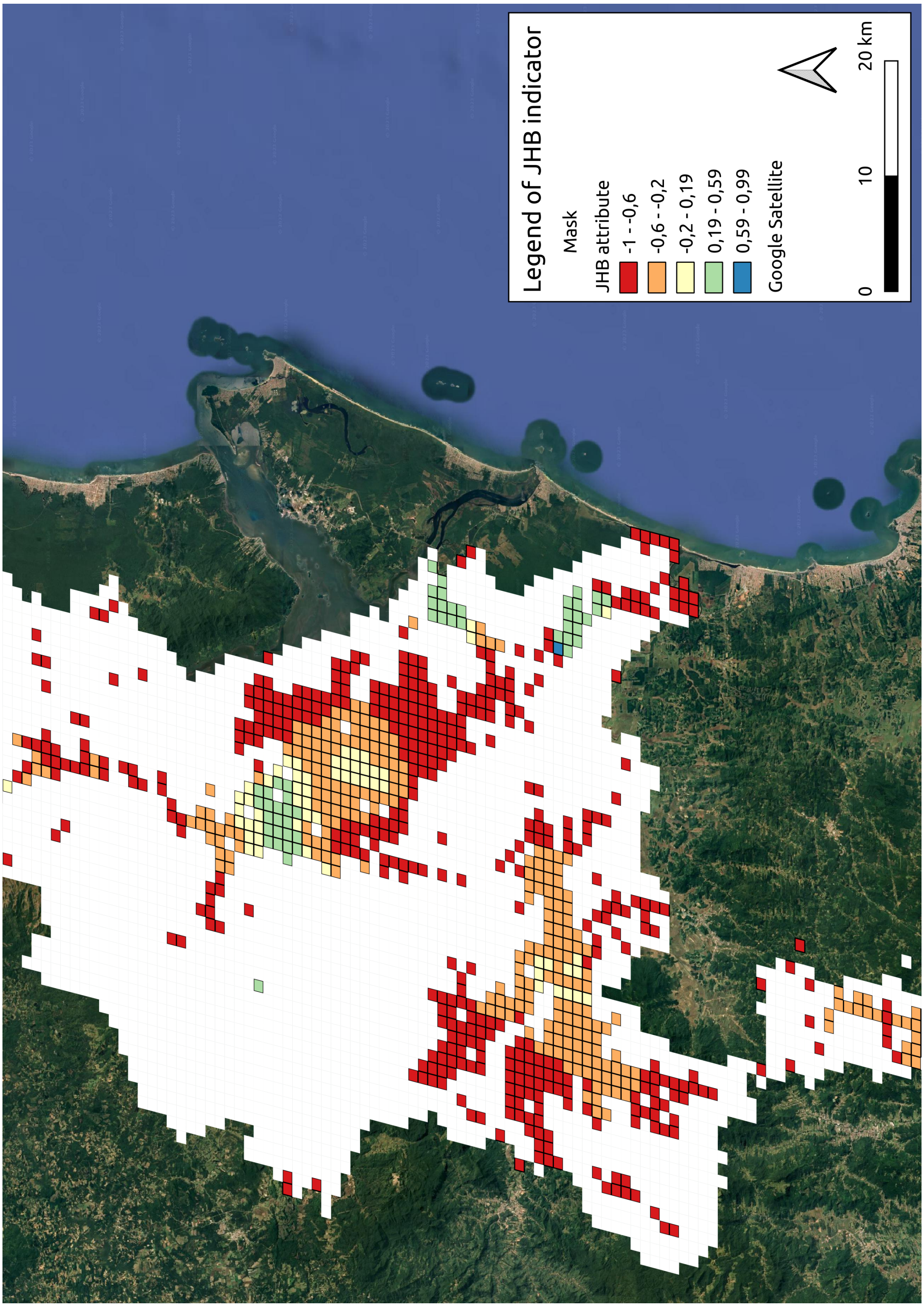

Figure 5 – Example of Diversity: Job-Housing balance indicator in the city of Joinville, SC.

Figure 5 presents the distribution of jobs and house measured by an JHB indicator for the city of Joinville, SC. As can be seen, there is a large concentration of residential areas and some locations with a concentration of jobs far from housing. This tends to generate a significant number of trips between home and work every day in similar time slots. This characteristic tends to create congestion and, based on the quality of the public transport service , may encourage car use. In this case, an efficient urban planning could guide an adequate density, according to centralities and transport axes.

The data base could also be used to observe and compare cities patterns. In Figure 6 the street design of Juiz de Fora, MG and Fortaleza, CE cities are compared. we can observe two types of very different street design patterns. Meanwhile, Fortaleza displays a rectangular pattern, with well-defined and connected blocks; Juiz de Fora has long streets with little connectivity. A citizen of Juiz de Fora's city needs to walk a longer distance to access a facility located a few meters away than a resident of Fortaleza's city. This tends to cause a discouragement to the use of active modes of transport.

Such visualizations can serve as a practitioner's tool for investigating the physical outcomes of planning and urbanization, as well as a tool for communicate unwanted characteristics in a simple way to improve planning and collaboration for change.

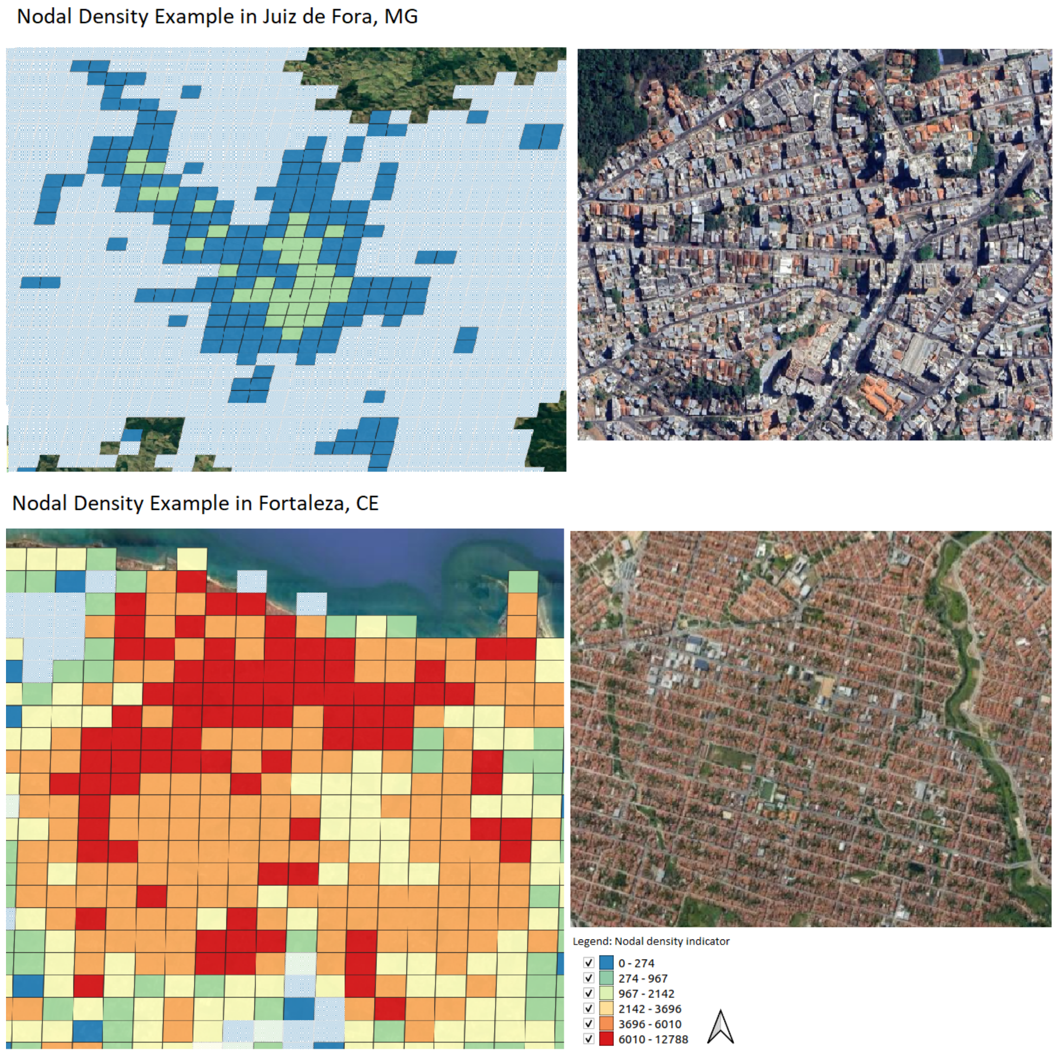

Figure 6 – Example of Design: Nodal Density indicator in the cities of Juiz de Fora (MG) and Fortaleza (CE).

3.5 Conclusion

Cities have become an essential part in strategic sustainable development. Urban planning gained a central position in order to create more inclusive and less car dependent cities. However, urban planning requires a good quality of information about physical, spatial, environmental and socio-economic conditions of its neighborhoods.

In the last years we have seen an intensification of data availability. Our daily lives are entangled with the generation of diverse data that promises to change the way we understand, conceive and plan our cities (ARRIBAS-BEL, 2014). The opportunities afforded by this form of data are immense. However, the acquisition, systematization and organization of databases is still a complex task and many municipalities are not able to take advantage of this information.

In this chapter we created a grid database based on direct attributes of the urban form (Density, Diversity, Design, Destination Accessibility and Distance to Transit) for 246 urban centers in Brazil divided in grids of 1km by 1km. Given the complexity inherent to cities, these attributes offer a streamlined view of the urban fabric, its shape and the organization of its elements. The data and metadata are available at GitHub repository: https://github.com/TatianaFerrari/Urban-Form-Statistical-Grid.

Is it also essential to understand how to use urban data for the development of cities? How could this data be useful?

As mentioned in Chapter 2, Brazilian cities over 20,000 inhabitants need to present an urban mobility plan. Under the methodology to develop such plan, it is necessary to create scenarios and assess impacts (Step 4.2 in WRI Brasil Guideline). The design of scenarios includes the expected impacts on land use and occupation, resulting from urban guidelines (Master Plan), growth trends and location of equipment and various projects.

The starting point to construct such analysis is the availability of data. We hope that the database created here can help cities with their development plans and in smart governance strategies. The grid format is friendly towards simulation processes, required in scenario analysis. Also, the grid base format can be easily opened and visualized in GIS softwares. The simple visualization can display specificities of a particular neighborhood and convey a more strategic spatial planning with new land regularization and management approaches. In addition to that, grid format helps with interoperability of data across different formats. So one can easily add socioeconomic information, such as those available by IBGE, or other institutions. Furthermore, in addition to creating the database, ways to disseminate and update the data should be discussed involving the participation of other stakeholders.

The analysis of this data can also help to compare places in search for similarities and shared experiences. We know that cities could be extremely different when it comes to certain solutions and local urban context. However, the process of sharing experiences brings a substantial gain to cities in their planning, preventing certain mistakes and problems from being repeated. One way to look for these similarities is through the creation of urban typologies. In the next chapter, the classification of urban areas is carried out through the created database.

4 URBAN TYPOLOGIES THROUGH DIRECT URBAN FORM MEASURES

Cities share relatively similar concerns about environment degradation, traffic congestion, road accidents, social exclusion, air quality and health and quality of life of its citizens. There is increasing evidence that the form and functionality of a city can have significant impact on the outcome of these concerns - as discussed in Chapter 2.

Untangling the impact of urban form however, is quite complex. Studies have focused on improving the metrics and mathematical modeling to better address the relation between urban form and travel behavior, as well as to control its socio-demographic characteristics (BHAT; SEN; ELURU, 2009), residential self selection (BHAT; GUO, 2007) and spatial heterogeneity (DING; CAO, 2019). Nonetheless, studies have been much slower to explore a comprehensive classification of differences in the urban form within cities and to adopt advances in disaggregated spatial data.

There is a need to understand the particularities of each location and look differently at each place in order to be able to successfully implement policies. In the last section, we developed a database to understand the territory in a way that is useful for policy planning. The database measures the built environment in a grid of 1km by 1km for urban cities centers in Brazil. In this chapter, we make use of this data to conduct a cluster analysis to classify the areas in terms of their urban attributes.

The main objective of this chapter it is to apply the methodology developed by Stokes e Seto (2018) for the identification and measurement of urban typological samples regarding their structure. We believe that a typology of the urban form with a high level of disaggregation (spatial detail) can help to understand important territorial particularities. The classification in combination with other data can be very useful to improve the understanding of the relationship between urban form and the development of sustainable mobility.

The second part of the chapter highlights the problems faced in relation to the growth of cities and how the search for a typology based on the urban form can be useful for urban planning. The third part address the methodology used and the cluster results. We than discuss the main findings in the fourth part. The fifth part concludes and addresses further work to be developed.

4.1 Characterizing urban areas

Despite the growing concern with urban and environmental problems, many cities still continue to prioritize motorized transport and their related infrastructure. In a context of rapid urbanization, policies aimed at motorized transport can collaborate to the sprawl of cities, meaning here a dispersed, segregated, automobile-oriented, urban-fringe development.

Santos (2013) when discussing the Brazilian urbanization shows, to some extent, that Brazilian cities present a dispersed urbanization, which occurs on the fringes of urban planning. Fast urbanization has been labeled as the cause of spatial inequalities and problems in many Brazilian cities. However, despite the lower growth rates since the 1980s, cities keep growing and developing in the same way (BARROS, 2004).

Another important trend in the most recent urbanization processes, is the growth and increasingly important role of medium cities in the configuration and structuring of the Brazilian urban network. However, little is known about the spatial pattern of their development. Studies worldwide suggest that small and medium-sized cities can present more fragmented and disperse occupation patterns than big cities (LIU et al., 2018).

The growth of cities in this sprawling way can cause unwanted outcomes. Larger land consumption causes an increase in traveled distances, reducing accessibility and generating inequalities. It also increases the cost for providing services and infrastructure and induces automobile ownership.

Studies have quantified and monetized the impacts of urban sprawl. Using real world data, Litman (2015) found that in the most sprawled cities the average annual per capita spent on public infrastructure is 50% more than in cities with the smartest growth. He also found an increase of 20-50% in the per capita automobile ownership and use, and a reduction of walking, cycling and public transit use by 40-80%, compared with smart growth communities.

However, most of these economic impacts have been evaluated in the USA, due to intense debate about sprawl and data availability. Brazilian sprawling growth is very different from the classic North American sprawling. Even though, most of the undesirable impacts occur in every city throughout the world, the extent and costs can be quite different, especially in social terms.

Hence, tracking and understanding how cities grow can help to implement proper policies and try to avoid economic, social and environmental issues.

What policy makers should seek is to promote urban design with effective measures addressing sprawl and settlement containment towards more responsible and sustainable urbanization strategy. Policies need to ensure that cities grow in compact urban neighborhoods, with good streets design and with provision of public services and opportunities. Also, it is necessary to pay attention to each neighborhood. The city as a whole is sustainable only if its parts are sustainable (FILIPPI, 2022).

The challenge lies precisely in designing policies to ensure sustainable growth given the size and reality of each location. As Litman (2015) emphasizes: “there is no single set of development policies that should be imposed everywhere”.

According to Krafta (2014), the most traditional way in science to treat compound problems involves reducing their complexity, most often achieved through two procedures: reducing the number of components and dividing the whole into subsets that are simpler to describe, analyze and understand. The reduction of city complexity in terms of material manifestation, on the territory gave rise to the descriptive and analytical instrument designated by typology.

A typology is basically a system used for putting things into groups according to certain similarities. The use of typologies that can describe aspects of the urban form can be very useful to support studies and policies in the terms discussed here.

Despite the relevance of observing and characterizing the urban structure within and across cities, few studies have performed this characterization and in those that do, only population density is used to represent the use and configuration of the city (STOKES; SETO, 2018; LITMAN, 2015).

To help city planners and policy-makers to better understand the territory, Stokes e Seto (2018) proposed a classification of urban form characteristics through cluster analysis using grid data.

Their classification is based on objective measures of the built and natural environments and is comparable across and within urban areas. The idea is to identify stands within urban landscapes, which "describe land units that are sufficient uniform in their structural composition and configuration, that they may benefit from similar planning and management"(STOKES; SETO, 2018). The study operationalizes this stand classification for 909 urban areas in the US to understand transportation behavior. As a measure of urban form, they used the built-up intensity (density), street intersection nodal density (design), job-housing balance (diversity) and job accessibility (destination accessibility), all of them are measured in a resolution grid of 1km by 1km . These attributes are used as inputs into an unsupervised k-means classification. The results created fourteen structural classes, with contiguous areas spatially clustered.

Stokes e Seto (2018) show that the structural variety within urban areas tends to be greater than across them. However, the application analyses only cities in the US, which does not bring evidence that this holds in comparison to other contexts. As Cervero (2013) exposes, the mobility challenges faced by developing countries can be quite different from those in advanced countries. Considering spatial form and land-use characteristics, they can be distinguished in terms of primacy, levels of monocentricity, population densities, roadway designs, and geographic locations of the poor (CERVERO, 2013, p. 9). In this matter it would be interesting to analyze the differences among stands due to differences in city contexts and geographies.

The proposed methodology given by Stokes e Seto (2018) could serve as indicator in a macro geographic scale and used as indicator for assessing and comparing neighborhood conditions, conduct scenario planning and prioritizing investments. Furthermore, the classification proposed by Stokes e Seto (2018) splits out some factors and tease out place types. It can be used to analyze important issues such as: Where to build and what kind of transportation to be built; How many people will benefit from the implementation of a type of policy. When resources are limited, planners need to chose wisely where to prioritize strategies to promote sustainable mobility and this way of looking at the spatial structure in cities could help in this matter.

In the next section we apply the methodology developed by Stokes e Seto (2018) for the case of 246 Brazilian urban centers. We make use of the database created in Chapter 3, considering five structural attributes - built-up density, population density, nodal density, job-housing balance and job accessibility.

4.2 Stand Classes Results

An important first analysis to be made for the stand classes consist in observing the structural variety between and within urban areas. Table 5 shows the variance in logarithmic scale for each attribute across all grid cells and within each urban area, presented in terms of quartiles.

The results indicate that there is high disparity in these measures among Brazilian cities. For all attributes, the structural variance across cities was higher then the structural variety within urban areas for at least 75% of the 246 urban areas. This finds contrast with the results found by Stokes e Seto (2018). In the case of urban areas in the US, they found that structural variety is larger between neighborhoods within a city than between urban areas in aggregate. So, we can see that Brazilian cities are more uneven in term of their urban structure.

Table 5 – Log variance of structural attributes within and across urban areas.

	Pop-dens	**Access**	**Nodal-dens.**	**JHB**	**Built-up**
Across	7.20	12.47	5.85	-1.15	2.93
Within per quartiles					
25%	6.53	5.81	4.27	-1.68	0.82
50%	6.69	6.77	4.46	-1.43	0.97
75%	6.90	7.75	4.68	-1.23	1.13
100%	7.68	12.23	6.84	-0.61	3.86

Based on the five structural attributes (built-up area, street intersection nodal density, accessibility and job-housing balance and population density), we conduct a cluster analysis with the aim to classify the stands, similar land units within urban areas. Stokes e Seto (2018, p.4) derived the idea of stands from the forest science and management, "where a contiguous community of trees, sufficiently uniform in composition and spatial arrangement, distinguishes it from adjacent communities".

After the normalization of the attributes, they are classified in clusters using the Partitioning Around Medoids (PAM) algorithm. The idea is to search for k representative objects in the data set, known as medoids, which represent the most centrally located point in the cluster. The other objects are assigned to the closest medoid in a way that the average dissimilarity between it and all the other members of the cluster is minimal. The k-medoid methods has the advantage to be less sensitive to noise and outliers compared to the k-means classification (KASSAMBARA, 2017).

This method requires that we previously establish the number of clusters. The Cindex measures the distance among points in a data set to find the optimal cluster number. It is calculated as:

$$Cindex = \frac{S - S_{min}}{S_{max} - S_{min}} \tag{4}$$

where, S is the sum of all distances between pairs of observations in the same cluster over all clusters. S_{min} and S_{max} are, respectively, the sums of lowest and highest distances across all pairs of observations. For the calculation of the Cindex to our database, 17 clusters was established as the optimal number, with an index of 0.061. The characteristics of each class are listed in Table 6.

Table 6 – PAM classification normalized attribute medoids for stand types.

Stand Class	Built-up	Pop-dens.	Access	Nodal-dens.	JHB
1	-0.832	-0.605	-1.342	-0.417	-1.051
2	-0.808	-0.592	-4.628	-0.443	-1.175
3	-0.779	-0.601	-0.346	-0.431	-1.054
4	-0.755	-0.596	0.276	-0.411	-0.915
5	-0.740	-0.588	0.317	-0.405	-0.325
6	-0.721	-0.554	-0.284	-0.372	0.320
7	-0.692	-0.548	-2.745	-0.453	-0.752
8	-0.677	-0.576	0.203	-0.365	1.193
9	-0.423	-0.533	0.304	-0.420	2.984
10	-0.117	-0.062	0.336	-0.158	-0.537
11	0.224	0.098	0.402	1.799	-0.310
12	0.246	-0.057	0.349	-0.172	0.747
13	0.843	0.382	0.458	-0.120	-0.068
14	1.588	1.850	0.634	4.150	0.074
15	1.639	0.643	0.621	0.000	1.049
16	1.743	1.511	0.582	0.060	-0.125
17	2.256	3.449	0.563	0.166	-0.0080

The stand classes 1 to 9 share a common characteristic of low built-up area, population and nodal density.

Stands 1, 2 and 7 are mostly present in smaller regions from center level 2B down. Their relative location to the urban core of the region is what differentiates them: places classified as stand 1 are in the borders of the core center or areas outside the suburbs of a city, consisting of residential areas with low accessibility; stand class 2 are isolated areas, with small communities; and stand class 7 refers to other urban centers of aggregated municipalities where, in the case of small regions, they are detached which imply a low level of accessibility to the main opportunities. Examples are shown in Figure 7 considering the region of Maringá (PR). The area of Mandaguari and Floresta fell on stand 7, which are areas with a some level of jobs, but a more rural place and a little far from the urban center of Maringá.

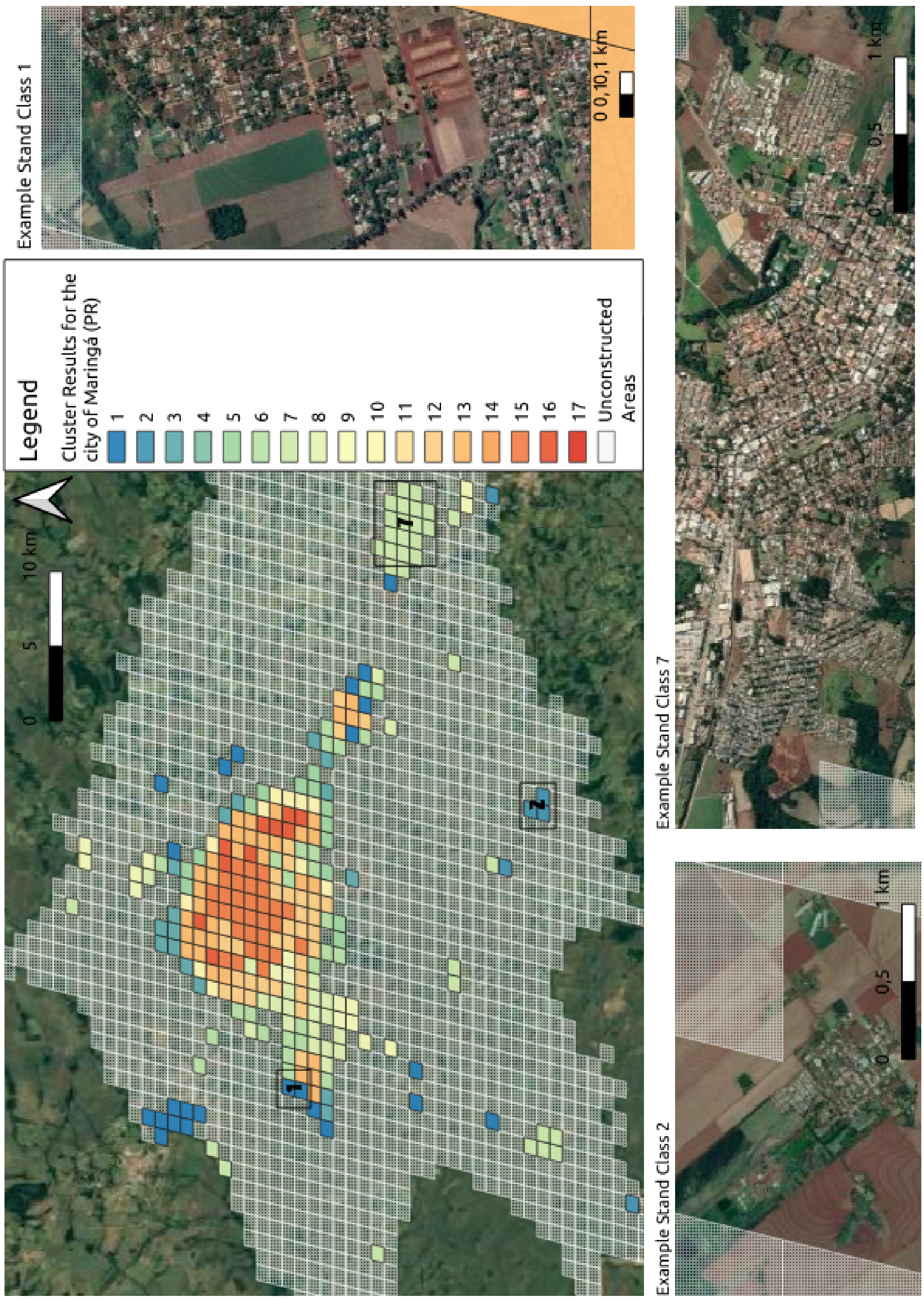

Figure 7 – Stand Class 1,2 and 7. Examples in the city of Maringá, PR.

The groups formed by stands 3, 4, 5 and 6 are present in most urban areas and are very similar to each other. The difference lies in the JHB index. Areas classified as stands 3 and 4 are practically residential, while areas 5 and 6 have better land use mix, with stand 5 slightly more residential and 6 with more jobs in the area. Furthermore, stand 3 has worse accessibility and is located further away from the urban center.

Industrial activities due to agglomeration diseconomies tend to redistribute spatially. It is these industrial locations that stands 8 and 9 are generally reporting. They are areas of low built-up, where large plots of land are destined for companies. Residential areas are non-existent or, when they do exist, they are settlements with low population density. Despite being far from the main urban center, they tend to be located close to highways and areas with easy production flow. These stands are present in all analyzed regions to a lesser or greater degree according to local economic activities. Figure 8 shows an example in the city of Valinhos, within Campinas' region, where there are industries located adjacent to Anhanguera highway.

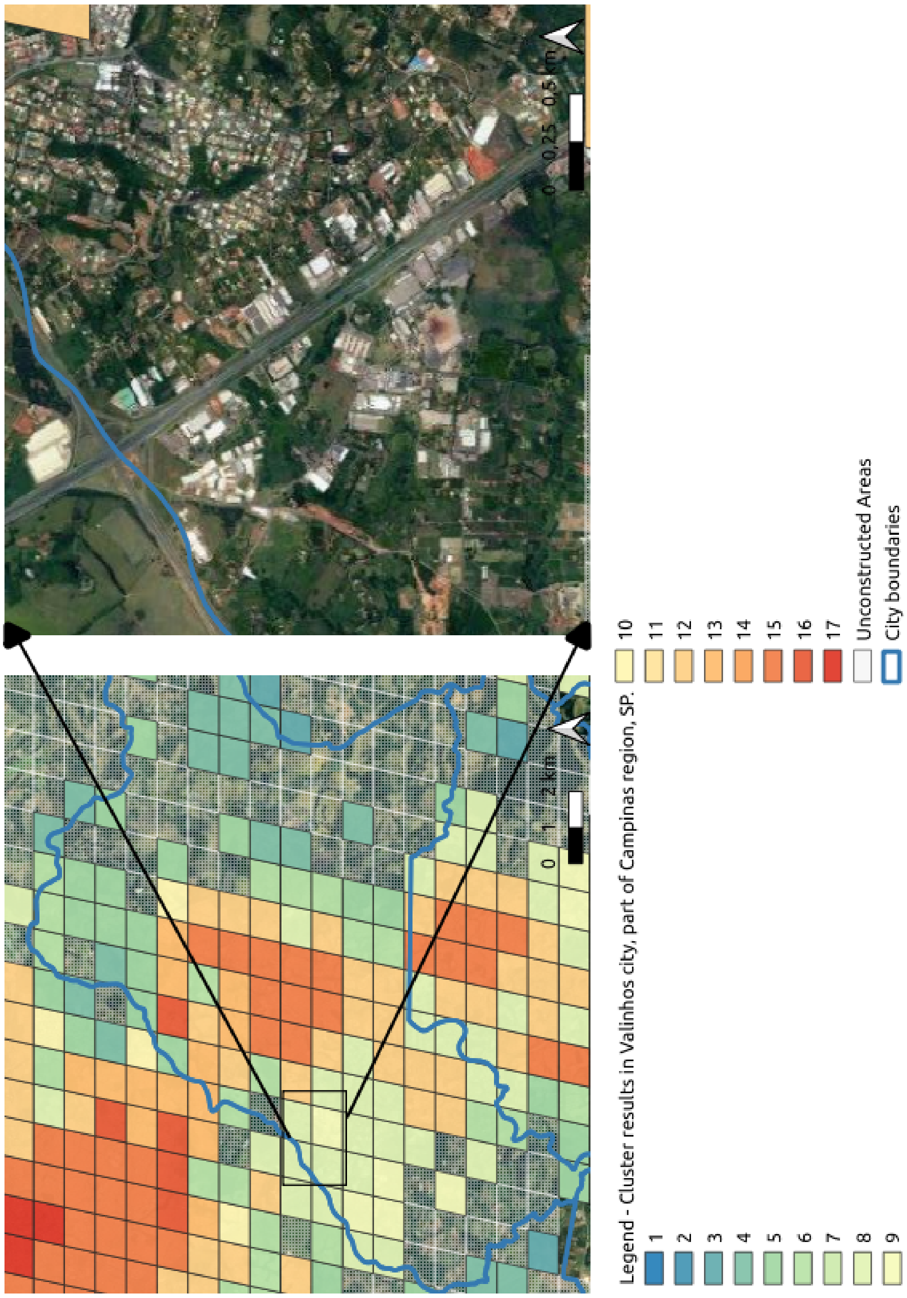

Figure 8 – Stand Class 8 and 9. Examples in the city of Valinhos, SP.

From stand 10 onwards we start to see areas more intensive in construction and population. Stands 10, 11, 12 and 13 are areas of medium occupation, located around the urban core. They present medium to high accessibility and vary in terms of JHB and nodal density. While stand 13 has a good land use mix, stand 12 is job intensive and stands 10 and 11 present more residential units. Furthermore, stand 11 has the particularity of having a high nodal density.

Stands 11 and 14 exhibit the highest nodal densities among the groups. Moreover, stand 14 has a high level of built-up areas and a good JHB mix. It is a stand usually located at the central area of the city. These characteristics make it an excellent candidate for active transport displacements.

The region of Fortaleza is presented in Figure 9 as an example of stand classes 10 to 14. Due to the the city's planning with a street layout in the form of a chessboard, a large part of the central area of the city is classified as stand 14. Stands 10, 11, 12 and 13 are located at the edge, but still in the conurbated part of the region. Stand 13, despite appearing to be a large industrial pixel area, differs from stands 8 and 9 due to the proximity of large residential areas in the surroundings, which guarantees a better mixed use area.

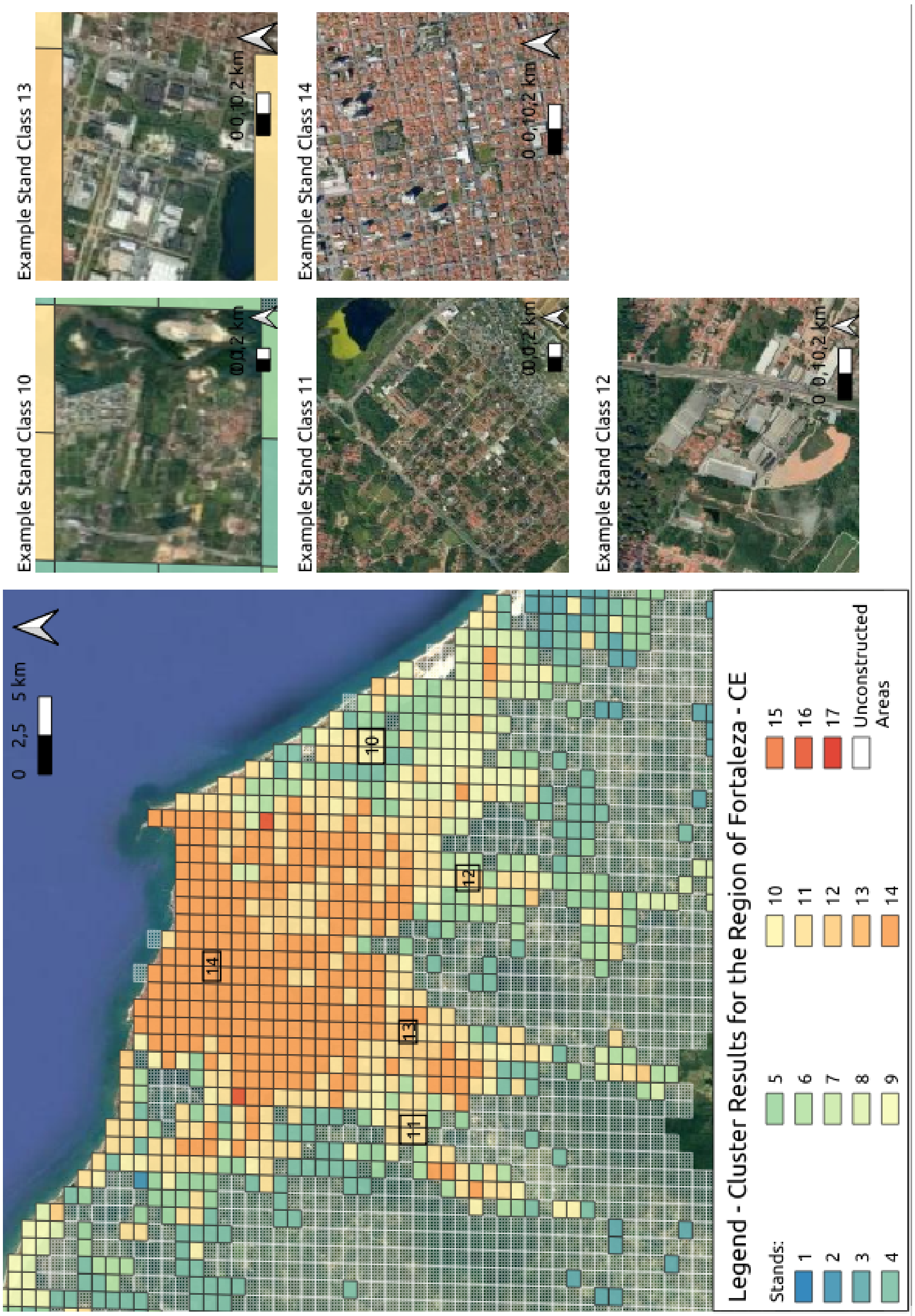

Figure 9 – Stand Class 10, 11, 12, 13 and 14. Examples in the region of Fortaleza, CE.

Lastly, stand classes 15, 16 and 17 are located usually in large cities where there are high built-up areas and large population concentration. They also have good to reasonable accessibility and nodal density. Figure 10 shows the example of the region of São Paulo, in which a large part of its urban center is classified as these stands. Stand class 15 presents a large concentration of jobs and stand class 16 and 17 a good land use mix. Considering this macro analysis level, stands 16 and 17 are good candidates for the use of active transportation.

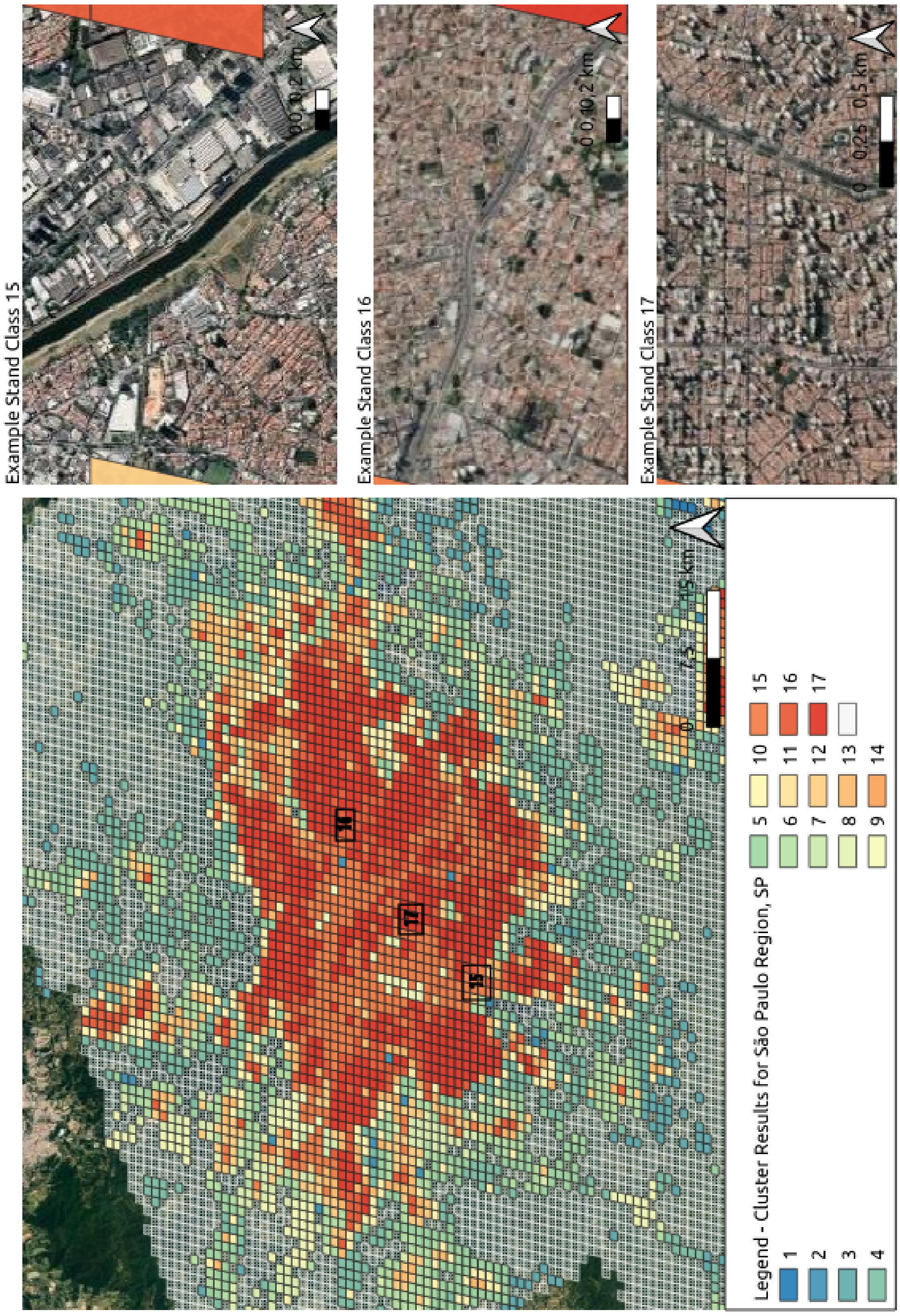

Figure 10 – Stand Class 15, 16 and 17. Examples in the region of Sao Paulo, SP.

Despite the fact that most of the classes are present to some degree in Brazilian cities, their composition is significantly different. To illustrate, Figure 11 shows the perceptual of each stand in Brazilian major cities - the ones classified as Metropolis. These are cities with a high population (ranging from 20 million to 2 million, see Appendix C), but the way they are allocated in the territory is quite different. High density areas represented by stands 15, 16 and 17 are approximately 30% in São Paulo, Manaus and Recife, while they have very low incidence in Fortaleza and Salvador, where stand 14 stands out. Stands with a high level of jobs (8 and 9) represent more than 10% in Brasilia, Manaus, Fortaleza and Belo Horizonte. The classes with less density: 3, 4, 5 and 6, are more homogeneous through the cities. Together they represent 23% in Belem and can reach 46% in Curitiba and 45% in Belo Horizonte. They also are very significant at city centers of level 2 and 3. This raises an alert about urban sprawl in Brazilian cities, which is something quite characteristic and relevant even in smaller urban centers.

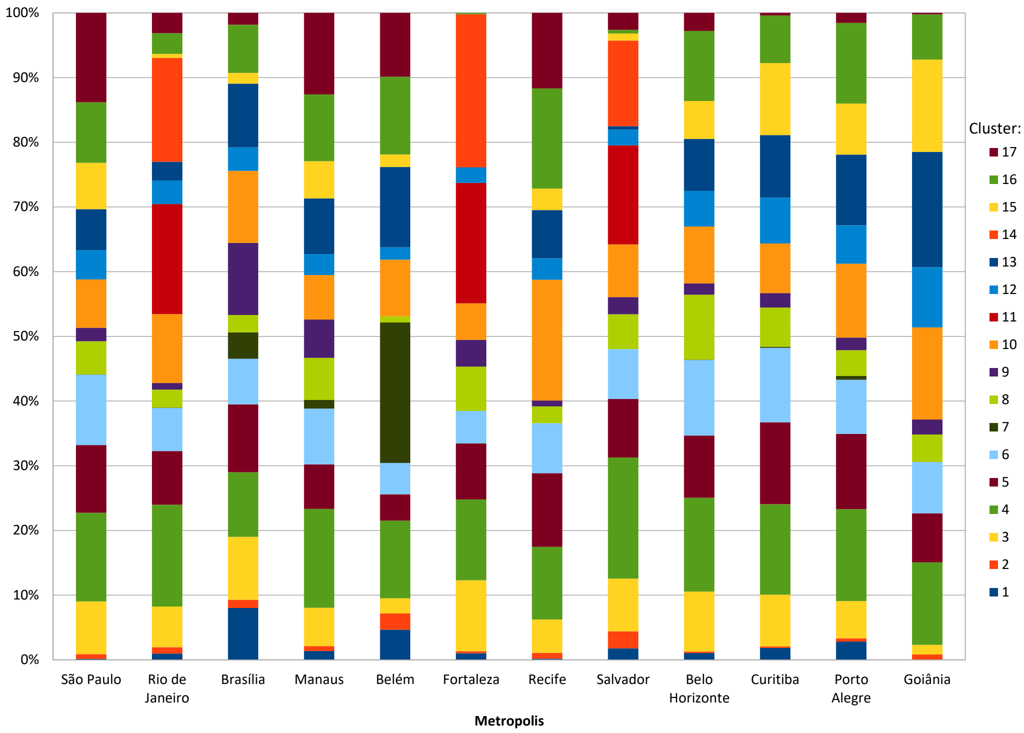

Figure 11 – Distribution of classes in major Brazilian cities.

4.3 Discussion

Stokes e Seto (2018) reported that in terms of academic studies, these classifications create opportunities for devising a sampling strategy. For policy and planning, stands create a way to correct scale mismatches between urban outcomes and the governance units managing these outcomes.

The result of our classification drew attention to the large number of areas classified in stands 3, 4 and 6 in most Brazilian cities. As previously described these are stands located on the edges of cities having a low population density. The high presence of these classes highlights the existence of urban sprawl, a common and worrying problem in terms of sustainability.

Sprawled development patterns are characterized by large distances between residences and frequent trip destinations. The detached and distanced neighborhoods increase the cost to provide adequate public transportation and other public services, which may cause higher use of private vehicles or leave some communities isolated.

Ojima e Hogan (2009) highlight that Brazilian sprawl differs from North American urban areas because there is an overlay of social processes that led to these urban forms. Brazilian urbanization can be divided in two phases; the first urban transition was characterized by a rural-urban migration which inflates the large cities; the second movement is urban-urban migration, where there is a decentralization and expansion of medium cities; 'regions and not cities are the most important scale of everyday life'... This new tendency of urbanization has huge impact in the city's urban form, where a great consumption of land is observed independently of the population size. Ojima e Hogan (2009) describe this urbanization pattern as 'a polynucleated city, fragmented, with low densities, over wideranging territorial extensions, but at the same time more and more integrated'.

As mentioned earlier, urban sprawl has significant environmental, economic and social consequences. In terms of sustainable transportation, low density and sprawled patterns increase the dependence of motorized transport, which increases congestion, air pollution and greenhouse gas emissions. Analyzing the major Brazilian cities, Ojima e Hogan (2009) found a statistical correlation between the degree of sprawl and the proportion of homes with at least one automobile, that is independent of the income.

Our results give just an insight about this unwanted feature of the urban form. A deep analysis into the multi-dimensional aspects of urban sprawl is necessary to diagnose, understand, monitor and outline policy options for sustainable urban development. But, one thing is certain, since transportation is recognized to be pivotal for the sprawl of cities, it is essential that policies coordinate and integrate transportation planning and urban development.

Density it is just one element in our analysis. We also show that other factors influence travel, such as the mix of population and jobs, accessibility and street design. The created stand classes were also efficient in dividing the areas according to these features.

Stands 8, 9 and 13 captured areas with a high concentration of jobs. Redirecting the location of industries to the periphery can be a strategy to avoid diseconomies of scale. In the case of stands 8 and 9, which are further away from residential areas, this might result in longer distance trips, which are more dependent on motorized transport.

Today, many cities are seeking sustainable transport strategies. However, developing efficient transport systems is a challenge. Stokes e Seto (2018) [p.11] highlight that “since same stands types are commonly found in multiple regions, collectively cities can share strategies more effectively across vastly different geographies, scaling up their impact. (...) city coalitions may engage broader financial and institutional support not usually available for a single neighborhood”.

We also know that cities face a diverse range of challenges at the local level that, beyond urban form features, can influence the implementation of sustainable mobility in cities. Additional factors could account for sociodemographic characteristics, crime, lack of mobility choices, and cultural norms and attitudes. Even so, we believe that the classification proposed here can inform about the landscape being built and with that, it can become an effective instrument for urban planners to redesign neighborhoods and create urban forms geared towards people and not to cars.

4.4 Summary

This chapter carried out a classification of the urban structure of 246 Brazilian cities using the methodology proposed by Stokes e Seto (2018). The results created 17 typologies based on five direct attributes of the urban form. In this way, Brazilian urban areas are divided into a collection of smaller landscapes, that are distinct in how they function.

The results show that the structural variety across cities are higher then within urban areas. This is a contrasting result with the one presented by Stokes e Seto (2018) for the US case, showing that Brazilian cities are more different from each other. Each class showed a peculiar characteristic that may benefit from different planning and management strategies. The high number of low-density areas present in most cities drew attention, warning a possible dispersed and segregated development.

Understanding and characterizing the urban structure is a step towards creating more sustainable, inclusive places and defining more efficient policies for these goals. Therefore, the classification result presented here is a first step towards a discussion to create compact, mixed used and walk friendly communities.

5 ATTITUDES TYPOLOGIES: AN METHODOLOGICAL PROPOSAL

5.1 Introduction

There are enormous challenges to Brazilian urban spaces with regard to the mobility of their citizens and the functioning of the transport system. Such problems are related to congestion, accidents, inadequate use of urban spaces, noise and emissions of greenhouse gases and pollutants.

The concept of sustainable transportation (ST) tries to promote a transport system that meets the needs of the people by providing safe and environmentally friendly modes of transportation (HUSSEIN, 2013). One of the goals of ST is to reduce the dependence on cars and promote the use of public transport, bicycles and walking in cities. This requires investments to promote such sustainable modes of travel, improving their quality, safety and efficiency, but also a change to population travel behavior.

As the WCED (1987) shows: “Perceived needs are socially and culturally determined, and sustainable development requires the promotion of values that encourage consumption standards that are within the bounds of the ecological possible and to which all can reasonably aspire”.

Xia et al. (2017) p.593, arguments that “convincing individuals to adopt more environmentally travel behavior patterns is a challenging task, as there are a variety of considerations affecting personal travel behavior”. It is common sense for most of society that automobiles are an ideal form of urban mobility, providing comfort and practicality. In addition, vehicle ownership becomes a form of social status and economic power, a way for the individual to maintain their class distinction. As a consequence, a significant part of the problem, as stated by Hussein (2013), is the enduring popularity of the private car that encourages people to turn a blind eye to its environmental and public health impacts, and puts the choice of public transport always in second.

Mobility Management (MM) is a concept that has been used to change the travel behavior through the communication and management of transportation and traffic systems. However, individuals have particular attitudes towards car use. As stated by Anable (2005) people must be treated differently because they are motivated by distinct factors and are affected in different ways by policy. The “soft” measures used in MM, such as marketing, information, communication and education are reported to be more effective to behavior change when they are personalized instead of mass communicated (FUJII; TANIGUCHI, 2006).

The first step is to understand the different attitudes and motivations of individuals. We want to propose a methodology to create group typologies in accordance to their travel behavior, beliefs and attitudes. To do so, we create a survey which is tested in the city of São José dos Campos, SP. The questions sought to capture concerns about environmental problems, knowledge of the impact of transport, the acceptability to different means of transportation and ST policies, as well as examine their current travel behavior.

The nonlinear canonical correlation analysis (OVERALS) is used to perform the classification. The advantage of the method proposed here is the possibility to consider a high number of variables that encompass a wide range of individual values.

The remainder of this chapter is organized as follows. The next section presents the methodology development in terms of the survey construction and statistical analysis to be performed. The third section describes the sample acquired and the results of the statistical segmentation. The fourth section addresses the conclusions and discusses improvements and next steps in this line of research.

5.2 Methodology

5.2.1 Research construction

The aim of this study is to understand the perception and attitude of individuals in relation to environmental problems, the impact of the transport system, and the acceptability of ST policies.

To this purpose, we design a quantitative survey based on the TPB theory and the existing literature. The questionnaire developed consists of three parts: 1) current travel behavior; 2) opinions and attitudes over statements; 3) sociodemographic characteristics. The full questionnaire is reported in Appendix C .

The first part has the intention to observe the current behavior of individuals. So, we ask questions about the frequency, which modal of transportation they use and have, the time usually spent, etc. All of that is used to trace a travel behavior profile. Also, three questions are inserted at the end: two to measure the degree of satisfaction of the individual with traffic and public transport in the city and one to observe the travel attributes considered to be of greatest importance in determining the mode of travel to be used.

In the second part, there are 25 attitudinal questions embracing participants' beliefs in climate change, their enjoyment of driving, their attitudes, barriers to use sustainable transport, and the acceptance of some policies. The level of agreement is measured by a 5-point Likert-scale with values ranging from 1-Strongly Disagree to 5-Strongly Agree. Based on TPB theory and in the literature the questions can be divided into six factors as follows:

- Factor I: related to environment beliefs. Statements number: 1, 2, 3, 5.

- Factor II - refers to transport problem awareness. Statements number: 10, 14, 23, 24.
- Factor III - refers to affective attitudes toward cars. Statements number: 12, 15, 19, 21, 22.
- Factor IV - assign the instrumental attitudes. Statements number: 8, 4, 18.
- Factor V - indicates the perceived control. Statements number: 6, 16, 25, 9, 20.
- Factor VI - observe the agreement with some policies. Statements number: 7, 11, 13, 17.

Finally, the third part gathered sociodemographic information, such as age, gender, family income, civil and household status, education and occupation.

This study conducted only a pre-survey, applied in August, 2019. It was run in the municipality of São José dos Campos (SJC), located in the state of São Paulo, Brazil. The city is in a strategic location, being connected to important highways that have also become part of the city's commuting line. The federal highway Presidente Dutra (BR-116) crosses the urban area, connecting two important Brazilian cities, São Paulo and Rio de Janeiro. There are also highways that connects SJC to the state of Minas Gerais, towards the interior of Brazil; to Campinas, another important industrial city; and to the coast, being close to the São Sebastião and Santos ports.

SJC is the main city of the Metropolitan Region of Vale do Paraíba e Litoral Norte. The municipality has one of the largest Brazilian technology parks, with emphasis on aerospace, automotive, petrochemical, pharmaceutical and telecommunication sectors. It extends through 1.099 km^2, with approximately 353 km^2 of urbanized area. The Master Plan for Integrated Development of the Municipality of SJC, divided the municipality in seven geographic regions: Center, North, East, West, South, Southeast and São Francisco Xavier (Figure 12).

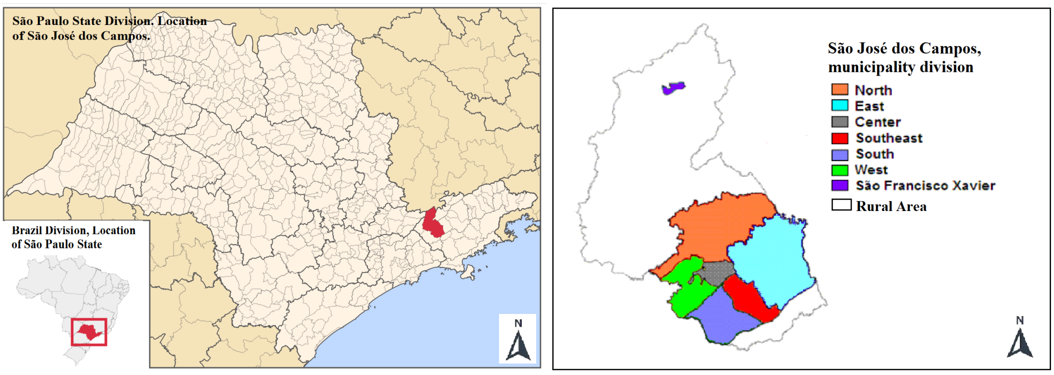

Figure 12 – Study area location and division

The Brazilian Census accounts for a population of 629 thousand in 2010, and the estimated population in 2019 is of about 721 thousand inhabitants[1]. This give us a growth rate of 1,52% per year.

[1] Source: IBGE Cidades. URL:https://cidades.ibge.gov.br/brasil/sp/sao-jose-dos-campos/panorama. Access Date: April, 2020.

Figure 13 shows the number of vehicles in the municipality registered in the month of January for the period between 2005 and 2020. It observes a high growth in the number of cars, with an increase of 40,4% from 2005 to 2010, 31,8% from 2010 to 2015, and 11,8% from 2015 to 2020. The total number of vehicles in january 2020 reached the amount of 449 thousand, being 308 thousand of private cars. The growth rate in the number of cars in the last 10 years is 3,96% far superior to population growth.

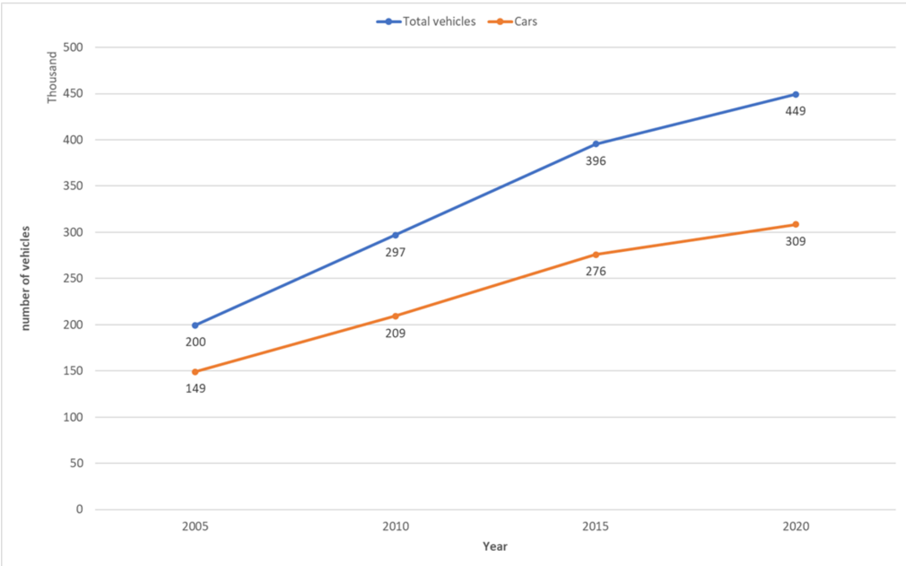

Figure 13 – Number of total vehicles and private cars in SJC, Jan., 2005-2020

The growth rate in the number of cars displayed in Figure 13 shows the need for policies to manage the demand for private vehicles. There is not enough road space and resources in the city to accommodate such an accelerated increase in the fleet and also this growth rate is not sustainable. The city already suffers from congestion and pollution problems, that are aggravated by the proximity to important highways.

The pre-survey experiment consisted of two days of data collection, in which 36 questionnaires were obtained. The objective was to test the survey questions and to see if convenience and random probability sampling could generate some bias. That is, convenience means that we approach people that happened to be at a specific place on a given day and time; and random means that we approach adults encountered with no distinction or seeking for a particular characteristic.

To each individual was given a consent form, which was read aloud by the interviewer before starting the survey. The purpose of the consent form is to inform about the research and set up an agreement of participation that states that participation is the person's decision, without pressure, coercion and no personal benefits. The consent form is available in Appendix B .

5.2.2 Analysis Procedures

The main objective of this statistical analysis is to explore the association between perception and attitude of individuals in relation to environmental problems, the impact of the transport system with its current travel behavior and the acceptability to ST policies.

First of all, it is interesting to know with which statements from the second part of the survey they agree the most. This knowledge can give a way to partition the individuals in different groups, according to their beliefs and attitudes. For instance, our data has a high number of variables and all of then are categorical. The nonlinear canonical correlation analysis (OVERALS) method is used to analyze the similarity among the statements suiting the particular characteristic of the data.

In a classical canonical correlation analysis the aim is to study the relationship between two sets of variables after removing linear dependencies in the sets (GIFI, 1991). OVERALS is a generalization to this approach used to compare K sets of variables after removing linear dependencies within each of the sets.

The OVERALS model is classified as a form of homogeneity analysis with restrictions. According to Gifi (1991) homogeneity analysis is a technique to finding p orthogonal vectors in the meet of the m indicator matrices G_j. An extension is to analyze p orthogonal vectors in the meet of K general matrices H_k, by using the loss function.

In other words, assume that J denotes the categorical variables collected for N objects or individuals, where $j \in J = 1, 2, ..., J$ has c_j categories. In OVERALS the set J of the j variables is classified into K subsets $J(1), ..., J(k), ..., J(K)$ (YAZICI et al., 2010).

One way to measure similarity is to ask which weights we need to apply to make the weighted sum of all sets of variables as similar as possible to each other (BURG; LEEUW; DIJKSTERHUIS, 1994). Considering our sample data we have 36 respondents that are going to be represented by n and 25 statements grouped in 6 sets as described in previous subsection. The statements represent the number of variables m in our model. Thus, the data can be denoted by a matrix H_j(n x m). We consider a two dimensional solution, that is denoted by $d = 2$. So, let A_j represent a matrix (m x d) that collects the weights for each set.

To find the solution an unmeasured matrix X(n x d) is used. As described by Burg, Leeuw e Dijksterhuis (1994) the k-sets canonical correlation problem can be translated into a loss function, minimizing the sum of squared (SSQ) differences between X and the weighted sums, as follows:

$$\text{minimize} \sum_{j=1}^{k} SSQ(X - H_j A_j) \quad \text{over} X \text{ and} A_j \tag{5}$$

The results of the model are given in a plot of centroids, that shows how well the variables separate groups of objects.

5.3 Results

The results of the pre-survey applied in SJC are going to be discussed in this section. Surveys can generate bias that negatively affects research results. Thus, it is important to test the questionnaire before its final application in order to reduce the risk of survey bias. The first part of this section analyzes the sociodemographic and travel behavior characteristics to figure out any possible sampling or response bias. The second part applies the OVERALS approach in order to observe whether the questions and the methodology were able to clearly distinguish groups of individuals based on their attitudes and beliefs.

5.3.1 Sociodemographic and travel behavior characteristics

Table 7 shows an overview of the respondent's characteristics. The sample has the same number of men and women. The majority are employees (33,3%), have an upper secondary education (44.4%) and a household income between R$1.908 to R$3.816 (33.3%). We can see that the percentage is well divided between the categories.

Table 7 – Sociodemographic characteristics of the respondents.

Variables	**Total**	**Percent(%)**	**Variables**	**Total**	**Percent(%)**
Gender			**Education**		
Male	18	50.0	No instruction	4	11.1
Female	18	50.0	Lower Secondary	1	2.8
Age			Upper Secondary	16	44.4
<18 years	1	2.8	Undergrad	6	16.6
18-24 years	9	25.0	Graduated	9	25.0
25-34 years	8	22.2	Post-graduate	0	0
35-44 years	6	16.7	**Civil Status**		
45-54 years	3	8.3	Single	16	44.4
55-64 years	7	19.4	Married	14	38.8
> 65 years	2	5.5	Divorced	6	16.6
Occupation			Widow	0	0
Employee	12	33.3	**Hosehold Income**		
Self-employed	7	19.4	No income	2	5.5
Public Server	0	0	Up to R$954	1	2.7
Entrepreneur	1	2.7	R$954 - R$1.908	10	27.7
Domestic Services	0	0	R$1.908 - R$3.816	12	33.3
Retired	5	13.9	R$3.816 - R$9.540	7	19.4
Student	3	8.3	R$9.540 - R$19.080	2	5.5
Intern	0	0	more R$19.080	1	2.7
Unemployed	5	13.9	No Stated	1	2.7
Other	3	8.3			

Table 8 – Travel behavior characteristics in the sample.

Variables	Total	Percent(%)	Variables	Total	Percent(%)
Travel Frequency			**Possession of:**		
Every day	25	69.4	Car	22	61.1
3-4 times per week	4	11.1	Motocycle	6	16.6
1-2 times per week	7	19.4	Bicycle	11	30.5
Seldom or never	0	0	**Time usually spent**		
Major trip purpose			< 30 min	8	22.2
Work	19	52.7	30 min - 1h	15	41.6
Study	5	13.8	1h - 1h30min	4	11.1
Leisure	4	11.1	1h30min-2h	8	22.3
Shopping	4	11.1	2h - 3h	1	2.7
Other	4	11.1	> 3h	0	0

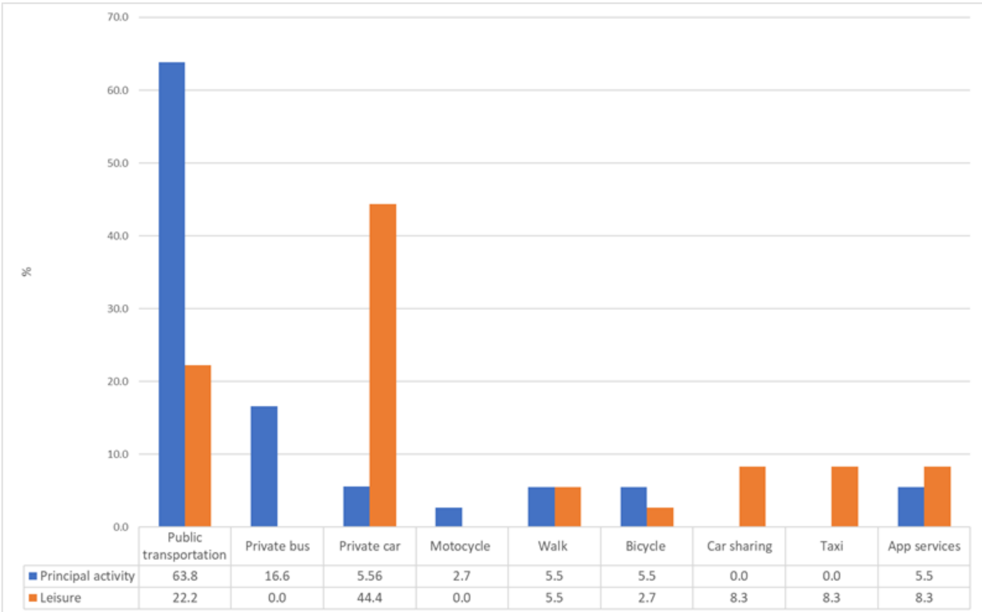

Figure 14 – Modal choice in the principal activity and leisure travels by the respondents, SJC

Table 8 and Figure 14 report the travel behavior characteristics of our sample. The majority of the participants perform journeys in the city every day (69.4%), commuting to work (52.7%) as the principal purpose. The time usually spent in the principal displacement took 30 minutes to one hour. No one reports to spent more than three hours on the travel.

Although 61.1% have declared to own a car, this means of transportation is not much used in the displacement for the principal activity (5,5%). On the contrary, in leisure activities the respondents seem more inclined to choose to use their car, being the major transportation choice (44.4%) (Table 8 and Figure 14).

It is interesting to notice that for daily commuting, 63.8% took public transportation or use private bus transport (16.6%). However, this number decreases to 22.2% when the trip is related to leisure activities (Figure 14).

The results presented so far show that data collection in a convenience and random way generates a sample bias. Basically, when certain people are systematically more likely to be chosen in a sample than others we have a sampling bias. In our case, the strategy of applying the questionnaires in the central points of the city allowed capturing residents from different neighborhoods. Despite achieving an excellent geographic representation, collection close to public transport hubs caused a sample bias in favor of public transport users.

Lastly, questions were asked regarding the quality of traffic and public transport in the city (Figure 15). The evaluation is relatively good, with 25.0% considering great or good for both traffic and public transport; most graded as regular - 52.7% to traffic conditions and 44.4% to public transport; and a smaller number evaluated as bad or terrible - 16.6% to traffic conditions and 22.2% to public transport.

We also asked the respondents to rank six transport attributes in order of importance when they make their modal transportation choice. In Figure 16 we can see that time and security have a high level of importance. This may indicate that investments in security can play a big role to promote active transportation. The cost attribute was pointed by 25% as the major factor, but at the same time, the same amount does not seem to care for the cost. Flexibility and the environment are pointed as the less important factors in their decision.

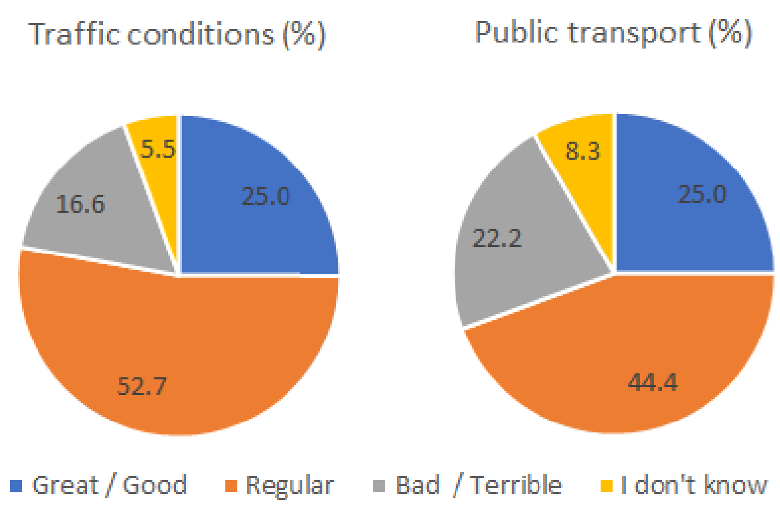

Figure 15 – Perception of the quality of traffic and public transport in SJC.

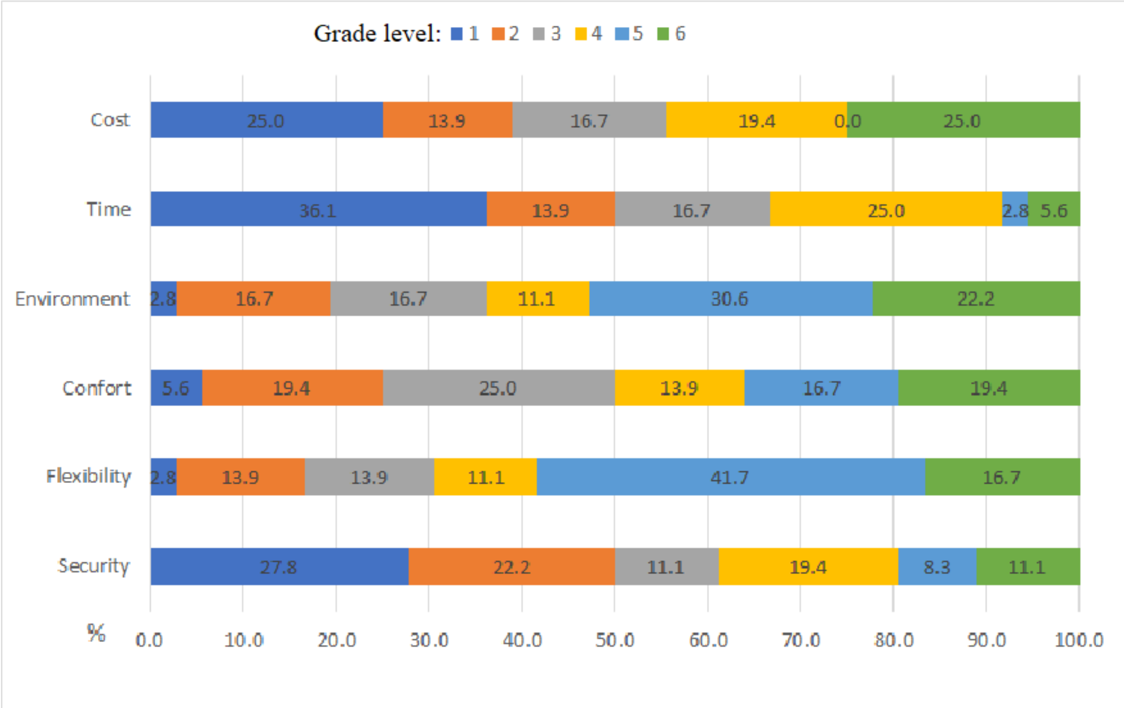

Figure 16 – Rank of the importance of transport attributes.

5.3.2 Analysis of travel attitudes

In the second part of the survey, participants were asked to show their agreement with 25 attitudinal questions ranked on a 5-point Likert-scale. Figure 9 display the participants' agreement in each statement. The participants show great awareness of environmental problems, the majority believe in climate change and are concerned about their behavior impact (Factor I). When it comes to the impact of transportation, they seem to understand the threats and problems, albeit they do not take public transportation as the better option when compared to cars from an environmental point of view (Factor II).

In the effective attitude (Factor III), which shows which behavior is preferred, most participants state to prefer to use public transport (question 21). Meanwhile, 61,1% agree that life gets harder without a car (question 12) but are divided about how essential a car is for a good quality of life (question 22). They also are divided with respect to the pleasure to drive (questions 15 e 19).

There is no clear pattern in instrumental attitudes (Factor IV). In addition, we observe high neutrality with respect to security related to cars and the impact of time spent in traffic (questions 8 and 18).

Table 9 – Percentage of responses in the attitude statements.

Statements	Percentage				
	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Factor I - environmental beliefs					
1. Radical changes need to happen in our society to minimize the environmental problens	30.56	61.11	2.78	2.78	2.78
2. Climate change is a reality and it scares me	30.56	47.22	13.89	5.56	2.78
3. I am not sure if climate change is really happening	0	33.33	5.56	41.67	19.44
5. I don't believe that climate change ia a real threat	5.56	19.44	0	38.89	36.11
Factor II - transport problems awareness					
10. Air pollution related to traffic is dangerous to my health	22.22	66.67	2.78	8.33	0
14. It is important reduce the use of cars because of their impact on the environment	22.22	52.78	2.78	16.67	5.56
23. Public transport is more environmentally friendly than cars	13.89	26.11	13.89	36.11	0
24. Diminishing the number of cars in the city would promote a gain in the life quality of the population	13.89	47.32	11.11	25	2.78
Factor III - affective attitudes					
12. I feel indifferent about having a car, but life gets harder without it	11.1	61.11	13.89	11.11	2.78
15. I like to use car, it grants me freedom and let me express myself	11.11	33.33	19.44	30.56	5.56
19. I feel nervous and stressed when I need to drive in the city	2.78	30.56	25	41.67	0
21. Given an efficient public transport system , I would rather use it then the car	27.78	55.56	2.78	13.89	0
22. Having a car is essencial to have a good life style	13.89	22.22	11.11	41.67	11.11
Factor IV - instrumental attitudes					
4. I believe that the damage caused by cars is not so big that I need to give up my confort in using it	13.89	22.22	8.33	38.89	16.67
8. The city is too dangerous, I don't feel safe and this is why I perfer to use cars	11.11	30.56	22.22	30.56	5.56
18. I spend many hours of my day in traffic and it affects my work	11.11	30.56	30.56	27.78	0
Factor V - perceived control					
6. Cycling would be a good option for me if we had a safe cycling infrastructure	25	47.22	13.89	11.11	2.78
9. The government is the one that needs to take responsability for the environmental problems	8.33	30.56	2.78	55.56	2.78
16. There are some difficulties and problems in using public transportation	8.33	52.78	11.11	25	2.78
20. Thinking about the impact I have on the environment is important to me	25	72.22	2.78	0	0
25. My personal habits don't have impact on the environment	2.78	27.78	5.56	52.78	11.11
Factor VI - policies					
7. Speed limit should be controlled in the city center and in residential areas	25	69.44	5.56	0	0
11. Cars should pay a toll to drive downtown	0	8.33	2.78	72.22	16.67
13. The City should limit parking spaces and designate other uses for the available areas	8.33	33.33	22.22	33.33	2.78
17. More parking areas should be created in the city center	13.89	41.67	19.44	22.22	2.78

The participants show strong perceived control (Factor V) to use bicycles as a mode of transport (question 6). Also, the use of public transportation seems difficult for around 60% of the sample (question 16).

In terms of policies (Factor VI), the statement with the lower agreement is related to taxation of the use of cars in the center of the city, where 72% disagree with this practice. However, car speed control is a very accepted policy (question 7).

The relationship and similarities among these six factors, which are analyzed using OVERALS, are presented in Table 10. Eigenvalue indicates the level of relationship of each dimension, being 1 as the maximum value indicating a perfect similarity. We found values of 0.788 for the first dimension and 0.662 for the second dimension, which are quite high. Fit and loss values show how well OVERALS explains the association among sets. A fit value of 1.450 in a 2-dimensional solution, means that 72.5% (1.450/2) of the variation was calculated in the analysis. The loss represents the proportion of variation and the small the value of loss, the larger the multiple correlations. In Table 10 we have a good mean loss of factors of 0.550 (maximum value is 2).

The correlation relationship among the variables is represented in Figure 17. The importance of each variable is given by the distance from the origin. Thus, statements number 5 in Factor I; 10, 14 and 24 in Factor II; 19 and 22 in Factor III, 4 in Factor IV; 9 and 25 in Factor V; and 17 in Factor VI, were the most effective in the relations between the statements. Statements number 3 in Factor I, 12 and 15 in Factor III, 8 and 18 in Factor IV, 6, 16 and 20 in Factor V and 7, 11 and 13 in Factor VI were of medium effectivity, and the remaining statements (numbers: 1, 2, 10, 23, 21) do not have much impact.

The plot of centroids shows how the variables are separated by groups (Figure 18). Since the existence of many variables makes it difficult to read, we summarize in Table 19 the most relevant statements in each quadrant plot and their answers.

The group exhibited in quadrant I do not believe in climate change and do not see many problems with car use, for them there is no clear relationship with environment and health problems and the current transportation system. They see the car as an essential object to have a good life; while they do not have a strong emotional attachment to the car, they seem to like the comfort that it provides. In relation to the use of alternative transport modes, they show interest in using the bicycle and do not see difficulties or problems in the current public transportation. These facts show that, if they currently are car users, they do so by personal choice based on characteristics such as comfort and practicality, but do not have any effective or practical impediments to change. They are in favor of policies that control the speed limit of cars, but they want to expand the benefits of their use, like increasing parking areas and are against charging traffic tolls. This suggests that although they do not have impediments to changing to a more sustainable travel behavior, they opt to use the car by a lack of awareness of the environmental implications and by instrumental factors related to car but not by an affective attitude.

In quadrant II we find a group that strongly denied climate change and does not believe that individual actions have any impact on it. The responsibility for environmental problems is put on the government and they are not willing to change their habits with respect to it. Cars are seen as good mode of transportation and have no environmental impact. However, just like group I, they do not have affective attitudes toward cars, they believe more that the car is a good option given security problems and difficulties in the use of other options of transport. They do not agree to pay tolls to drive downtown and want more parking spaces in the city.

On the other side, the group presented in quadrant III does not have a clear position in relation to environmental concerns. They answered to be neutral to almost all the questions related to climate change and transport's impact on the environment and health. This group is the one that we can call "car lovers", they have a strong emotional attachment to cars that involves pleasure and empowerment in driving, meanwhile reported to feel stressed in driving in the city. Cycling does not appear as an option to them. In terms of policy agreement the are in favor of speed limit control, but strongly disagree in limit parking spaces in the city.

Quadrant IV concentrates the most respondents of our sample. They are characterized by a good awareness of environmental problems and transportation impact. They do not have an affective attitude towards car. They have a strong perceived control about how the individual's attitudes impact the environment. At the same time, they strongly agree with statement 16 (There are some difficulties and problems to use the public transportation), which shows that individuals in this quadrant are strong candidates for not using individual transport if a good public transport service is offered. As consequence individuals in this segment support policies to diminish parking spaces and control the speed limit of cars in the city. However, they are neutral to statement 11 (Cars may pay a fee to drive in downtown).

Table 10 – Two dimensional solution results.

	Factors	**Dimension 1**	**Dimension 2**	**Sum**
Loss	**Factor I**	0.600	0.360	0.960
	Factor II	0.075	0.364	0.439
	Factor III	0.100	0.263	0.363
	Factor IV	0.362	0.507	0.870
	Factor V	0.025	0.158	0.183
	Factor VI	0.109	0.376	0.484
	Mean	0.212	0.338	0.550
Eigenvalue		0.788	0.662	
Fit				1.450

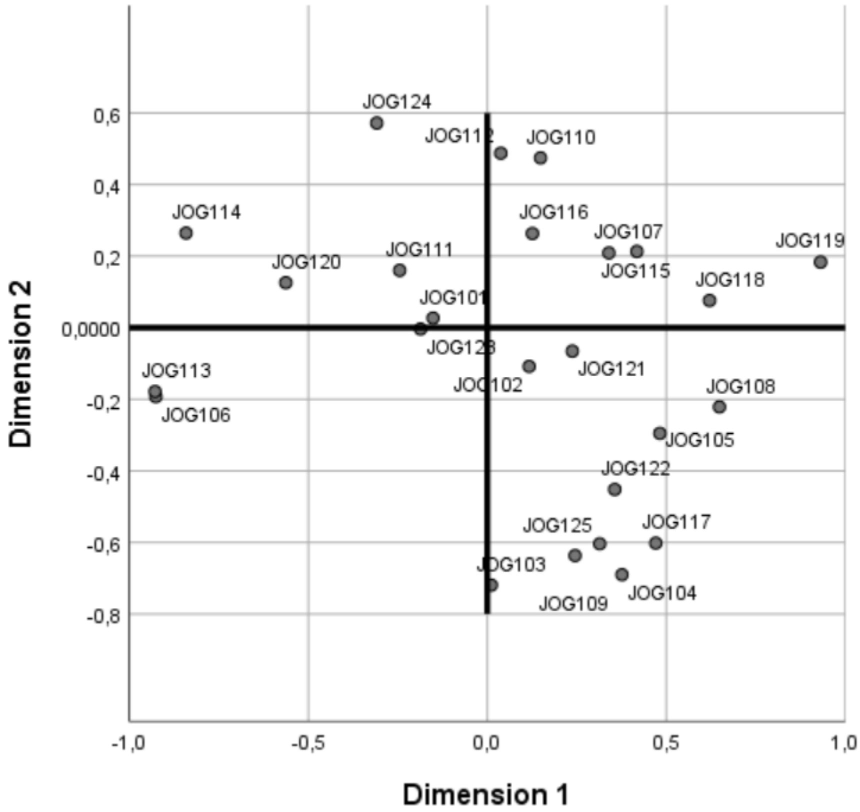

Figure 17 – Component loadings.

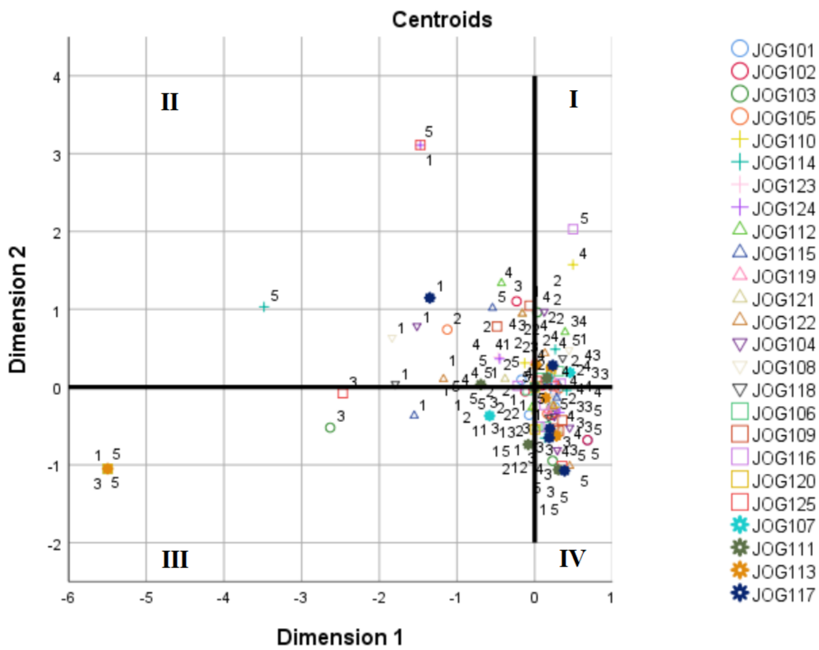

Figure 18 – Centroids plot.

Quadrate	Relevante Statements			Agreement Level				
	Factor	Number	Question	1. Strongly Agree	2. Agree	3. Neutral	4. Disagree	5. Strongly Disagree
I	I	3	I am not sure if climate change is really happening		X			
	II	10	Air pollution related to traffic is dangerous to my health				X	
		14	It is important reduce the use of cars because of their impact on the environment				X	
	III	12	I feel indifferent about having a car, but life gets harder without it			X		
		22	Having a car is essencial to have a good life style		X			
	IV	4	I believe that the damage caused by cars is not so big that I need to give up my confort in using it		X			
		8	The city is too dangerous, I don't feel safe and this is why I perfer to use cars					X
	V	6	Cycling would be a good option for me if we had a safe cycling infrastructure		X			
		16	There are some difficulties and problems in using public transportation				X	X
	VI	7	Speed limit should be controlled in the city center and in residential areas		X	X		
		11	Cars should pay a toll to drive downtown				X	
		17	More parking areas should be created in the city center		X			
II	I	5	I don't believe that climate change ia a real threat		X			
	II	14	It is important reduce the use of cars because of their impact on the environment					X
		24	Diminishing the number of cars in the city would promote a gain in the life quality of the population				X	X
	III	12	I feel indiferent about driving a car, but life gets harder without it				X	
		15	I like to use car, it grants me freedom and let me express myself					X
		22	Having a car is essencial to have a good life style	X				
	IV	4	I believe that the damage caused by cars is not so big that I need to give up my confort in using it	X				
		8	The city is too dangerous, I don't feel safe and this is why I perfer to use cars	X				
	V	9	The government is the one that needs to take responsability for the environmental problems	X	X			
		25	My personal habits don't have impact in the environment	X				
	VI	11	Cars should pay a toll to drive downtown					X
		17	More parking areas should be created in the city center	X				
III	I	3	I am not sure if climate change is really happening			X		
	III	15	I like to use car, it grants me freedom and let me express myself	X				
		19	I feel nervous and stressed when I need to drive in the city	X				
	V	6	Cycling would be a good option for me if we had a safe cycling infrastructure					X
		20	Thinking about the impact I have on the environment is important to me			X		
		25	My personal habits don't have impact in the environmental problems			X		
	VI	7	Speed limit should be controlled in the city center and in residential areas	X				
		13	The City should limit parking spaces and designate other uses for the available areas					X
IV	I	3	I am not sure if climate change is really happening			X	X	X
		5	I don't believe that climate change ia a real threat				X	X
	II	14	It is important reduce the use of cars because of their impact on the environment	X				
		24	Diminishing the number of cars in the city would promote a gain in the life quality of the population		X	X		
	III	12	I feel indifferent about having a car, but life gets harder without it					X
		19	I feel nervous and stressed when I need to drive in the city		X			
		22	Having a car is essencial to have a good life style				X	X
	IV	4	I believe that the damage caused by cars is not so big that I need to give up my confort in using it			X	X	X
	V	9	The government is the one that needs to take responsability for the environmental problems			X	X	X
		16	There are some difficulties and problems in using public transportation	X				
		20	Thinking about the impact I have on the environment is important to me	X				
		25	My personal habits don't have impact in the environmental problems					X
	VI	7	Speed limit should be controlled in the city center and in residential areas					X
		11	Cars should pay a toll to drive downtown			X		
		13	The City should limit parking spaces and designate other uses for the available areas	X		X		
		17	More parking areas should be created in the city center			X	X	X

Figure 19 – Summary of relevant questions in each quadrant of OVERALS result.

5.4 Conclusion

The segments reported in the OVERALS analysis provide an indication of how strongly people are willing to accept more sustainable urban transportation, using fewer cars in their daily trips, and support policies in this direction.

For groups I and II a massive provision of information about climate change and the problems with the expansion of motorized traffic are necessary. But, this does not mean that these groups will have the same willingness to change their travel behavior. Group II has a negative perceived control towards the more sustainable transportation options. For them stopping using cars could be very difficult and challenging. Instead, for group I, the instrumental attitudes hold them using cars. They require good investments in the other modes to be willing to change their behavior. The same happens with group IV. They can easily change to a good public transportation service and cycling if infrastructure is provided. The difference is that group IV already has good awareness of the necessity and benefits of the reduction of car use. Group III may have the most obstacles to using alternatives to cars. They have strong affective attitudes, meaning that they have pleasure in driving and not necessarily a lack of awareness of environmental problems.

In terms of policies, it is clear that public attitudes were more negative towards road pricing than other measures targeted at decreasing car use. This result is interesting since tolls and car fee policies have had positive results in other places. But for the Brazilian reality, implementing another taxation does not seem acceptable even among those who do not use individual transport. Such findings, although preliminary, show the need to know the local public for greater effectiveness of public policies.

Although this analysis is made with a preliminary sample it already shows the importance of attitude factors to establish the individuals' travel behavior. The approach carried out here shows adjustments and improvements that can be made in methodological terms. Some questions can be modified since there are overlapping. As well as questions more focused on the reality of local policies can be used. Furthermore, the way we conducted data collection tended to select public transport users causing a sample bias. A way around the problem may be applying the survey choosing locations more targeted to car users, such as near parking lots and malls. In terms of analysis, an econometric model could also be applied in order to investigate the willingness to change and also include sociodemographic characteristics.

The procedure developed here opens up a line of research both in the form of studies in travel behavioral change, as in the development of tailored communication. It would be interesting to observe the application and the results that this survey could give considering a representative sample of a city population.

6 FINAL CONCLUSION

6.1 Introduction

The territory and individuals are complex and have particularities. For a better design of public policies, their specificity needs to be considered. It is clear that there is no single solution in the design of sustainable policies; the solutions may even vary at the neighborhood level.

Thus, this thesis proposes an individualized look. First, we present the theoretical foundation in Chapter 1, which is the basis for the other chapters. The following chapters proposed methodologies that contributed to the understanding of the singularities in a way to help to guide urban sustainable mobility planning.

This chapter concludes the thesis with a general discussion concerning the project as a whole. It begins by addressing the main contributions and follows pointing the limitations. Finally, we discuss possibilities for future work.

6.2 Contributions of the thesis

This thesis aimed to suggest some ways to analyze key factors that impact urban mobility. We start from the assumption that for public policies to be more efficient it is necessary to know the specificities of the territory and the population. To have this broader understanding, the work focuses on three points:

1. Creation of a database that allows a better view of the territory.

   Brazilian cities over 20,000 people need to develop an Urban Mobility Plan in order to comply with the requirements laid down by law. Since the promotion of sustainable mobility is increasingly linked to territorial planning, it is extremely important that municipalities are aware of the spatial characteristics of urbanization in detail. Recognizing that there is a gap between municipalities and the availability of data in their planning process, this chapter sought to create a simple database that allows a detailed look at the main aspects presented in the urban form literature that most influence mobility.

   The database includes indicators of population and employment density, job-housing balance, nodal density, access to job, and number of bus stops for 246 Brazilian urban centers divided in grids of 1km by 1km.

   This database aims to contribute in order to democratize data access among municipalities. Furthermore, the grid division seeks improve the analyses through the territory. Having territories the same division of their neighborhoods in grid, allows comparisons and exchange of experiences between them.

The creation of grid cells with measures of urban environment has the advantage of providing spatial-temporal stability, flexibility, create an ease data to use in modeling, minimize the MAUP problem and provide better interpretation of urban areas. By dividing the urban area in small units it is possible to better understand the variety and distribution of processes within.

2. Characterization of the urban form structure.

   In this paper we seek to extend the systematic classification scheme developed by Stokes e Seto (2018) to Brazilian cities. We make use of main factors pointed in the literature to shape travel demand - density, mix use areas and street netwoorks. The results show how diverse the cities are, but also, that the structural variety within urban areas is huge.

   The results generated 17 typologies that distinguished well the different urban forms presented in 246 Brazilian cities. This division brings the advantage of showing particular characteristics in smaller units that can help different planning and management strategies.

   Stokes e Seto (2018) show that this classification can be linked to multiple sustainability processes that can lead to a better understanding of the urban development. Meanwhile, the grid classification can help management policies to target specific neighborhoods instead of the entire city.

3. Creates a segmentation of the population based on their travel behaviour, beliefs and attitudes toward sustainable transportation.

   In parallel to redesigning the cities, it is also essential to change travel behavior at the population level.

   A better understanding of individuals' travel behavior will help in designing and implementing interventions that promote alternative forms of transportation to be widely used. Researchers have proposed segmentation of the population and target communication to each group.

   Thus, in this study, we developed a survey in order to observe and distinguish the citizens by their perception and attitudes in relation to climate change, attachment to cars, barriers to using sustainable transport, and the acceptance of some policies.

   Four attitude factors were extracted from the OVERALS analysis. Policies that aim to inform citizens about the problems generated by excessive car use seem to be necessary to affect some individuals. While others need investments to building a supportive physical environment for alternative transport and along with that information to facilitate its use and cultural change.

   In addition, it was observed that special care is needed when designing policies that promote negative incentives for car use. Policies such as the car use fee, which have been successfully implemented in some places, have not proved to be acceptable even among individuals who do not use cars. Xia et al. (2017) states that if transport policies have low acceptability, it could be less feasible and less effective.

6.3 Limitations and Future Work

This thesis includes three chapters that develop a specific methodology, which can provide useful information in different aspects. However, given some constraints associated with the time of a PhD and a pandemic event, there is still room for improvement in each part.

In the development of the grid database in Chapter 3, there is improvement to be done in the way of measuring the variables, adding other attributes and increasing the spatial granularity. The job accessibility variable was calculated considering only the fastest route by private transport. This is a big limitation in the analysis. However, most Brazilian cities do not have data or information on bus routes and timetables, such as GTFS. Also, other destinations' accessibilities must be considered such as shopping, leisure, and school. Given the need to georeference each of these destinations in each municipality and the time available, these destinations were not included.

In any analysis and mobility plan design there are multiple spatial scales to be considered. UN-HABITAT (2013) distinguishes three levels of spatial scale for good integration of transportation and urban development, namely: neighborhoods, corridors and regions. In our study, we worked on a spatial scale at the neighborhood level building the data based on five core dimensions (5 Ds): density, diversity, design, destination accessibility and the distance to transit. The other dimensions need to be considered for the successful integration of transportation and urban development. Also, at the neighborhood scale, other factors on a finer grain can be measured to help in policy planning.

An attempt to cover other urban characteristics at a neighborhood level was made by the United States Environmental Protection Agency (EPA)[1]. They developed three data products across the United States: 1) Smart Location Database is similar to our database and provide indicators associated with urban form and demographic statistics; 2) Access to Jobs and Workers Transit Tool provides indicators of accessibility to destinations by public transit; and 3) National Walkability Index that provides walkability scores. Despite a very complete database, the EPA data works with a census block division. These other indicators can be very useful and serve as guidelines to improve the database developed here.

Many of the limitations of chapter 3 were transferred to chapter 4 given the database used. Furthermore, chapter 4 presents limitations in the analysis of the results and their expansion. The lack of a more comprehensive discussion between policy strategies in each typology was felt which demands a broader review of current policies and implementation experiences.

[1] https://www.epa.gov/smartgrowth/smart-location-mapping

One of the main objectives of the classification made is to be able to extrapolate the concept of stand to sustainability processes. This work was intended to be related to the sustainable mobility processes. However, the lack of data was an impediment to complete such analysis. Also, ways to include sociodemographic characteristics were not addressed. Thus, here we have another path to improve the analysis, which is also a limitation of the study made by Stokes e Seto (2018).

The main limitation of Chapter 5 is that the results are based on a pre-survey. The amount of data - 36 respondents - is too low to expand or generalize the results obtained. The Covid 19 pandemic made it impossible to collect the final questionnaires. The change to an online version would require a restructuring of the survey format. In addition, online surveys usually have a significant sampling bias. Although, we also identify a bias generated by the way we collected the data. Intercepting people on the street did not capture many car users. It would be necessary to go to places, perhaps to parking lots, where it would be possible to intercept this specific public causing the research to lose its random characteristic.

Finally, the analysis by OVERALS performed in Chapter 5 was interesting in order to segment the population. However, ways to include sociodemographic characteristics were not addressed.

Besides the aforementioned improvements, some options for future work emerged from this thesis. We would like to highlight three research lines that can be followed from here.

First, making use of the advantage of the data in grid one research path would be the development of simulation models. The database and the stands classification could provide input for cellular automata land use models in order to support land use planning and explore scenarios for future development. Also, the travel behaviors could be incorporated into simulations with the use of agent-based modeling (ABM) techniques that are efficient to simulate heterogeneous behaviors and predict interactions between agents and spatial structures.

Second, it would be interesting to explore economic justifications for interventions in the urban form and travel behavior. This could be done by applying a cost-benefit analysis. By redesigning cities to improve accessibility, the kilometers traveled per vehicle are expected to decrease. Thus, many benefits can be computed from this outcome, such as improvements in air quality, physical activity, reduction of congestion, among others. Carrying out an economic cost-benefit analysis in these terms can be of great importance since promoting alternative transport may need a significant investment that could be justified through this kind of analysis.

Third, there is a lot of room for studies on travel behavior change. The profiles drawn in this preliminary research can be studied further through qualitative research. This would help to better understand the motivations behind the attitudes of individuals. Another path would be studying the individuals' perception of accessibility by different means of transportation in a way that connects with urban form policies. Furthermore, an analysis that investigates the individuals' costs and benefits in multiple aspects in the use of public and active transport will be desirable. Finally, our study sought to observe the acceptability of individuals to some policies that limit car use. Policy makers usually are concerned about the citizen's resistance to such policies. In this line, an important research path would be to promote dialogue between the public and policy makers and improve the communication channel for the acceptance of sustainable policies.

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Appendix

APPENDIX – A - DESCRIPTION OF REGIONS INCLUDED IN THE STUDY OF CHAPTER 2 AND 3.

Region	Center Level	Population 2010	ACP	Aggregate municipalities
São Paulo (SP)	1A	20096809	Yes	Alumínio, Araçariguama, Arujá, Barueri, Bom Jesus dos Perdões, Caieiras, Cajamar, Carapicuíba, Cotia, Diadema, Embu, Embu-Guaçu, Ferraz de Vasconcelos, Francisco Morato, Franco da Rocha, Guararema, Guarulhos, Itapecerica da Serra, Itapevi, Itaquaquecetuba, Itatiba, Jandira, Juquitiba, Mairinque, Mairiporã, Mauá, Mogi das Cruzes, Morungaba, Nazaré Paulista, Osasco, Piracaia, Pirapora do Bom Jesus, Poá, Ribeirão Pires, Rio Grande da Serra, Santa Isabel, Santana de Parnaíba, Santo André, São Bernardo do Campo, São Caetano do Sul, São Lourenç da Serra, São paulo, São Roque, Suzano, Taboão da Serra, Vargem Grande Paulista.
Rio de Janeiro (RJ)	1B	11968973	Yes	Belford Roxo, Duque de Caxias, Guapimirim, Itaboraí, Itaguaí, Japeri, Magé, Mangaratiba, Maricá, Nilópolis, Niterói, Nova Iguaç, Paracambi, Petrópolis, Queimados, Rio de Janeiro, São Gonçalo, São João de Meriti, Seropédica.
Brasília (DF)	1B	3460637	Yes	Águas Lindas de Goiás, Brasília, Cidade Ocidental, Formosa, Luziânia, Novo Gama, Padre Bernardo, Planaltina, Santo Antônio do Descoberto, Valparaíso de Goiás.
Manaus (AM)	1C	1802014	Yes	Manaus.
Belém (PA)	1C	2125135	Yes	Ananindeua, Barcarena,Belém, Benevides, Marituba.
Fortaleza (CE)	1C	3327021	Yes	Aquiraz, Caucaia, Eusébio, Fortaleza, Itaitinga, Maracanaú, Maranguape, Pacatuba.
Recife (PE)	1C	3706628	Yes	Abreu e Lima, Cabo de Santo Agostinho, Camaragibe, Escada, Igarassu, Ilha de Itamaracá, Itapissuma, Jaboatão dos Guararapes, Moreno, Olinda, Paudalho, Paulista, Recife, São Lourenço da Mata.

Salvador (BA)	1C	3528530	Yes	Amélia Rodrigues, Camaçari, Candeias, Dias d'Ávila, Itaparica, Lauro Freitas, Madre de Deus, Mata de São João, Salvador, São Francisco do Conde, São Sebastião do Passé, Simões Filho.
Belo Horizonte	1C	5039123	Yes	Belo Horizonte, Betim, Brumadinho, Caeté, Capim Branco, Confins, Cantagem, Esmeraldas, Ibirité, Igarapé Juatuba, Lagoa Santa, Mário Campos, Mateus Leme, Matozinhos, Nova Lima, Pedro Leopoldo, Prudente de Moraes, Raposos, Ribeir ao das Neves, Rio Acima, Sabará, Santa Luzia, São Joaquim de Bicas, São Jos'e da Lapa, Sarzedo, Sete Lagoas, Vespassiano.
Curitiba (PR)	1C	2993678	Yes	Almirante Tamandaré, Araucária, Campina Grande do Sul, Campo Largo, Campo Magro, Colombo, Curitiba, Fazenda Rio Grande, Itapecuru, Pinhais, Piraquara, Quatro Barras, Rio Branco do Sul, São José dos Pinhais.
Porto Alegre (RS)	1C	2919754	Yes	Alvorada, Arroio dos Ratos, Cachoeirinha, Canoas, Eldorado do Sul, Esteio, Gravataí, Guaíba, Nova Santa Rita, Porto Alegre, Sapucaia do Sul, Viamão.
Goiânia (GO)	1C	2011735	Yes	Abadia de Gioás, Aparecida de Goiânia, Goiânia, Goianira, Nerópolis, Senador Canedo, Trindade.
São Luís (MA)	2A	1309330	Yes	Paço do Lumiar, Raposa, São José de Ribamar, São Luís.
Teresina (PI)	2A	982968	Yes	Timon, Demerval Lobão, Teresina.
Natal (RN)	2A	1251459	Yes	Parnamirim, Extremoz, Macaíba, Natal, Nísia Floresta, São Gonçalo do Amarante, São José de Mipibu.
João Pessoa (PB)	2A	1017742	Yes	Bayeux, Cabedelo, Cruz do Espírito Santo, Joaão Pessoa, Santa Rita.
Maceió (AL)	2A	1028249	Yes	Coqueiro Seco, Maceió, Rio Largo, Santa Luzia do Norte, Satuba.
Aracaju (SE)	2A	879061	Yes	Aracaju, Barra dos Coqueiros, Laranjeiras, Maruim, Nossa Senhora do Socorro, São Cristóvão.
Vitória (ES)	2A	1670679	Yes	Cariacica, Guarapari, Serra, Viana, Vila Velha, Vitória.
Campinas (SP)	2A	2603819	Yes	Americana, Campinas, Cosmópolis, Hortolândia, Indaiatuba, Jaguariúna, Monte Mor, Nova Odessa, Paulínia, Pedreira, Santa Bárbara d'Oeste, Sumaré, Valinhos, Vinhedo.

Florianópolis (SC)	2A	866098	Yes	Biguaçu, Florianópolis, Governador Celso Ramos, Palhoça, Paulo Lopes, Santo Amaro da Imperatriz, São José.
Campo Grande (MS)	2A	786797	Yes	Campo Grande.
Cuiabá (MT)	2A	803694	Yes	Cuiabá, Várzea Grande.
Porto Velho (RO)	2B	428527	No	
Palmas (TO)	2B	228332	No	
Campina Grande (PB)	2B	452162	Yes	Campina Grande, Lagoa Seca, Queimadas.
Feira de Santana (BA)	2B	556642	Yes	Feira de Santana.
Ilhéus - Itabuna (BA)	2B	388903	Yes	Ilhéus, Itabuna.
Vitória da Conquista (BA)	2B	306866	No	
Juiz de Fora (MG)	2B	532474	Yes	Chácara, Juiz de Fora, Matias Barbosa.
Montes Claros (MG)	2B	361915	No	
Uberlândia (MG)	2B	604013	Yes	Uberlândia.
Ribeirão Preto (SP)	2B	791295	Yes	Jardinópolis, Ribeirão Preto, Serrana, Setãozinho.
São José do Rio Preto (SP)	2B	502494	Yes	Bady Bassit, Cedral, Guapiaçu, Mirassol, São José do Rio Preto.
Londrina (PR)	2B	709494	Yes	Cambé, Ibiporã, Londrina, Rolândia.
Maringá (PR)	2B	546408	Yes	Floresta, Mandaguari, Marialva, Maringá, Paiçandu, Sarandi.
Cascavel (PR)	2B	286205	No	
Blumenau (SC)	2B	309011	No	
Chapecó (SC)	2B	183530	No	
Joinville (SC)	2B	748470	Yes	Araquari, Guaruva, Guaramirim, Jaraguá do Sul, Joinville, Schoroeder.
Caxias do Sul (RS)	2B	499199	Yes	Caxias do Sul, Faroupilha.
Passo Fundo (RS)	2B	184826	No	
Santa Maria (RS)	2B	261031	No	
Rio Branco (AC)	2C	336038	No	
Boa Vista (RR)	2C	284313	No	
Marabá (PA)	2C	233669	No	
Santarém (PA)	2C	294580	No	
Macapá (AP)	2C	499466	Yes	Macapá e Santana.
Araguaína (TO)	2C	150484	No	
Imperatriz (MA)	2C	247505	No	
Juareizo do Norte (CE)	2C	426690	Yes	Juareizo do Norte, Crato Barbal.
Sobral (CE)	2C	188233	No	
Mossoró (RN)	2C	259815	No	
Caruaru(PE)	2C	314912	No	

Petrolina (PE) - Juazeiro (BA)	2C	491927	Yes	Petrolina, Juazeiro.
Arapiraca (AL)	2C	214006	No	
Barreiras (BA)	2C	137427	No	
Divinópolis (MG)	2C	213016	No	
Governador Valadares (MG)	2C	263689	No	
Ipatinga (MG)	2C	468378	Yes	Coronel Fabriciano, Ipaba, Ipatinga, Santana do Paraíso, Timóteo.
Pouso Alegre (MG)	2C	130615	No	
Teófilo Otoni (MG)	2C	134745	No	
Uberaba (MG)	2C	295988	No	
Varginha (MG)	2C	123081	No	
Cachoeiro de Itapemirim (ES)	2C	189889	No	
Campos dos Goytacazes (RJ)	2C	463731	Yes	Campos dos Goytacazes.
Volta Redonda - Barra Mansa (RJ)	2C	579427	Yes	Barra do Piraí, Barra Mansa, Pinheiral, Piraí, Volta Redonda.
Araçatuba	2C	181579	No	
Araraquara (SP)	2C	208662	No	
Bauru (SP)	2C	343937	No	
Marília (SP)	2C	216745	No	
Piracicaba (SP)	2C	364571	No	
Presidente Prudente (SP)	2C	207610	No	
Santos (SP)	2C	1604363	Yes	Bertioga, Cubatão, Guarujá, Itanhaém, Mongaguá, Praia Grande, Santos, São Vicente.
São José dos Campos (SP)	2C	1392552	Yes	Caçapava, Jacareí, Pindamonhangaba, São José dos Campos, Taubaté, Tremembé.
Sorocaba (SP)	2C	1148035	Yes	Araçoiaba da Serra, Boituva, Iperó, Itu, Porto Feliz, Salto, Salto de Pirapora, Sorocaba, Votorantim.
Ponta Grossa (PR)	2C	311611	No	
Criciúma (SC)	2C	192308	No	
Ijuí (RS)	2C	78915	No	
Novo Hamburgo - São Leopoldo (RS)	2C	736405	Yes	Araricá, Campo Bom, Capela de Santana, Dois Irmãos, Estância Velha, Ivoti, Lindolfo Collor, Morro Reuter, Novo Hamburgo, Portão, São Leopoldo, Sapiranga.
Pelotas - Rio Grande (RS)	2C	525503	Yes	Pelotas, Rio Grande.
Dourados (MS)	2C	196035	No	
Ji-Paraná (RO)	3A	116610	No	
Castanhal (PA)	3A	173149	No	

Rendenção (PA)	3A	75556	No
Bacabal (MA)	3A	100014	No
Caxias (MA)	3A	155129	No
Pinheiro (MA)	3A	78162	No
Santa Inês (MA)	3A	77282	No
Floriano (PI)	3A	57690	No
Parnaíba (PI)	3A	145705	No
Picos (PI)	3A	73414	No
Crateús (CE)	3A	72812	No
Iguatu (CE)	3A	96495	No
Quixadá (CE)	3A	80604	No
Caicó (RN)	3A	62709	No
Pau dos Ferros (RN)	3A	27745	No
Cajazeiras (PB)	3A	58446	No
Guarabira (PB)	3A	55326	No
Patos (PB)	3A	100674	No
Sousa(PB)	3A	65803	No
Guaranhuns (PE)	3A	129408	No
Serra Talhada (PE)	3A	79232	No
Guanambi (BA)	3A	78833	No
Irecê (BA)	3A	66181	No
Jacobina (BA)	3A	79247	No
Jequié (BA)	3A	151895	No
Paulo Afonso (BA)	3A	108396	No
Santo Antônio de Jesus (BA)	3A	90985	No
Teixeira de Freitas (BA)	3A	138341	No
Alfenas (MG)	3A	73774	No
Barbacena (MG)	3A	126284	No
Lavras (MG)	3A	92200	No
Manhuaçu (MG)	3A	79574	No
Muriaé (MG)	3A	100765	No
Passos (MG)	3A	106290	No
Patos de Minas (MG)	3A	138710	No
Poços de Caldas (MG)	3A	152435	No
Ponte Nova (MG)	3A	57390	No
Ubá (MG)	3A	101519	No
Colatina (ES)	3A	111788	No
São Mateus (ES)	3A	109028	No
Cabo Frio (RJ)	3A	186227	No
Itaperuna (RJ)	3A	95841	No
Macaé (RJ)	3A	206728	No
Nova Friburgo (RJ)	3A	182082	No

Barretos (SP)	3A	112101	No
Botucatu (SP)	3A	127328	No
Catanduva (SP)	3A	112820	No
Franca (SP)	3A	318640	No
Jaú (SP)	3A	131040	No
Limeira (SP)	3A	276022	No
Ourinhos (SP)	3A	103035	No
Rio Claro (SP)	3A	186253	No
São Carlos (SP)	3A	221950	No
São João da Boa Vista (SP)	3A	83639	No
Apucarana (PR)	3A	120919	No
Campo Mourão (PR)	3A	87194	No
Foz do Iguaçu (PR)	3A	256088	No
Francisco Beltrão (PR)	3A	78943	No
Guarapuava (PR)	3A	167328	No
Paranaguá (PR)	3A	140469	No
Paranavaí (PR)	3A	81590	No
Pato Branco (PR)	3A	72370	No
Toledo (PR)	3A	119313	No
Umuarama (PR)	3A	100676	No
Caçador (SC)	3A	70762	No
Itajaí (SC)	3A	183373	No
Joaçaba (SC)	3A	27020	No
Lages (SC)	3A	156727	No
Rio do Sul (SC)	3A	61198	No
Tubarão (SC)	3A	97235	No
Bagé (RS)	3A	116794	No
Bento Gonçalves (RS)	3A	107278	No
Erechim (RS)	3A	96087	No
Lajeado (RS)	3A	71445	No
Santa Cruz do Sul (RS)	3A	118374	No
Santa Rosa (RS)	3A	68587	No
Santo Ângelo (RS)	3A	76275	No
Uruguaiana (RS)	3A	125435	No
Barra do Garças (MT)	3A	56560	No
Cáceres (MT)	3A	87942	No
Rondonópolis (MT)	3A	195476	No
Sinop (MT)	3A	113099	No
Anápolis (GO)	3A	334613	No
Itumbiara (GO)	3A	92883	No

Rio Verde (GO)	3A	176424	No	
Ariquemes (RO)	3B	90353	No	
Cacoal (RO)	3B	78574	No	
Vilhena (RO)	3B	76202	No	
Cruzeiro do Sul (AC)	3B	78507	No	
Parintins (AM)	3B	102033	No	
Tefé (AM)	3B	61453	No	
Abaetuba (PA)	3B	141100	No	
Altamira (PA)	3B	99075	No	
Bragança (PA)	3B	113227	No	
Breves (PA)	3B	92860	No	
Cametá (PA)	3B	120896	No	
Capanema (PA)	3B	63639	No	
Itaituba (PA)	3B	97493	No	
Paragominas (PA)	3B	97819	No	
Tucuruí (PA)	3B	97128	No	
Gurupi (MA)	3B	76755	No	
Balsas (MA)	3B	83528	No	
Chapadinha (MA)	3B	73350	No	
Pedreiras (MA)	3B	39448	No	
Presidentre Dutra (PI)	3B	44731	No	
Campo Maior (PI)	3B	45177	No	
São Raimundo (CE)	3B	32327	No	
Itapipoca (RN)	3B	116065	No	
Açu (RN)	3B	53227	No	
Currais Novos (PB)	3B	42652	No	
Itaporanga (PE)	3B	23192	No	
Afogados da Ingazeira (PE)	3B	35088	No	
Araripina (PE)	3B	77302	No	
Arcoverde (PE)	3B	68793	No	
Palmares (PE)	3B	59526	No	
Vitória de Santo Antão (PE)	3B	129974	No	
Santana do Ipanema (AL)	3B	44932	No	
Itabaiana (SE)	3B	86967	No	
Alagoinhas (BA)	3B	141949	No	
Bom Jesus da Lapa (BA)	3B	63480	No	
Brumado (BA)	3B	64602	No	
Cruz das Almas (BA)	3B	58606	No	
Eunápolis (BA)	3B	100196	No	
Itaberaba (BA)	3B	61631	No	

Ribeira do Pombal (BA)	3B	47518	No
Senhor do Bonfim (BA)	3B	74419	No
Valença (BA)	3B	88673	No
Caratinga (MG)	3B	85239	No
Cataguases (MG)	3B	69757	No
Conselheiro Lafaiete (MG)	3B	116512	No
Itajubá (MG)	3B	90658	No
Ituiutaba (MG)	3B	97171	No
Janaúba (MG)	3B	66803	No
São João del Rei (MG)	3B	84469	No
São Lourenço (MG)	3B	41657	No
Viçosa (MG)	3B	72220	No
Linhares (ES)	3B	141306	No
Angra dos Reis (RJ)	3B	169511	No
Resende (RJ)	3B	119769	No
Teresópolis (RJ)	3B	163746	No
Andradina (SP)	3B	55334	No
Araras (SP)	3B	118843	No
Assis (SP)	3B	95144	No
Avaré (SP)	3B	82934	No
Bragança Paulista (SP)	3B	146744	No
Guaratinguetá (SP)	3B	112072	No
Itapetininga (SP)	3B	144377	No
Itapeva (SP)	3B	87753	No
Registro (SP)	3B	54261	No
Cianorte (PR)	3B	69958	No
Ivaiporã (PR)	3B	31816	No
Santo Antônio da Platina (PR)	3B	42707	No
União da Vitória (PR)	3B	52735	No
Araranguá (SC)	3B	61310	No
Balneário Camboriú (SC)	3B	108089	No
Brusque (SC)	3B	105503	No
Concórdia (SC)	3B	68621	No
Mafra (SC)	3B	52912	No
São Miguel do Oeste (SC)	3B	36306	No
Videira (SC)	3B	47188	No
Xanxerê (SC)	3B	44128	No

Carazinho (RS)	3B	59317	No
Cruz Alta (RS)	3B	62821	No
Frederixo Westphalen (RS)	3B	28843	No

Table 11 – Urban Centers included in the study.

APPENDIX – B - CONSENT FORM

CONSENTIMENTO PARA PARTICIPAÇÃO

PERCEPÇÃO SOBRE O TRANSPORTE URBANO E SUA SUSTENTABILIDADE: UM ESTUDO DE CASO EM SÃO JOSÉ DOS CAMPOS - SP

Este termo, em duas vias, deve ser lido pela pesquisadora quando for convidar as pessoas para participar da pesquisa.

Bom dia/ boa tarde/ boa noite, meu nome é Tatiana Ferrari. Estou convidando você para participar de uma pesquisa sobre o transporte urbano na cidade de São José dos Campos. Se você concordar em participar, gostaria de lhe explicar sobre a pesquisa e ver se sua participação seria possível. A pesquisa tem por objetivo analisar a percepção sobre o transporte urbano e a aceitabilidade da população a determinadas políticas públicas. A sua participaçã é confidencial e nenhum nome completo ou endereço será associado às suas respostas. Você pode deixar de participar a qualquer momento, sem que isso lhe cause nenhum prejuízo. É importante ressaltar que os dados serão guardados em local seguro e mantidos sob responsabilidade da coordenadora da pesquisa. Os resultados obtidos serão utilizados somente para fins desta pesquisa e das publicações dela advindas. O tempo estimado da pesquisa é de 10 minutos.

Você só participa se quiser, mas a sua participação é muito importante para que se possa conhecer melhor o que as pessoas pensam e desejam em seus deslocamentos urbanos. Você concorda em participar?

[ ] NÃO CONCORDA (agradeça a atenção)

[ ] CONCORDA

Nome Assinatura

Data

APPENDIX – C - QUESTIONNAIRE.

Pesquisa de Perfil em Transportes – São José dos Campos, SP
Data da aplicação:

Parte 1: Vou começar perguntando um pouco sobre o seu deslocamento pela cidade

2.1) Qual a frequência dos seus deslocamentos ao longo da semana?
( )Todos os dias ( ) de 3 a 4 dias ( ) de 1 a 2 dias ( ) raramente ou nunca ( ) não sabe

2.2a) Possui automóvel/carro?
( ) Sim ( ) Não

2.2b) Possui moto?
( ) Sim ( ) Não

2.2c) Possui bicicleta?
( ) Sim ( ) Não

2.3 Nos seus deslocamentos na cidade, indique quais os meios de transporte que você utilizou no último mês?
( ) ônibus (transporte público)
( ) ônibus/van particular (empresa)
( ) Carro próprio
( ) a pé
( ) bicicleta
( ) Carona
( ) táxi ou mototáxi
( ) serviços oferecidos por aplicativos (Uber, 99, Cabify, etc)
( ) Outros

2.4) Qual o motivo do seu deslocamento mais frequente na cidade?
( ) trabalho
( ) estudo
( ) lazer
( ) compras
( ) outro. Especifique:

2.5) No deslocamento da atividade principal do seu dia-a-dia, qual o meio de transporte costuma utilizar?
( ) ônibus (transporte público)
( ) ônibus/van particular (empresa)
( ) Carro próprio
( ) a pé
( ) bicicleta
( ) Carona
( ) táxi ou mototáxi
( ) serviços oferecidos por aplicativos (Uber, 99, Cabify, etc)
( ) Outros

2.6) Quanto tempo em média você leva para se deslocar pela cidade para realizar a atividade principal do seu dia-a-dia, considerando ida e a volta?
( ) até 30 minutos
( ) mais de 30 minutos a 1 hora
( ) mais de 1 hora a 1 hora e meia
( ) mais de 1 hora e meia a 2 horas
( ) mais de 2 horas e 3 horas
( ) mais de 3 horas a 4 horas
( ) mais de 4 horas
( ) não realiza atividade que precisa sair de casa
( ) não sabe

2.7) No deslocamento para atividades de lazer, qual o meio de transporte costuma utilizar?
( ) ônibus (transporte público)
( ) ônibus/van particular (empresa)
( ) Carro próprio
( ) a pé
( ) bicicleta
( ) Carona
( ) táxi ou mototáxi
( ) serviços oferecidos por aplicativos (Uber, 99, Cabify, etc)
( ) Outros

2.8) Como você avalia o trânsito na sua cidade?
( ) Ótimo / bom
( ) Regular
( ) Ruim/ péssimo
( ) Não sabe

2.9) Como você avalia o transporte público da sua cidade?
( ) Ótimo / bom
( ) Regular
( ) Ruim/ péssimo
( ) Não sabe

2.10) Numa escala de 1 a 5, coloque em ordem de importância as características abaixo considerando a sua escolha do meio de transporte nos seus deslocamentos: (em que 1 é o importante e 5 o menos importante)

	1	2	3	4	5
Custo					
Tempo					
Conforto					
Meio Ambiente					
Flexibilidade					
Segurança					

Figure 20 – First part of the survey.

Parte 2: Agora eu vou ler algumas frases e peço que você me indique o quanto você concorda ou não concorda com as afirmações. Para isso você deve utilizar essa escala (entregar escala) que vai de 1 a 5, onde o número 1 significa que você concorda plenamente com a afirmação, o 2 que você concorda em partes, o 3 que você nem concorda nem discorda, ou seja é indiferente, o 4 que você discorda em partes e o 5 que você discorda totalmente com a frase.

		1	2	3	4	5
		Concordo Plenamente	Concordo	Indiferente	Discordo	Discordo completamente
1	Mudanças radicais na sociedade precisam acontecer para minimizar os problemas ambientais					
2	A mudança climática é uma realidade e isso me assusta					
3	Eu não tenho certeza se a mudança climática está realmente acontecendo					
4	Acredito que os danoscausados pelos carros ao meio ambiente não são tão grandes o suficiente para que eu precise abrir mão do meu conforto					
5	Eu não acredito que a mudança climática seja um problema real					
6	Com ciclovias seguras as bicicletas seriam uma boa opção de transporte para mim					
7	A velocidade dos carros deve ser limitada no centro e nas áreas residenciais					
8	A cidade está muito violenta, não me sinto segura e por isso só ando com o meu carro					
9	O governo é quem deve assumir a responsabilidade pelo problemas ambientais					
10	A poluição do ar causada pelos carros é perigosa para a minha saúde					
11	Os carros deveriam pagar uma taxa para circular no centro da cidade					
12	Me sinto indiferente em andar de carro, mas a vida fica mais difícil sem ele					
13	A prefeitura deve limitar as áreas de estacionamento e aproveitar o espaço para outros usos					
14	Do ponto de vista ambiental é importante diminuir o uso de carros					
15	Gosto de andar de carro, ele me dá liberdade e me permite expressar quem eu sou					
16	Existem muitos problemas e dificuldades para se usar o transporte público					
17	Deveriam se criar mais espaços de estacionamento para os carros no centro da cidade					
18	Gasto muitas horas do meu dia no trânsito e isso afeta no meu trabalho					
19	Me sinto nervoso e estressado ao dirigir pela cidade					
20	Pensar no impacto que eu tenho sobre o meio ambiente é importante para mim					
21	Com um transporte público eficiente eu prefereria andar de ônibus ao carro					
22	Ter um carro é essencial para ter um bom estilo de vida					
23	O transporte público é ambientalmente melhor que andar de carro					
24	Reduzir o número de carros na cidade melhoraria a qualidade de vida da população					
25	Os meus hábitos individualmente não tem impacto sobre os problemas ambientais					

Figure 21 – Second part of the survey.

Parte 3: Para finalizar eu gostaria de saber um pouco mais sobre você. Lembrando que a pesquisa é confidencial e não identificável.

4.1) Qual a sua faixa etária?	
	menos de 18 anos
	de 18 a 24 anos
	de 25 a 34 anos
	de 35 a 44 anos
	de 45 a 54 anos
	de 55 a 64 anos
	mais de 65 anos
4.2) Qual o seu gênero?	
	Masculino
	Feminino
4.3) Informe sua faixa de renda familiar	
	Sem rendimento
	Até ¼ S.M - (até R$238)
	Mais de ¼ até ½ S.M - (mais de R$238 a R$477)
	Mais de ½ até 1 S.M - (mais de R$477 a R$954)
	mais de 1 a 2 S.M (mais de R$937 a R$1.908)
	mais de 2 a 4 S.M - (mais de R$1.908 a R$3.816)
	mais de 4 a 10 S.M - (mais de R$3.816 a R$9.540)
	mais de 10 a 20 S.M - (mais de R$9.540 a R$19.080)
	acima de 20 S.M - (mais de R$19.080)
	Prefiro não responder
4.4) Qual seu estado civil?	
	Solteiro
	Casado ou união estável
	Separado/Divorciado
	Viúvo
4.5) Quantas pessoas pertencem ao seu grupo familiar, que dependem da renda informada?	
	sozinho
	1
	2
	3
	4
	5
	mais de 5 pessoas

4.6) Você tem filhos? Quantos?	
	Nenhum
	1
	2
	3
	mais de 3
4.7) Nível de escolaridade	
	Sem instrução
	Fundamental incompleto ou equivalente
	Fundamental completo ou equivalente
	Médio incompleto ou equivalente
	Médio completo ou equivalente
	Superior incompleto ou equivalente
	Superior completo
	Não determinado
4.8) Qual a sua ocupação?	
	Empregado
	Autônomo
	Funcionário público ou militar
	Empregador
	Empregado doméstico
	Aposentado
	Estudante
	Trabalhador do Lar
	Desempregado
	Outro
4.9) Qual o CEP da sua residência? Caso não saiba, favor informar o nome da Rua.	
CEP:	

Você estaria disposto a participar de uma entrevista complementar (pessoalmente ou por telefone) para discutir questões do transporte da sua cidade mais a fundo? Tal como neste questionário, as entrevistas serão estritamente confidenciais.
( ) Sim ( ) Não

Se sim, poderia me indicar um contato seu:

Figure 22 – Third part of the survey.