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Urban Freight Transport Measures in São Paulo Metropolitan Area

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Medidas relacionadas ao Transporte Urbano de Cargas na Região Metropolitana de São Paulo

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ABSTRACT

There is a general perception that urban freight vehicles are relevant contributors to worsened livability in urban areas. To address citizens' complaints, local authorities interfere usually by regulating truck traffic within their jurisdiction boundaries. The objective of this study is to provide insight in the emergence of UFT management measures in large cities and adjacent areas. It is an exploratory research and, as such, it aims to produce generalizations derived from inductive reasoning. To achieve this objective, we conducted a detailed account of UFT measures in the São Paulo Metropolitan Area from 1960 to 2019. We searched cities document databases and employed Python routines to recognize and filter text information, then compared the emergence of measures with changes in population, GDP, fleet and accidents data. We found that public policies have not been coordinated among cities and that most initiatives are not assessed before implementation.

KEYWORDS: Urban freight transport, Sao Paulo Metropolitan Area, truck restriction regulations, urban freight transport measures.

RESUMO

É amplamente aceito que veículos de carga no ambiente urbano contribuem para diminuir a qualidade de vida nesses locais. Para atender a demandas da população, as autoridades locais intervêm normalmente através da regulamentação ao trânsito de caminhões dentro dos limites de suas jurisdições. O objetivo deste estudo é aprofundar a compreensão sobre o surgimento de medidas de gerenciamento do transporte urbano de mercadorias (“UFT” na sigla em inglês, “Urban Freight Transport”) em grandes cidades e áreas adjacentes. É uma pesquisa exploratória e, como tal, busca obter generalizações a partir de raciocínio indutivo. Para atingir o objetivo, realizou-se uma descrição detalhada de medidas relacionadas a UFT na Região Metropolitana de São Paulo (“SPMA” na sigla em inglês) de 1960 a 2019. Buscou-se informações nas bases de dados documentais das cidades da SPMA, utilizando rotinas em Python para reconhecer e filtrar informações textuais, que foram comparadas com surgimento de medidas com mudanças na população, GDP, frota e acidentes. Verificamos que as políticas na SPMA não são articuladas entre as cidades e que a maioria das iniciativas não tem sua implementação previamente avaliada.

PALAVRAS-CHAVE: Transporte urbano de carga, Região Metropolitana de São Paulo, restrição de caminhões, medidas de transporte urbano de cargas.

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1. INTRODUCTION

In 1950, people living in urban areas were estimated in around 30% of world's inhabitants. The proportion of urban dwellers has since then increased rapidly, comprising 55% of world population in 2018 and outlining a global urbanization process, although with differences among locations. Upper-middle income countries like Argentina, Brazil, China, Mexico and South Africa have been experiencing the fastest paces of urbanization, with an average rate of 1.6% annually, compared to a 0.25% per year in high-income countries. Urban growth is decelerating, though, with the former group expected to present annual rates of 0.5% between 2030 and 2050, while low-income countries are estimated to have a urbanization rate of 1.4% per year in the same period (UNITED NATIONS, 2018).

In Brazil, the largest urban agglomeration is in São Paulo Metropolitan Area (SPMA), where the number of inhabitants has increased roughly threefold between 1970 and 2018, exceeding 22 million people and turning it into one of the five largest megacities in the world. There are currently 33 megacities, more than threefold the observed in 1990 (UNITED NATIONS, 2018).

According to Hall and Barret (2012), the establishment of cities and their evolvement is linked to socioeconomic transformations, serving to a primary economic function as the location for performing business operations. This trend is strengthened by the increasing importance of services in national economies, thus being coherent with the fact that large cities are accountable for the generation of approximately 80% of gross domestic product (GDP) (DANIELS, 2004). Nonetheless, cities encompass a high level of social disparity, as demonstrated by the existence of slums and squatter settlements and the advance of informal economic activities.

Slums are related to unplanned or inappropriately managed urban expansion, which leads to sprawl, pollution and degradation of the land and natural resources. In addition, urban dwellers consume more per capita than rural dwellers, implying in less sustainable production and consumption patterns. Such facts compose challenges to sustainability in urban areas. However, controlling for income level, urban living can be more sustainable, and high-density areas are less consumption-intensive than low-density urban areas, due to some sort of economy of scale. As an example, the energy consumption per-capita in the low-density regions of the urban area of Toronto is twice as large as that observed in the high-density urban core (UNITED NATIONS, 2018).

Populations of large urban areas compose, therefore, a spatially heterogeneous, high demand for services and goods. Consumers can obtain such goods by either purchasing them in commercial facilities, where products are promptly available, or by shopping on-line, in which case the items can either be delivered at home or picked-up in specific locations. Goods come from many different places, as they can be produced in the same city, state, country or anywhere else in the world. In all cases, though, freight operations are part of the process that allows for the products to reach their end destination; and a portion of the transport and handling sequence takes place in the urban environment.

Thus, urban freight transport is vital for the way of living in urban areas. The functioning of urban agglomerations relies on the supply of basic goods (food, medicines) and services (waste removal), in the sense that they ensure minimum living conditions. Beyond that, the highly dynamic economies of urban areas involve industrial, trade and leisure activities, many of which imply in freight operations in inner areas of the city (MUÑUZURI *et al.*, 2005). Thus, the growth of freight transport is desirable as an indicator of economic growth, for the freight transport demand is a derived demand (QUAK, 2008). Finally, e-commerce expansion contributes to a higher demand for urban freight (VISSER; NEMOTO; BROWNE, 2014). For instance, in the first five months of 2020 online shopping in Brazil grew by 57% from a year earlier, due to customers' avoidance of risks posed by the COVID-19 pandemics. All considered, it makes sense to seek efficiency in transport operations and supply chain management.

However, large urban areas are a complex, costly, and constrained space (DABLANC, 2007). There is a perception that truck traffic is specifically detrimental to traffic inside urban areas, besides worsening living conditions due to noise and air pollution (QUAK, 2008). The latter is possibly related to health problems (HE, GOUVEIA and SALVO, 2018). Such undesired effects of an economic activity characterize externalities, a concept originally developed in the context of economic sciences.

Externalities imply that markets will not adjust to the desired direction, i.e., affects the principle of dynamic efficiency (NASH, 2015). So, if there is demand for the transport of goods in the urban area, trucks will transit, and the freight price will not be adjusted only due to the caused nuisance. Thus, when population complaints arise, public authorities are ultimately responsible for addressing the issues affecting the communities. A quick way to respond is to set rules for truck traffic, directly impacting shippers and freight transport operators. Customers may also be affected, as prices can increase. Higher prices compromise a more considerable amount of income of the poor than they do for other extracts of the population.

Effectivity of regulations and side effects of restricting truck traffic is not always evaluated before they are put in place; usually they are not assessed after, either, due to several aspects like data availability and resources. However, there are descriptive reports on urban freight transport available, most of them developed by programs and projects funded by the European Union (EU), such as the Alliance for Logistics Innovation through Collaboration in Europe (ALICE), European Road Transport Advisory Council (ERTRAC), Best Urban Freight Solutions (BESTUFS), Transferability of Urban Logistics Concepts and Practices from a Worldwide Perspective (TURBLOG_WW), among others. There is not any initiative in that sense by public agents in Brazil in our knowledge. Only recently, in 2012, Brazilian Law 12587 established the Urban Mobility National Policy (UMNP), determining that cities with more than 20,000 inhabitants should develop an Urban Mobility Plan (UMP) comprising both passenger and cargo transport (DIAS et al.*,* 2018).

Therefore, urban freight is a component of complexity in large cities that has economic and social relevance. Its different aspects can be of interest in diverse science fields like engineering, economics, geography and public health. Research work in UFT focuses on the performance of proposed solutions, discussion of their practice and the roles and reactions of UFT stakeholders. There is also extensive work addressing the pollution caused by freight vehicles. Ideally, the findings of studies in the many science areas would provide foundation to authorities for a better planning and implementation of policies that address the urban freight transport, however that does not seem to be the case.

This study proposes a change of paradigm on UFT research. Instead of evaluating the performance of UFT measures, we aim to obtain insights by investigating how measures emerge in the first place by studying the case of São Paulo Metropolitan Area. Although the replicability of findings in other regions consists in a different topic of research, this study can support other urban areas in establishing policies and planning that includes UFT as a fundamental aspect of sustaining the city and its economy. It can also provide insights for SPMA on what can be improved for its future development, considering its social and economic heterogeneities.

1.1. Objective

The objective of this study is to provide insight in the emergence of UFT management measures in large cities and adjacent areas. It is an exploratory research and, as such, it aims to produce generalizations derived from inductive reasoning. To achieve this objective, we conducted a detailed account of UFT measures in the São Paulo Metropolitan Area from 1960 to 2019. Then, we investigate the changes in population, GDP, fleet and accidents in that time span following the UFT system model proposed by Kin, Verlinde and Macharis (2017).

Propositions that provide direction to this study are:

<u>Drivers for implementation of UFT measures</u>

Urban freight transport is managed as a local issue in most countries, which leads to local authorities creating regulations as an attempt to control its impacts (Dablanc, 2007). Holguin-Veras et al. (2018) points out that public decision-makers face difficulties in identifying effective measures to address urban freight transport issues, due to the lack of data and training to support their actions. Therefore, they frequently resort to familiar approaches, such as engineering and regulations of various types. Quak (2008) states that urban freight transport policies usually emerge from the (perceived) problems caused by the transport, rather than an essential activity supporting urban living.

The authors suggest that there comes a point where authorities feel pressured to regulate UFT, however little information is given on what triggers it. Thus, we elaborate the following propositions about possible thresholds:

a) Observable and measurable externalities of truck traffic in urban areas are the reason for governance measures restricting their circulation.

b) Observable and measurable characteristics of the urban area, such as demographics, are the implicit drivers behind emergence of governance measures restricting truck circulation.

<u>Consequences of UFT Measures</u>

The impacts of widely adopted UFT solutions, as well as their transferability to other settings, are not completely understood (QUAK, 2008). As an illustration of that, road pricing initiatives can result in drivers diverting routes, causing pollution and congestion in another area and limiting efficiency and effectiveness of such measures (KARRER AND RUESCH, 2007). He, Salvo and Gouveia (2019) studies indicate that congestion may be relieved by a ring road; however, results are not sustained over time, in contrast to the reduction of nitrogen oxide emissions, which are lower for as long as the prohibition to truck traffic persists.

Finally, McLeod *et al.* (2019) point out that problems caused by freight transport policies can reach beyond local planning jurisdiction limits, so that a local initiative exert effects across regions.

Therefore, we present a third proposition to guide this research:

c) UFT actions have effects in surrounding municipalities.

To categorize city's administration initiatives as a UFT measure, we consider everything that can affect the circulation of goods in the urban areas. Therefore, there is no need for a given rule to explicitly state the intention to control UFT. Nevertheless, although urban planning initiatives like master plans, land use and zoning influence the flows of UFT, we do not consider them as UFT *per se* but as a source of information of whether there is a concern to address urban freight in the process of planning the city. This study does not include rules focused on dangerous goods transport, neither the requirements for excessive loads, e.g., large equipment or cargo not routinely transported and that, therefore, require special handling operations and licensing.

1.2. Research Overview

The dissertation is structured in chapters, as follows:

In **Chapter 2,** we provide a theoretical review of the delimitation of the urban space to better characterize the issues related to Urban Freight Transport (UFT). We review the scientific literature on UFT, its scope and characterization. Characterizing it also comprises its consequences on the population of the urban areas and the actions taken to address such effects. The last topic in the chapter discusses how the effectiveness of such measures is approached by their practitioners and the academy.

Chapter 3 is the description of SPMR, presenting data on population, economics, and infrastructure.

Chapter 4 defines the methodological approach of this study.

Chapter5 contains results and their discussion. The upcoming of regulations on urban freight management is depicted for municipalities in this section.

Chapter 6 integrates the previous chapters and outlines findings and recommendations.

2. LITERATURE REVIEW

2.1. Urbanization and Urban Planning

Although urbanization is, simply defined, the population shift towards urban environments, the most recent UN report on urbanization defines urbanization as a much more complex socio-economic process, that transforms the built environment both by converting formerly rural into urban settlements and shifting the spatial distribution of a population from rural to urban areas (UNITED NATIONS, 2019). It leads to changes in occupations, lifestyle, culture and behavior, therefore impacting the demographic and social structure of both urban and rural areas.

The definitions of urban and rural areas vary among countries. Part of governments take into consideration a criterion or a combination of criteria such as demographic density, area size, total population and proximity to large cities. However, some countries either do not have rules or legally designate specific municipalities as urban areas. In Brazil, Decree-Law nº. 311/1938 delegates the definition of what districts are urban or rural zones to each municipality, without defining criteria in the country level (BRAZIL, 1938). This dichotomic view is not the only theoretical approach to urbanization, though, provided that an alternative concept acknowledges a rural-urban *continuum*, many times referred to as *peri-urban areas* (UNICEF, 2012).

Although sometimes used as a synonym for urban areas, *urban agglomerations* are formally defined as “a contiguous territory inhabited at urban levels of residential density” (UNITED NATIONS, 2019), disregarding administrative borders. Megacities are, in fact, the largest urban agglomerations, and emerged from the demographic transition, i.e., population growth with smaller household sizes, migration and geographic expansion (KIN; VERLINDE; MACHARIS, 2017). Diversely, the *metropolitan area* comprises the urban agglomeration and neighboring areas at a lower settlement density but with strong economic and social relations to the core city (UNITED NATIONS, 2019).

The beforementioned concepts are crucial for planning and policymaking by local governments, even though the precise delimitation of urban areas does not have a unique procedure. Setting a global threshold to distinguish urban and rural areas would not be suitable due to countries' idiosyncrasies concerning land occupation. For instance, in the European Union, spatial clusters with more than 300 dwellers per square kilometer and over 5,000 inhabitants total are deemed urban areas (RIGOTTI; HADAD, 2016), whereas in China a density of 1,500 or more inhabitants per square kilometer characterize an urban area (UNITED NATIONS, 2019).

Within this context, the modernist approach to urban planning has become outdated. Modern urban planning emerged in the second half of the 19th century to address disorganized cities growth caused by the Industrial Revolution. Throughout the 20th century, such planning approaches generally involved comprehensive plans (master, directive, strategic, general or layout plans and land-use zoning, among others) created by experts and sought to implement specific urban forms, thus precluding involvement of stakeholders and leading to plans that are completely detached from governance systems. The traditional methods, e. g., land-use zoning, directive plans etc., are still widely in use, notably in developing countries, even though they have been increasingly criticized since the 1960s (UN-HABITAT, 2009). *The Death and Life of Great American Cities,* book published in 1961 by Jane Jacobs, is one of the main references in the shift of urbanism paradigms. It addresses the problems of zoning laws and the need for a deeper understanding of the urban environment to develop valuable planning and policies.

Therefore, the UN present an updated definition of urban planning:

> A decision-making process aimed at realizing economic, social, cultural and environmental goals through the development of spatial visions, strategies and plans and the application of a set of policy principles, tools, institutional and participatory mechanisms and regulatory procedures. (UN-HABITAT, 2018, p. 5)

However, public authorities rarely addressed issues related to the transportation of goods in the city. The possible reason for that is the fact that freight transportation is essentially a private industry and authorities did not perceive themselves as having anything to do with such operations (CRAINIC; RICCIARDI; STORCHI, 2004). As an example, the UN-Habitat (2009, p. 11) mentions the road hierarchies as one of the urban forms proposed in traditional planning approaches. The purpose is the design of driveways for public circulation (people):

> Road hierarchies, 1960s (UK): informed by the 1963 report by Colin Buchanan (traffic in towns). Provides a rationale for urban traffic management and the problems of traffic congestion by creating a hierarchy of roads with different functions. At the lowest level of the hierarchy an environmental cell (or residential area) carries only local

> traffic on “local distributors”. At higher levels, district and primary distributors (freeways) carry passing and longer-distance traffic. The assumption is that every household will eventually own a car and all urban movement will be car based. These ideas fitted well with urban modernism and the two strands became closely interlinked.

Dias *et al*. (2018) state that public management seems to have a lack of background to develop Urban Master Plans (UMPs), being unaware of urban logistics demands within their cities or having neglected aspects of urban freight within the UMPs. Actions addressing UFT seem to be just replicated by cities without local impact assessment. Public authorities should increase efforts in data collection process, training, interaction with stakeholders and communication between agencies to elaborate UMPs properly.

Urban Freight Transport became part of planning discussions by the end of the 1970s, as conferences held by the OECD and the US Highway Research Board recognized the neglect of urban goods distribution in transport planning studies in urban areas. By the end of the decade, trucks had been included in the Transportation Systems Management (TSM) guidelines, especially related to traffic engineering measures, and had their circulation regulated, without major developments throughout the 1980s (OGDEN, 1992). From 1990 on, public pressure due to problems raised by traffic motivated a renewed interest in urban freight distribution and new developments took place especially in Europe and Japan (CRAINIC; RICCIARDI; STORCHI, 2004).

Moreover, by the end of the 1980s and early 1990s, emerging concepts of “sustainability” and “sustainable development”[1] led to a new focus in policy action, requiring consistency with environmental and climate change guidelines (ANDERSON; ALLEN; BROWNE, 2005). Several studies approach UFT from a new perspective that includes sustainability as a goal, referring to it as sustainable urban freight transport or sustainable urban distribution (KIN; VERLINDE; MACHARIS, 2017). However, there is not a set of indicators or a clear definition of sustainability applied to urban distribution, both facts posing an obstacle to the development of sustainable freight transport strategies that would simultaneously result in economic benefits, a reduced environmental impact and social responsibility (QUAK, 2008).

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[1] According to the World Commission on Environment and Development (1987), “sustainable development is development that meets the needs of the present without compromising the needs of future generations to meet their own needs’’.

2.2. Urban Freight Transport Definition

UFT has been defined differently by the many authors in the field (QUAK, 2008), and frequently it is referred to by terms that relate to other formal concepts. To illustrate that, we mention the systematic literature review conducted by Lagorio *et al*. (2016), in which they selected the following keywords in their search for UFT literature: “urban logistics”, “city logistics”, “urban freight”, “last mile delivery” and “urban delivery”. Lindholm (2012) noted that the concepts are similar, however there is little coherence in how they are used. They have 3 elements in common: geography, transport and commodity, although the concept of urban area, i.e., the geographic aspect, is not clearly outlined by many authors (VERLINDE, 2015).

The word freight refers to the carriage of goods, sometimes also referred to as “goods transport” (LINDHOLM, 2012). In this study, we employ the related term word “distribution” to refer to it, although it has a specific definition in the context of supply chain management. Another term used is “last mile delivery”, that relates to part of the urban freight in which goods reach receivers. According to Visser, Nemoto e Browne (2014), when purchases occur in stores, the last-mile transport is carried out by consumers’ passenger trips, while in electronic shopping the last-mile freight transport substitutes passenger shopping trips. The term is common in the literature about the e-commerce supply chains. Lindholm (2012) pointed out that most definitions of UFT exclude shopping trips by people, beginning with the first definition by Hicks (1977), that includes journeys into, out of, and within a designated urban area by road vehicles specifically aiming to pick-up or deliver goods (whether the vehicle be empty or not), except for shopping trips.

Ogden (1992) suggested a broader understanding of urban goods movement by not specifying vehicles involved and explicitly excluding movements of people to, from, within, and through urban areas. Allen *et al*. (2000) presented a detailed definition, including under the scope of UFT: a) all types and sizes of goods vehicles and other motorized transport used mainly for goods collections and deliveries at premises in the urban areas; b) all types of movement of such vehicles to and from urban premises, including transfers between them, ancillary goods deliveries to urban locations, money collection and deliveries, waste collections and home deliveries from urban locations to customers; and c) vehicle trips for service or commercial purposes which are fundamental to the functioning of urban premises. This definition seems to exclude deliveries to customers in urban areas when coming from warehouses located in the outskirts of the city, though. Muñuzuri *et al*. (2005) recovered the broader approach given by Ogden back in 1992, and provided an even more generic definition of UFT comprising all those movements of goods that are affected by particularities associated to urban traffic and morphology, to refer to all goods movements influenced by conflicting interests of freight vehicles and pedestrians, car drivers, bikes and buses for the use of urban streets, parking spaces etc.

The OECD (2003) characterized UFT as “the delivery of consumer goods (not only by retail, but also by other sectors such as manufacturing) in city and suburban areas, including the reverse flow of used goods in terms of clean waste”. This definition precludes the transport of refuse produced by households, comprising only that under responsibility of entities collecting materials within reverse logistics schemes.

With the increasing interest on urban goods transport in Europe, Ambrosini and Routhier (2004) analyzed different countries and proposed a common definition for industrialized countries, which should include also “household purchasing trips, urban road maintenance and building, waste collection, etc.”

The most recent definitions are given by Dablanc (2008), who stated that a professional carrying out the transport of goods in the urban environment is a necessary condition to characterize UFT and, thus, ruling out shopping trips. The same author provided an updated definition in 2011, explicitly mentioning that UFT includes all goods movements generated by economic needs of local business such as deliveries and collections of supplies, materials, parts, consumables, mail and refuse, also including home deliveries resulting from commercial transactions (Dablanc, 2011). In this case, we highlight that the word local as in “local business” excludes traffic of goods through the city, that is, the roads in the urban environment are only part of the route between other locations.

Taking in consideration the work of previous authors, Lindholm (2012) proposed to merge previous definitions, stating that UFT comprises all movements of goods (as distinct from people) in to, out from, through or within urban areas, performed by light or heavy vehicles, including as well service transport and demolition traffic, shopping trips by private households and waste (reverse logistics). In the context of her studies with focus in local authorities, Lindholm (2012) included as much of the goods movements as possible, even shopping trips, as they generate impacts that substitute those associated to home delivery.

Finally, we resume to the term city logistics, mentioned in the first paragraph of this item. City logistics has been defined in by Taniguchi *et al*. (2001, p. 2) as:

> The process for totally optimizing the logistics and transport activities by private companies with support of advanced information systems in urban areas considering the traffic environment, the traffic congestion, the traffic safety and the energy savings within the framework of a market economy.

Although related to urban freight transport, the concept of city logistics involves improvement and efficiency. Lindholm (2012) pointed out that the use of the word "city" can be misleading, as it can be interpreted as the central business district instead of the whole urban area, and that the definition is limited to the perspective of private companies, differing of all previous definitions by both the focus on improvement and on a specific stakeholder of UFT.

2.3. Externalities of Urban Freight Transport

Externalities are defined as situations in which activities of agent A, such as production and consumption of goods and services, affect the utility position of agent B, provided that B has no choice or control over being affected and A is not influenced by that effect (VICKERMAN, 2015). The concept of externality or external effect excludes cases in which someone deliberately does something to affect someone else, which means that an externality is an unintended effect. Such aspect can be highlighted even further by saying that an externality exists whether or not payment for the effect is imposed on the decision maker (VASCONCELLOS, 2005).

Freight activities, although necessary, bring undesirable impacts that negatively affect quality of life in urban areas (QUAK, 2008). Such undesirable effects can be considered negative externalities of UFT.

The negative effects of UFT can be classified in three groups (BINSBERGEN; VISSER, 2001 and ALLEN; THORNE; BROWNE, 2007), in consistency to each of the sustainability pillars, as presented Table 1. Also known as the triple bottom-line, the three sustainability pillars correspond to social, economic and environmental pillars, or triple-P, respectively: people, profit, and planet (QUAK, 2008).

Table 1 - Externalities of Urban Freight Transport.

Sustainability Pillar	Externality
Social	Public health issues caused by pollution
	Accidents resulting in injuries
	Decreased quality of life due to land use with loss of green sites
	Potential damage to streets, buildings and infrastructure due to the weight of vehicles and vibration
	Increased nuisance due to noise disturbance, visual intrusion, stench, and vibration (QUAK, 2008)
Economic	Increased traffic congestion resulting in time losses and resource waste (VERLINDE, 2015) (QUAK, 2008)
	Unreliable journey and delivery punctuality, with potentially worsened customer service and market loss
	Decreased city accessibility (QUAK, 2008)
	Cost of public regulation and planning (VERLINDE, 2015)
Environmental	Emissions that contribute to the greenhouse effect and, thus, to climate change (mostly CO_2)
	Decreased air quality locally due to emissions of carbon monoxide (CO), nitrogen oxides (NO_X), volatile organic compounds (VOC), ozone (O_3) and particulate matter (PM)
	Use of fossil fuels, a non-renewable natural resource
	Generation of waste products such as tires and oil

Source: adapted from Quak (2008).

Concerning the economic impacts, Quak (2008) points out that problems in the access to urban areas affect the efficiency of the urban freight transport system. With an increase in mobility, mainly due to the growing number of car owners, people can live in farther locations and drive to work, in a process of suburbanization that, for its turn, contributes to congestion and aggravates the other impacts of urban freight.

2.4. Urban Freight Transport Management

The publication “A Guide to Implement Road Freight Transport Management in Urban Environment” (PIARC, 2012) proposed a framework for freight management in urban areas, recommending the sequence of design, assessment, implementation, and evaluation. These steps correspond to the plan, do, check and act (PDCA) cycle. The design and assessment phases correspond to the planning, the implementation stage corresponds to the “do” (execution of the plan) and the evaluation stage is similar to the “check” and “act” procedures (TANIGUCHI, 2014), as it is further detailed in *Table 2*. Lindholm (2012) discussed how to include UFT in overall transport planning. Although with different designations, approaches have similar considerations, like the importance of partnerships and involvement of stakeholders.

Table 2 - Framework for UFT management.

Stage	**PDCA Cycle Corresponding Stage**	**Description**
Design	Plan	a) identify problems in the target area. b) find causes. c) set goals. d) describe freight vehicle movements. e) combine approaches and measures as a proposal for solving the issues identified.
Assessment	Plan	Effect of planned actions are assessed (ex-ante evaluation)
Implementation	Do	Execution of previously planned efforts
Evaluation	Check Act	Analysis of actual results versus goals, generating input to the beginning of the process on what needs to be improved (ex-post evaluation).

Source: adapted from PIARC (2012).

In the Design stage, stakeholders identify issues to be addressed in the chosen area and investigate their causes, which support the establishment of goals and, with the understanding of freight vehicle flows altogether, the proposal of approaches to achieve those goals. The approaches to be defined in the design stage are incentives or ideas organized in the following categories: (a) Infrastructure, (b) Regulatory, (c) Logistical, (d) Co-operative, (e) Technical, (f) Behavioral. Muñuzuri (2005) stated that a combination of compatible, not redundant measures composes a strategic policy for logistics in the city, although the result cannot be estimated by the sum of effects.

In the assessment stage, the planned actions are examined, as there may be negative, unanticipated impacts alongside or instead the desired outcome. As an illustration, Taniguchi (2014) pointed out that restricting large trucks in urban areas increases the number of small trucks, which leads to higher level of traffic congestion and negative environmental impacts. Techniques for this stage may include simulation, brainstorming, scenario examination and a pilot program (PIARC, 2012).

For an effective implementation stage, Taniguchi (2014) outlined that collaboration between public authorities and private companies is essential. The success of any measures of urban freight transport management relies upon the mutual understanding and cooperation among stakeholders. Experience shows that the wise use of subsidies from municipalities is required, as the initiative is unfeasible in the long run if it depends too much on subsidies.

In the evaluation stage, implementation results are assessed using multiple criteria such as costs for freight carriers, environmental impacts, traffic safety and energy consumption. This feedback supports improvements to be studied and possibly adopted in a new turn of the PDCA cycle (TANIGUCHI, 2014). UFT management is, therefore, a continuous effort.

2.5. UFT Measures

The beforementioned measures are defined as “different solutions or pilot actions that are carried out to test different physical solutions to urban freight transport” (LINDHOLM, 2012). Holguín-Veras *et al* (2015) wrote in a recent guide: “The term initiative is used […] to refer to the set of public-sector actions that could be considered to address a freight issue”. The words *initiative* and *measure* by Holguín-Veras *et al (2015)* are interchangeable, as evidenced by the following extracts: “the review that produced this Guide led to the identification of 54 measures. […] The review […] led to the identification of 54 initiatives”. Various publications consist in case studies of such measures, comparison of experiences, classification in groups or taxonomies etc. Muñuzuri et al. (2005, p. 16) provided two different criteria for classification: by scope and by stakeholder responsible for implementation. The categorization by scope comprised five groups of solutions, according to the field where they are applied: public infrastructure, land use management, access conditions, traffic management and solutions related to enforcement and promotion. Classification by implementing group of stakeholders contains three categories: carriers and logistics operators, receivers or local authorities). Holguin-Veras *et al*. (2018) cataloged more than 45 initiatives in 8 categories: infrastructure management; parking/loading areas management; vehicle-related strategies; traffic management; pricing, incentives, and taxation; logistical management; and freight demand/land use management. A category titled stakeholder engagement included in Holguin-Veras *et al*. (2015) has been suppressed in the more recent publication.

Technology has evolved rapidly, turning wireless devices less expensive and increasing speed and reliability of connection and data transmission. Considering the grouping criteria proposed by Muñuzuri et al (2005), UFT use of technologies mentioned in the beginning of this paragraph could appear in both public infrastructure and traffic management or as a measure applied by all stakeholders. Thus, for a more comprehensive presentation of measures we chose to use a third criterion, the characteristics of the measures, which results in four groups: material infrastructure, immaterial infrastructure, equipment measures and governance (RUSSO and COMI, 2011).

2.5.1. Material Infrastructure Measures

Material infrastructure involves the physical arrangement of the environment where the freight vehicles move and operate. Construction and modification of existing elements can be rather costly and difficult to implement thus the focus of these measures is mostly in repurposing of built infrastructure (LINDHOLM, 2013).

According to Russo and Comi (2011), there are two types of material infrastructure, linear and surface (and/or nodal). Linear material infrastructure involves taking actions to improve freight vehicle movement in the urban/metropolitan network, and surface material infrastructure refer to reservation of areas for other freight activities and operations. The category “infrastructure management” in Holguin-Veras et al. (2015, 2018) comprises two subgroups, namely “major improvements” and “minor improvements”, having little in common with the division proposed by Russo and Comi (2011). Specific initiatives on material infrastructure and comments on how they are approached by authors are detailed in the next subsections.

2.5.1.1. Reserved Lanes

Driveways with multiple lanes enable segregating the traffic of different kinds of vehicles. If a specific fleet shares similar routes and is not large to the point of exceeding lane capacity, the creation of a traffic corridor for vehicles of that fleet increases their journey time reliability and decreases delays. Thus, autonomous drivers and logistics operators can largely benefit from it. Also, increased efficiency of truck movements leads to lower environmental impact, and reduced interaction of heavy and light vehicles may decrease the risk of accidents (Holguin-Veras et al, 2018).

Reserved lanes are already common if considered the bus corridors implemented in congested cities as a mobility solution for the public transportation. Regarding solutions involving freight transport, the possibilities are:

a) assignment of one lane or more only for traffic of goods vehicles, referred to by dedicated truck lanes or lorry lanes;

b) “no-car lanes”, allowing buses as well as freight vehicles. In situations where bus usage is insufficient to justify an exclusive bus lane, the creation of no-car lanes can provide a viable alternative;

c) “high occupancy vehicle lanes” (HOV) to receive traffic of vehicles with more than a predefined number of occupants (ALLEN; THORNE; BROWNE, 2007).

Exclusive truck lanes or dedicated truck lanes are categorized by Holguin-Veras et al. (2018) as a traffic management measure, sub-category “traffic control/lane management”, along with many initiatives enforced by regulations (sub-categories “access and vehicle-related restrictions” and “time-access restrictions”). Although in practice the implementation of reserved lanes involves the use of existing infrastructure along with decisive action of authorities, it also involves much more complexity due to the physical space and construction needed, as also pointed out by Holguin-Veras et al. (2018). Construction involves not only physical barriers to separate exclusive lanes from adjacent general-purpose lanes if that is the case. Even without such barriers, the use of an available lane may require significant improvements to the pavement so that it endures the intense flow of heavy vehicles.

Therefore, it is not surprising that dedicated truck lanes are rare or even nonexistent in the precise meaning that they are reserved only to goods vehicles. Holguin-Veras et al. (2018) illustrates it with the New Jersey stretch of the interstate highway I-95, built from 1950 to 1952 and expanded in 1966 to account for separated flows of cars and trucks in order to reduce congestion. Some segments of the New Jersey Turnpike consist of inner lanes for passenger cars and outer lanes for the remaining vehicles, separated by barriers and in both directions, a configuration referred to as dual-dual. Accident data for dual-dual and mixed traffic segments suggest increased safety for homogeneous flows of vehicles, but further research is required to assess if truck traffic is a factor itself for an increased number of accidents (Lord et al., 2005; FHWA, 2003).

The implementation of time-windows for use of reserved lanes and what vehicles may or may not use them can at different times can make users confused and impose additional challenges to effective enforcement of such initiatives. Thus, signalization and communication are fundamental factors for success, as well as the appropriate design of lanes for a safe interaction among vehicles (BESTUFS, 2007).

Reserved lanes in the context of this research should not be confused with the lane reservation problem either, which is an operational research problem on the best configuration of dedicating lanes in some sections of a roadway to fulfill a required travel time. It is also worth to mention that bicycles and cargo bikes are treated separately in the literature, not being clearly included in the concept of lane management, although the Urban Electric Mobility Initiative (UEMI) by the United Nations indicated that cargo-cycles need to have access to the road network, and bus and bicycle lanes to operate effectively.

In a survey conducted by Dias, Sobanski, et al. (2018) on the implementation of the National Mobility Policy in Brazil, 13% of the 70 respondent municipalities reported the existence of reserved lanes for freight transport. However, the survey did not provide a definition of reserved lanes to respondents, resulting in an open, possibly non-unique interpretation of the questionnaire terms; thus, responses may include the preferential traffic of trucks in the right lanes, keeping the left available for faster vehicles, instead of the dedicated truck lane or no-car lanes concepts previously presented.

2.5.1.2. Improvement of Intersections Geometry

Old parts of cities can be very constrained, with intersections configurations that restrain movement of freight vehicles (ALLEN; THORNE; BROWNE, 2007). Trucks have wider turning radii, so they may be unable to make right turns without hinder oncoming traffic or overrunning sidewalks. Thus, improving intersections geometry relieve traffic limitations. Also, heavy vehicles may also be too high to go under overpasses in historical city zones, among other issues (Holguín-Veras et al., 2018).

It is common to have restrictions for heavy vehicles in such areas of cities, although in some cases it is unavoidable to have large vehicles moving in their neighborhoods. Therefore, geometry improvements in selected intersections can be useful to avoid impacts in traffic and safety, noting that they cannot interfere with elements of historical interest. The redesign of a few chosen intersections, as it is not feasible to modify all of them (Holguín-Veras et al., 2018), can support operation performance of preferred or dedicated routes for freight vehicles. It is important that upgrades and construction of new infrastructure ensure appropriate street geometry for truck maneuvers.

2.5.1.3. Truck Parking and Loading/Unloading

Goods vehicles reportedly have issues finding places to park and carry out unloading operations in crowded urban areas, which sometimes causes drivers to stop on a 2^{nd} parking row. Besides that, the space can be inadequate for freight vehicles, resulting in overruns over sidewalks and roadways (Holguin-Veras et al., 2018). This decreases road capacity, contributing to traffic and increasing risk of accidents. The same issues may also arise in loading operations of small businesses units. Therefore, providing capability in urban zones for freight vehicles to park, load and unload can positively affect commuters, end-consumers, receivers and logistics operators. Benefits for the latter consist in less risk of fines and penalties and time saved in searching for appropriate space to perform tasks (Russo and Comi, 2011).

In this context, Russo and Comi (2011) mentioned loading and unloading zones with the examples of Rome, that had a plan for 700 spots for freight handling in inner city, and Stuttgart, that carried a trial between 2001 and 2003 on dedicated areas for freight operations managed electronically, the MOSCA initiative, as part of BESTUFS project. Russo and Comi (2011) included loading and unloading zones in the subcategory “surface measures” of infrastructure solutions, which refer to areas that can be reserved for freight activities other than vehicles' movement. Lindholm (2013) adopted a similar approach, mentioning parking used for delivery and improved loading zones as infrastructure solutions. Holguin-Veras et al. (2018) proposed a broader category named "parking/loading areas management", with the subgroups "on-street parking and loading" and "off-street parking and loading". This division refers to the fact that loading and unloading zones can be implemented by allocating curbside space to freight vehicles, a solution that Holguín-Veras *et al*. (2018) called *freight parking and loading zones*. An example of this measure exists in London, with the 'loading gaps', painted lines along or on the curb, and the 'loading bays', boxes drawn on the road surface. In fact, management of parking in public space is a widely adopted practice. Many cities have parking meters and limit parking time for personal, service and freight vehicles and may even forbid stopping during peak traffic hours. If and how the parking spots are shared by different types of vehicles varies among and within cities. Holguín-Veras *et al*. (2018) gave specific designations for each of these actions: peak-hour clearways and loading and parking, mentioning vehicle parking reservation systems as a solution for the competing demand for parking spots. According to Russo and Comi (2011), such systems classify as immaterial measures.

The interaction between pedestrians and goods moving from and to the trucks in business districts or retail areas is a point of attention for safety when implementing loading and unloading zones.

Holguin-Veras et al. (2018) proposed the subcategory "off-street parking and loading" to group parking in buildings and other related actions, such as the enactment of building codes requiring freight handling areas for new premises and major renovations, which can be classified as a governance measure according to Russo and Comi (2011); timeshare of parking space, i.e., optimize the schedule of private parking spaces to accommodate different uses; improve parking areas and loading docks so that trucks can maneuver with safety and minimized traffic impact; and truck stops outside of urban zones, where drivers could rest, wait for the scheduled delivery time or to avoid traffic. The scope of such facilities could also involve staging or consolidation. Staging areas are themselves a concept considered an off-street solution by Holguin-Veras et al. (2018), corresponding to spaces where large freight vehicles transfer goods to smaller ones for the final distribution leg. The case of allocating space close to the urban area that generates the freight demand usually receives the name of *nearby delivery area*. In Bordeaux, France, the nearby delivery area or ELP (*espace de livraison de proximité*) consists of spaces for a few trucks and staff available to perform transshipments to smaller, environmental friendly vehicles, that move more easily in the inner downtown and bring the goods to the receiver. This initiative has been considered successful to the point where it has been extended to other cities in France (ALLEN; THORNE; BROWNE, 2007).

2.5.1.4. Ring Roads

Ring roads consist of highway networks around the city to divert truck traffic from inside the urban area. The implementation of this measure is complex and costly, with better results in the cases where traffic crosses the urban area on the travel between origin and destinations located outside the city. Holguin-Veras *et al*. (2018) classified ring roads in a subgroup of major improvements within their infrastructure management category.

2.5.1.5. Urban consolidation centers (UCCs)

UCC are facilities for consolidation of cargo that otherwise would be separately delivered to the same target areas, improving load factors in the last leg of deliveries. Browne et al. (2011) describe the initiative of UCCs in London and Paris as having beneficial effects in traffic and emissions. However, Holguin-Veras et al. (2018) highlight that many UCCs were not financially sustainable without public funding and, therefore, have been closed.

Nomenclature and definitions of UCC and other measures may be conflicting. The BESTUFS report (ALLEN; ANDERSON; BROWNE, 2007) mentions that UCCs can be hard to differentiate from similar schemes such as intermodal terminals and collection points. The report also lists other names for the UCCs, for example co-operative delivery systems, urban distribution centers and even freight village, which is mentioned by Holguin-Veras et al. (2018) as a distinguished measure.

Collection or pickup points and parcel lockers should not be confused with UCCs, as they consist in a different initiative and are found in facilities or stores designed for customers to access and collect their on-line purchased goods. The physical structure can be owned by the retailer or a commercial partner and receives items of multiple customers that choose this option usually due an incentive by the retailer, such as reduced freight price or delivery time. The shipment to this one facility represents a much simpler transport scheme when compared to delivering packages individually in customers' homes.

2.5.2. Immaterial Infrastructure Measures

The category of measures labeled immaterial infrastructure consists of the many deployments of Information and Communication Technologies (ICT) for more efficient transport and handling of goods, more recently known as Intelligent Transport Systems (ITS). The BESTUFS report (ALLEN; ANDERSON; BROWNE, 2007) classifies immaterial measures in two groups, according to the scope of such initiatives:

a) freight transport management systems – vehicle routing and scheduling, slot booking systems, navigation for route guidance and real-time information. Freight operators implement initiatives like routing and route guidance, among others, to optimize their operations;
b) traffic management systems – exemplified by UTMC (Urban Traffic Management and Control) centers like those operating in London, Berlin and Paris, that coordinate traffic signal times and electronic roadside signs and automated access control. ICTs also enable security monitoring and Vertical Height Detection Systems (VHDS) (Holguin-Veras *et al*., 2018). In SPMA, the Traffic Engineering Company (CET in the Portuguese acronym) is the public institution in charge of research for future implementation of UTMC (CET, 2020).

2.5.3. Equipment Measures

Equipment measures comprise more efficient or environmental-friendly vehicles (EFVs) such as truck and forklifts with electrical propulsion, alternative fuels, filters and particulate traps etc. The BESTUFS report (ALLEN; ANDERSON; BROWNE, 2007) points out that electric vehicles are the best suitable option to reduce noise and emissions. Other fuels for EFVs are LPG, hydrogen and biofuels. Biofuels are effective in the reduction of greenhouse gases in a lifecycle perspective; however, it is not for the purpose of reducing externalities from emissions *per se* (unless used with other technologies, like filters), as biodiesel combustion actually results in higher particulate emissions. Smaller vehicles for city deliveries belong to this group (RUSSO and COMI, 2011), as well as cargo-bikes, trolleys and carts; these are applied in the nearby delivery area initiative, in France (ALLEN; ANDERSON; BROWNE, 2007).

In Brazil, national programs fostered the use of renewable fuels since the 1970s for small vehicles. Currently, Law Nº. 11097/2005, regulated by the National Oil, Natural Gas and Biofuels Agency (ANP, in the Portuguese acronym) resolutions, requires commercial diesel fuel to be a blend with 12% of biodiesel. Regulations also impose the use of a product named ARLA 32 to reduce nitrogen oxides (NOx) emissions, therefore new truck models need additional technology. ARLA 32 is not a fuel additive, thereby it has its own storage tank, being employed in the exhaustion treatment system, commonly known as catalyst. Enforcement of the use of ARLA 32 is challenging and many drivers employ “tricks” to avoid using of the product as required (AFEEVAS, 2020).

An equipment measure that is arguably effective according to Holguín-Veras *et al.* (2018) is the use of motorized smaller vehicles, commonly a response from governance measures that restrict truck size. It can result in increased vehicle-miles traveled, thus having a more relevant contribution to congestion. In 1997, São Paulo Municipality Decree No. 37185/97 defined VUCs and VLCs (urban freight vehicle and light freight vehicle, in the Portuguese acronyms), resulting from negotiations between government, vehicle manufacturers and local commerce representatives to address the need for vehicles with appropriated size to access UFT restricted areas. The differentiation between VUCs and VLCs has been revoked, and currently all vehicles up to 7,2 m are designated VUCs.

2.5.4. Governance Measures

Governance in the UFT context consists of the implementation of policies, regulations, and programs to influence or control either UFT or its externalities. It embodies a broad range of approaches: regulations, financial charges and/or incentives and certification and recognition programs to discourage undesired behaviors or foster and award desired ones.

Examples of financial charges are urban tolls, parking pricing and taxation. Usually, they do not render the desired effect, as decision-making in the logistics chain is not really affected (Holguin-Veras *et al.*, 2018). Financial incentives like taxes reduction and low interest funding to foster the use of less pollutant vehicles, for example, have shown effectiveness in France, the UK and the Netherlands. Operational incentives also apply, such as allowing only electric vehicles in some areas or ensuring priority in parking for EFVs, as the practice implemented in Bremen.

Programs to foster anti-idling technologies and driver training for more energy-efficient ways to perform deliveries are considered as a governance measure as well, the latter being a cost-effective approach (Holguin-Veras *et al*., 2018).

However, as pointed out by Lindholm (2012), the most common approach to urban freight by governments is the implementation of regulations: access restraints to specific zones and streets, called ZMRC (Maximum Zone of Restrained Traffic) and VER (Restricted Arterial Roadway) in the Portuguese acronyms commonly used in SPMA; access and delivery time-windows, mentioned previously in the Material Measures section as an auxiliary solution to measures involving infrastructure; maximum truck size and weight; maximum number of trips; minimum load; emissions standards. As highlighted by Dablanc (2007), those measures are cheaper rules with low investment and low maintenance and can be easily revoked if it does not work as expected.

In Brazil, large cities such as São Paulo and Belo Horizonte have implemented restrictions (OLIVEIRA and OLIVEIRA, 2016). In the SPMA, many cities adopt restrictions to truck traffic.

2.6. Measures Evaluation

Endeavors for evaluating and sharing best practices have taken place in Europe and North America, like the BESTUFs (Best Urban Freight Solutions) and CIRRELT (Interuniversity Research Centre on Enterprise Networks, Logistics, and Transportation), among others (Table 3). However, Lindholm (2012) states that “how to evaluate, monitor and assess urban transport measures have been widely researched. Nevertheless, there is little consensus on what the process should look like”.

Table 3 - Initiatives on UFT in Europe.

Category	Initiative Acronym	Initiative Title
Horizon 2020 and related	Horizon 2020	Smart, Green and Integrated Transport
	INEA	Innovation and Networks Executive Agency
	CIVITAS	Cleaner and better transport in cities
	TRIP	Transport Research and Innovation Portal
Other CIVITAS 2020 Urban Freight projects (CIVITAS UF Cluster)	CITYLAB	City Logistics in Living Laboratories
	Novelog	New Cooperative E-Business Models and Guidance for Sustainable City Logistics
	SUCCESS	Sustainable Urban Consolidation CentrES for construction
	U-TURN	Rethinking Urban Transportation through advanced tools and supply chain collaboration
Urban Freight related research projects	ALICE	Alliance for Logistics Innovation through Collaboration in Europe
	BESTFACT	Best Practice Factory for Freight Transport
	BESTUFS II	Best Urban Freight Solutions
	CityHush	Acoustically Green Road Vehicles and City Areas
	CITYLOG	Sustainability and efficiency of city logistics
	C-LIEGE	Clean last mile transport and logistics management
	COFRET	Carbon footprint of freight transport
	CO-GISTICS	Deploying co-operative logistics
	Compass4D	Cooperative Mobility Pilot on Safety and Sustainability Services for Deployment
	DELIVER	Design of Electric Light Vans for Environment-impact Reduction

Category	Initiative Acronym	Initiative Title
Urban Freight related research projects	DISCWISE	Digital Supply Chains for European SMEs based on the Freightwise Framework
	DOROTHY	Urban Logistics Cluster
	FREIGHTWISE	Management Framework for Intelligent Intermodal Transport
	FREILOT	Urban Freight Energy Efficiency Pilot
	FREVUE	Freight Electric Vehicles in Urban Europe
	GRASS	Green and sustainable freight transport systems in cities
	LaMiLo	Last mile logistics
	LogiCon	Low-cost, low-barrier freight data connectivity solutions
	PRO-E-BIKE project	Promoting clean and energy efficient vehicles, electric bicycles and electric scooters
	Smartfusion	Smart Urban Freight Solutions
	SMARTSET	Efficient urban freight transport
	SMILE	SMart green Innovative urban Logistics for Energy Efficient Mediterranean cities
	SOLUTIONS	Sharing Opportunities for Low carbon Urban transporTatION
	STADIUM	Smart Transport Applications Designed for large events with Impacts on Urban Mobility
	STRAIGHTSOL	Strategies and measures for smarter urban freight solutions
	SUGAR	Sustainable Urban Goods logistics Achieved by Regional and local policies
	TELLUS (CIVITAS)	Transport and Environment Alliance for Urban Sustainability
	TRAILBLAZER	Reducing energy use in urban freight transport
	TURBLOG_WW	Transferability of urban logistic concepts and practices from a worldwide perspective
	URBACT (Freight TAILS)	Freight TAILS: Tailored Approaches Implementing Lasting Solutions
	Viajeo Plus	Greening urban mobility
Other relevant institutions and initiatives	EGVI	European Green Vehicles Initiative
	ERTRAC	European Road Transport Research Advisory Council

Source: adapted from NOVELOG (2019).

The evaluation after the implementation of a measure is an *ex-post evaluation*. If studies are performed to estimate effects before implementation, it is called an *ex-ante evaluation*. The latter can be valuable to rate and choose among the alternatives (RUSSO and COMI, 2011). Although, as presented in Table 3, there were many initiatives in Europe regarding UFT, their results were not sistematically evaluated; instead, the reports on projects list many implementations of measures and the perception of results, with highlight to the BESTUFS deliverables, without an established methodology of assessment. In many cases, the project involved pilot initiatives and assessment by stakeholders on the pilot results. The main outcome of these reports is that the decision on continuation or interruption of the pilots and projects is their indicator of success (Holguín-Veras *et al.*, 2018).

Since urban freight involves four major stakeholders: shippers, freight carriers, administrators, and residents (TANIGUCHI, 2014), indicators to be monitored or estimated are also diverse. The main stakes are cost and margin optimization for carriers and shippers, and minimization of emissions, noise or another transport externality for population and government, thus multi-objective optimization techniques are applicable (TANIGUCHI and THOMPSON, 2015).

Taniguchi *et al*. (2001) state that "predicting the impacts of city Logistics initiatives for evaluation purposes requires modelling to be undertaken". CRAINIC; RICCIARDI; STORCHI (2009) clarify that many models proposed for city logistics come from other parts of transportation system planning methodologies, usually well-known and aimed to address passenger transportation in cities and passenger and freight in regional and national levels. The three main components of such models are supply, demand and assignment of flows. Supply modeling aims to represent the transportation infrastructure and services with their operation characteristics and economic, service, and performance measures and criteria; the demand modeling addresses the product definition, producers, shippers, and intermediates identification, production, consumption, and point-to-point distribution volumes, and the mode choice for particular products or origin-destination markets; finally, the assignment focuses on multicommodity flows (from the demand model) to the multimode network (the supply representation) (BENJELLOUN and CRAINIC, 2009). The objective is to simulate the "behavior of the transportation system and its output forms the basis for strategic analysis and planning activities" (CRAINIC; RICCIARDI; STORCHI, 2009).

The systematic literature review by Kin, Verlinde and Macharis (2017) discussed such models, pointing out that the most complete framework for UFT as a system corresponds to the three layers' model of transport, published by Behrends in 2011. It includes a third element in the system, the context, consisting of the physical environment regulated by authorities. Demand for goods result in freight flows that, in their turn, require logistics facilities and infrastructure, all of that happening in a physical environment, the urban area. Stakeholders act and interact within this scenario and each of the components has certain factors influencing it. This system and indicators that describe it are in Table 4.

Table 4 - Holistic framework for the UFT system (KIN; VERLINDE; MACHARIS, 2017).

Component	**Stakeholders**	**Factors**	**Indicators**
Demand	Receivers	Population size and growth	#
			%
		GDP growth	%
		Supply chains	Descriptive
			%
			#
Supply	Transport operators	Logistics facilities	% of land
	Shippers	Vehicles	#
			% (modal split)
			Descriptive
		Efficiency of operations	Descriptive
Context	(Local) authorities	Size	km^2
	Citizens	Density	People/km^2
		Urban form and sprawl	Descriptive
			km
		Infrastructure	Land allocated to streets - %
			Vehicle fleet - per 1000 people
			Congestion level - %
		UFT policy/objectives	Descriptive
		Supportive measures	Descriptive
		Restrictive measures	Descriptive

Source: adapted from Kin, Verlinde and Macharis (2017).

There are numerous variables involved in modelling urban freight systems, and the input data is not available in many cases, due to confidentiality of freight operators and lack of collection schemes, for example. Besides that, simulation results are difficult to validate due to the same unavailability of data (TANIGUCHI *et al*., 2001 and LINDHOLM, 2012). The increasing access to tracking systems and technology to monitor, store and handle large amounts of data can enable that more analyses are performed in the future.

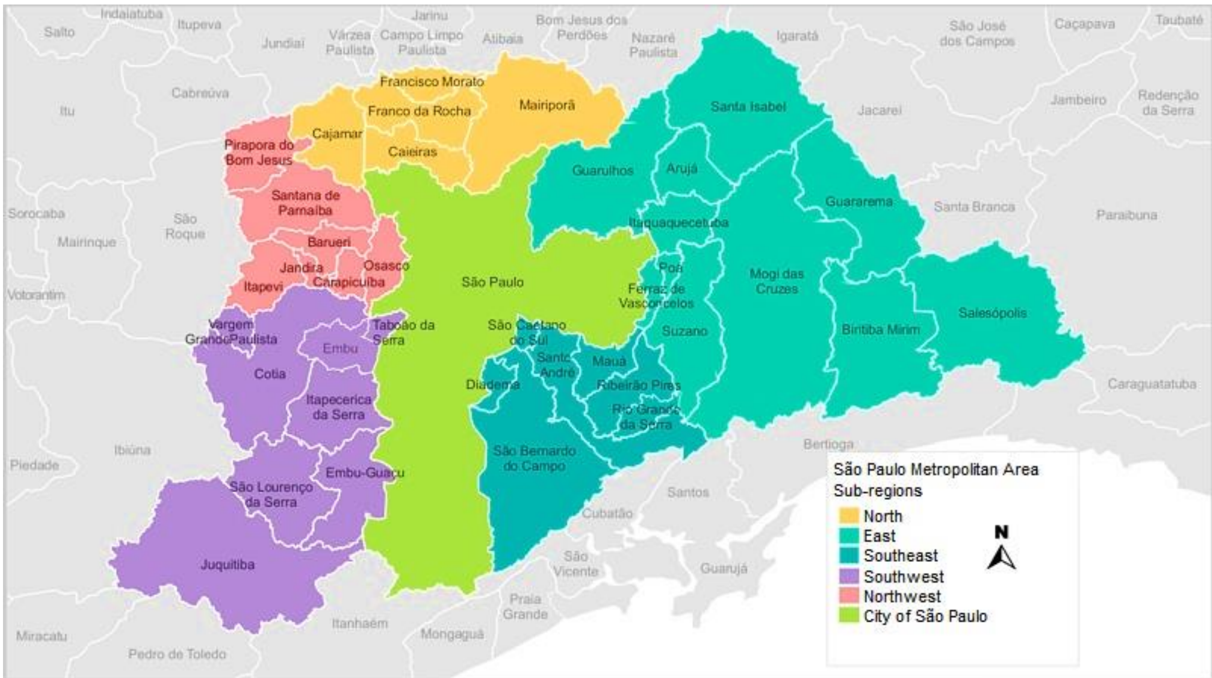
A distinct approach feasible for ex-post evaluation if data is available is the employment of econometrics. Usually, large datasets are needed, since many factors can affect a given phenomenon. As an example, we take the fact the congestion is correlated to fleet size, however we also observe more congestion in rainy days than in clear ones. Thus, to assess the impact of fleet growth in traffic, it would be necessary to have changes only in fleet growth while climatic conditions are kept the same. In real life, it is hard to make such experiments, and thus a large dataset that can account for other effects on the desired system is needed. Econometrics provides the ground and tools to assess the probability that the studied variables affect the studied outcome. HE, GOUVEIA and SALVO (2018) published an analysis of a quasi-experimental scenario that occurred with the inauguration of the São Paulo beltway, comparing health, pollution and congestion data prior to and after the decrease of truck traffic in a road that crosses the city.

3. SÃO PAULO METROPOLITAN AREA

3.1. Political Aspects

The São Paulo Metropolitan Area has been established by Complementary Federal Law Nº. 14 of 1973 and subordinate Complementary State Law Nº. 94 of 1974. In 2011, Complementary State Law Nº. 1139 reorganized the 39 municipalities of SPMA in five subregions, as presented in Figure 1. The creation of agencies with jurisdiction on the region aims to foster integrated planning in the region level in fields such as socioeconomical development, increased well-being, environmental protection, integrated planning and execution of public services and reduction of social and regional inequalities.

Figure 1 - Legal Division of SPMA.



Source: EMPLASA, 2019.

The settlement in São Paulo developed from religious communities established in the sixteenth century. The village evolved into a trading post alongside Brazilian sugar, gold and coffee economic cycles, as it became part of commercial routes – from the south to the gold mines and northeast of the country and from countryside to the Santos port. Another factor of relevance for the development of the region is the Tietê

River, that runs towards the countryside instead of the sea and, thus, allowed exploration of Brazil's inner lands. The construction of São Paulo Railway in the nineteenth century (for improved coffee exportation logistics) and the efforts to organize trade infrastructure in the first half of the 1900's consolidated the commercial tradition of the region. The development of industries in the area, notably promoted from the 1950s on, transformed São Paulo into the most important city of the country.

3.2. Economic and Sociodemographic Aspects

The São Paulo Metropolitan Area is in the State of São Paulo, in the Southeast of Brazil's territory. The population of the state in 2019 was estimated in 44.3 million people, which corresponds to 20% of Brazil's population, living in an area of 248,219.94 km², or 3% of the country's territory. The city of São Paulo is the capital of the state. Dwellers of the city alone correspond to 10% of national population and almost half of the state's inhabitants' number, turning it into one of the most relevant consumption markets in Brazil.

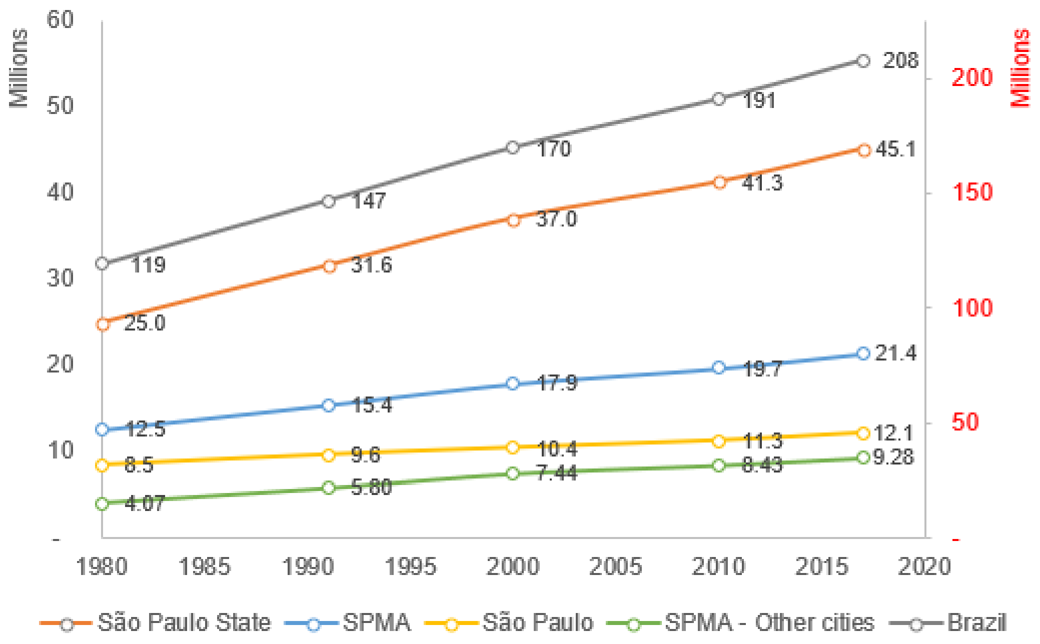
In 2017, SPMR contributed with 17% of Brazil's gross domestic product (SEADE, 2019). Although having the highest GDP in the country, in 30% of SPMR households the income per capita is below half Brazil's minimum wage. This amount corresponds to less than U$ 150 per month (exchange rate in 2010, year of the survey).

The city of São Paulo is considered the economic core of the country; the only stock exchange in Brazil is in São Paulo and many multinational companies and institutions in the sectors of industry and services have offices in the city. The state has an expressive industry. In the SPMA, manufacturing facilities are located mostly in the southeast sub-region, Guarulhos and Osasco. Although there still is relevant industrial activity in the city of São Paulo, its industrialization degree has decreased due to the urban expansion and many facilities moved to other locations in the state.

3.2.1. *SPMA Population and Territory*

In 2019, the population of the SPMA was estimated in almost 21 million people (SEADE, 2020). São Paulo, the core city, covers 19% of the SPMA territory and holds approximately 56% of its dwellers, as it is shown in Figure 2.

Figure 2 - Population according to census and estimations.



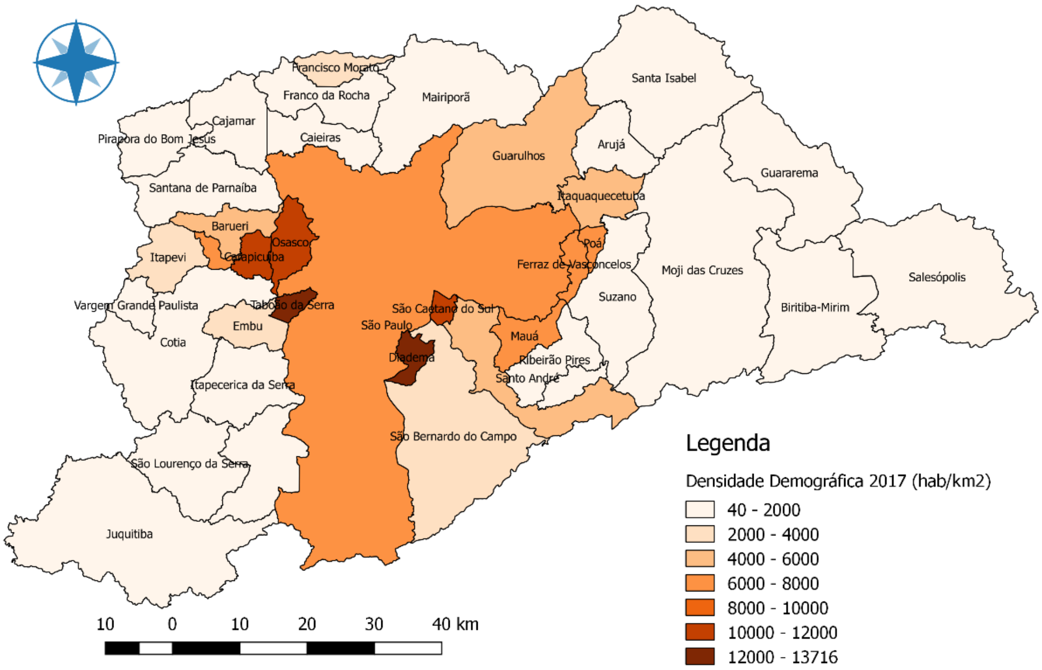
Source: SEADE, 2020.

Figure 2 shows that the population growth rate, provided by the curve slope, is higher for the state and country since the 1980s. From 1991 to 2000, other cities of SPMA had a total growth rate of 3.2% per year, in opposition to the 0.9% observed in São Paulo. In fact, for the whole period to which data is available (1980-2017), the other cities in SPMA had a more expressive population growth rate than the core city, although in the time range 2010-2017 it slowed down to similar rates – 1.1% per year fort the set of remaining cities and 1.4% per year for São Paulo.

Figure 2 curves shows that the population in other cities grew faster until the 2000s than the number of São Paulo's inhabitants. This demographic movement towards other cities of SPMA is consistent with the globally observed phenomena of urban sprawling, supported in its turn by improved access to the core city, changes in urban mobility, economic incentives, high cost of land and real estate in urban centers, search for increased well-being outside the main city due to pollution and traffic.

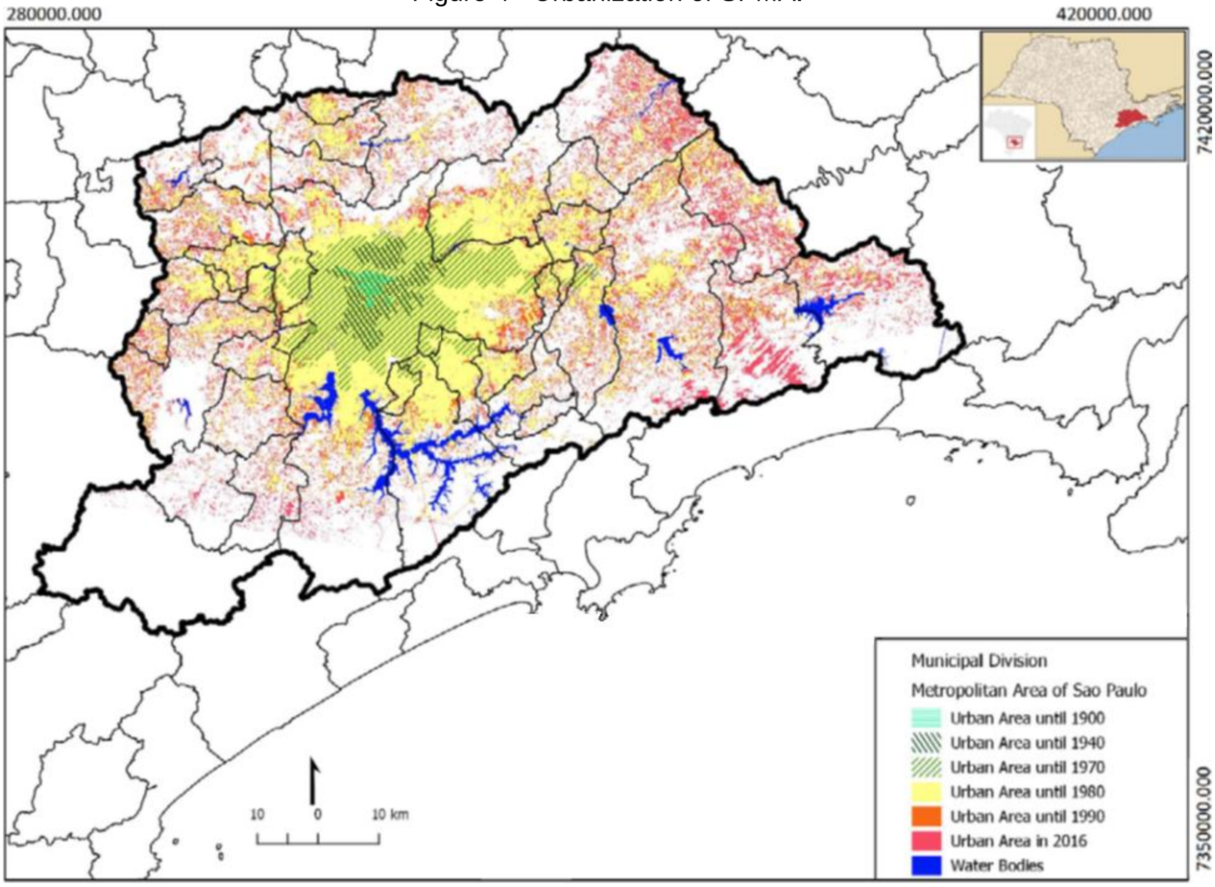
Considering the demographic density of the municipalities, São Paulo presents values above 7.7 thousand people per km², however other cities such as Taboão da Serra, Diadema, Carapicuíba, Osasco and São Caetano do Sul have larger values. All these municipalities are bordering São Paulo, except for Carapicuíba, and all of them have small territories. Figure 3 presents the average demographic density per city in SPMA, and Figure 4 shows the evolution of the São Paulo city urban area, evidencing that its occupation is heterogeneous with smaller densities in the south of the capital.

Figure 3 - SPMA demographic density per city.



Source: Guerin, 2019.

Figure 4 - Urbanization of SPMA.



Source: edited by the author from LIMA and RUEDA, 2018.

3.2.2. Fleet

SPMA population grew around 30% in 20 years (UN, 2018) and the number of cars increased from 5.8 million in 2007 to 8.6 million in 2017, which represents a 48% expansion. Average daily time spent on transportation is 1.4 hours, with 46% of people using mostly private transport.

In December 2017, the total number of registered vehicles of all types in the SPMA was 28,138,698, considering everything from motorcycles to trucks. The total number of vehicles in Brazil is 97,091,956, that is, the SPMA owns 13% of all vehicles in Brazil (Denatran, 2020). However, when looking at the evolution of the numbers over the years, the SPMA has been reducing its participation in the total numbers, as Table 5 shows.

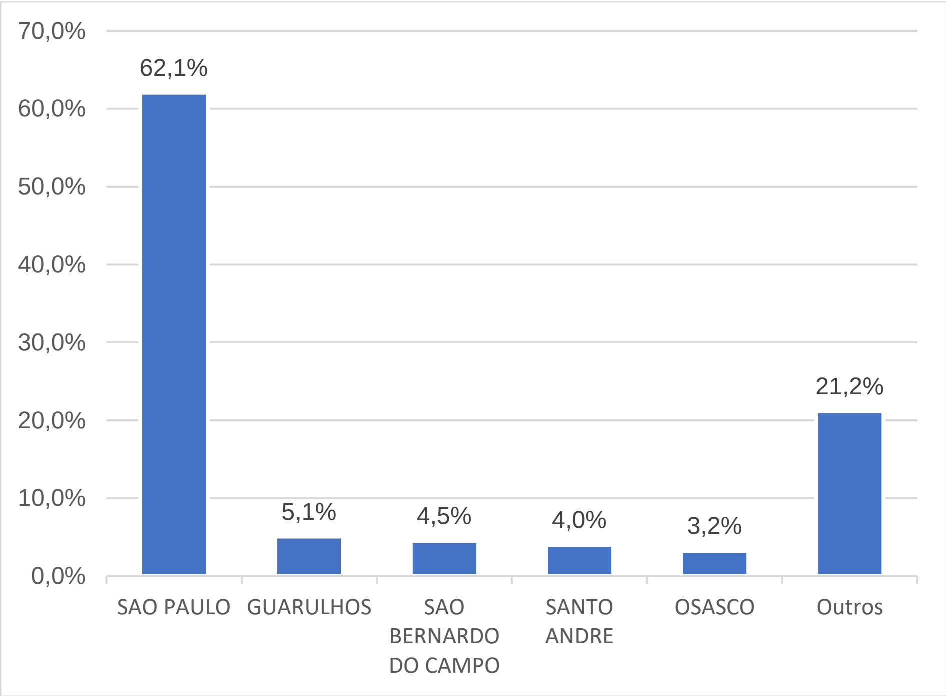
Table 5 - São Paulo State and SPMA fleets and national fleet share.

Location	2001		2010		2017	
Brasil	31.912.829	100%	4.817.974	100%	97.091.956	100%
São Paulo State	11.348.349	36%	20.537.980	32%	28.138.698	29%
SPMA	5.687.084	18%	9.787.712	15%	12.949.812	13%

Source: SEADE, 2020.

Detailed data shows that most vehicles are registered in the city *of* São Paulo (Figure 5).

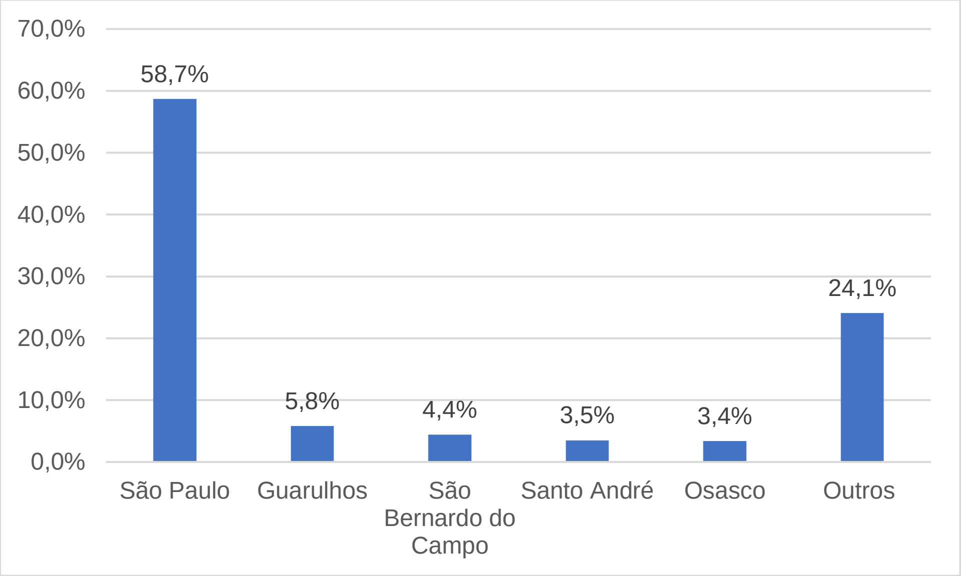
Figure 5 - Municipalities share in SPMA fleet.



Source: SEADE, 2020.

Considering vehicles that are related to logistics, e.g., trucks (over 3,500kg) and vans (below 3,500kg), the representativeness of the SPMA in Brazil's fleet is much smaller. In December 2017, the SPMA dwellers owned 9.5% of the truck fleet and 10.8% of all vans in Brazil. In relation to trucks, the city of São Paulo holds 50.42% of the entire fleet of trucks in the SPMA. Guarulhos is the second municipality with 8.09%, followed by São Bernardo do Campo with 4.3%. Regarding vans, the municipality of São Paulo has 61.4% of the fleet, followed by Guarulhos with 5.1% and São Bernardo do Campo with 4.3%. This concentration of pickup trucks in São Paulo is possibly due to city traffic restrictions to trucks (SEADE, 2020). The representativeness of each municipality considering the sum of trucks and vans is detailed in Figure 6.

Figure 6 - Trucks and vans fleet in SPMA cities.

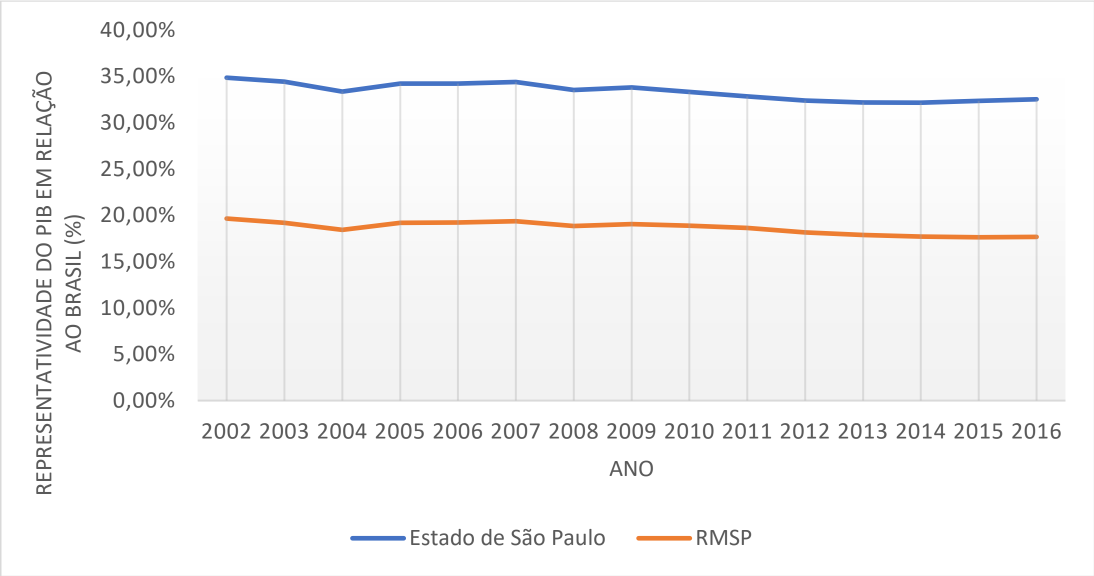


Source: Denatran, 2018

3.2.3. SPMA Gross Domestic Product

The values of Gross Domestic Product (GDP) by municipalities are at current prices, considering the three sectors of the economy: agriculture, industry and services, in addition to public administration and taxes. It should be noted that IBGE changed its calculation methodology as of 2010. Thus, for the years prior to 2010, data extrapolation was carried out, adapted to CNAE 2.0 (IBGE, 2020). São Paulo and SPMA share of GDP are shown in Figure 7.

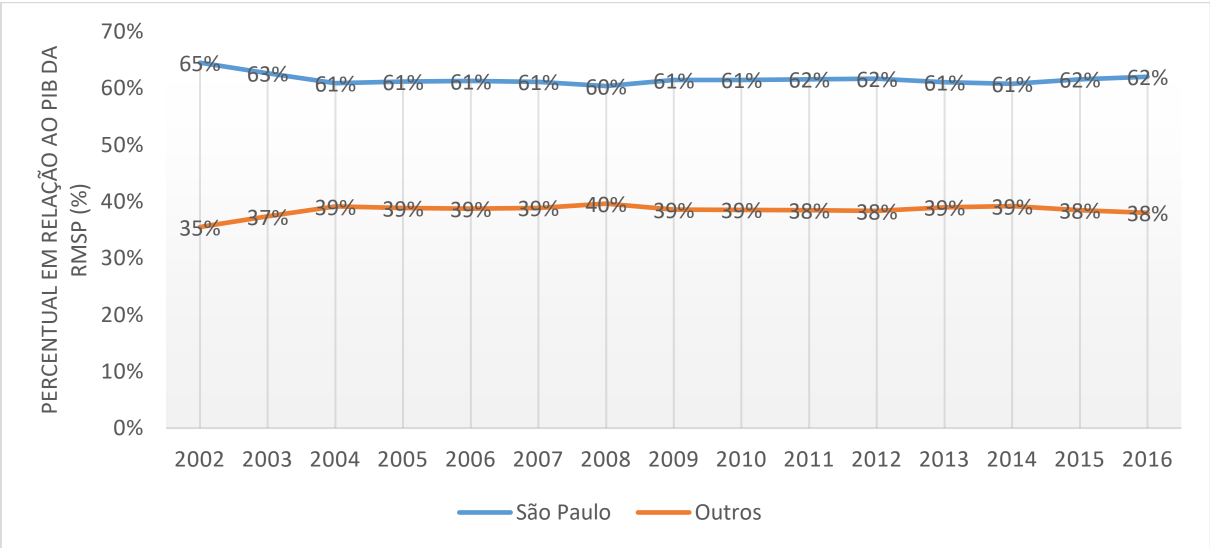
Figure 7 - São Paulo state and SPMA share of national GDP.



Source: IBGE, 2020.

When analyzing the SPMA, in 2016 the city of São Paulo concentrated a large share of the region's GDP, representing 62% of it, with the remaining municipalities representing 38%. Figure 8 reveals that the participation of the city of São Paulo fell sharply from 2002 to 2004 and since then the relationship between GDPs has remained stable, with a slight increase in the last two years of analysis.

Figure 8 - SPMA GDP distribution between main city and surroundings.



Source: IBGE,2019

Osasco, Barueri, Cajamar and Itapevi, located to the West of São Paulo, improved their share of SPMA’s GDP between 2002 and 2016, as shown in Table 6. On the other hand, municipalities located in the called ABC region, such as Santo André, São Bernardo do Campo, São Caetano do Sul, Diadema and Mauá had a reduction in the share of the SPMA's GDP, with a drop in the position of the municipalities. In the eastern region of SPMA, the highlights are Mogi das Cruzes, Arujá and Itaquaquecetuba, that also jumped positions in the ranking. Finally, Guarulhos, the second municipality in population of the SPMA, maintained its position in the ranking and the percentage in relation to the GDP of the SPMA increased.

Table 6 - GDP share of SPMA cities.

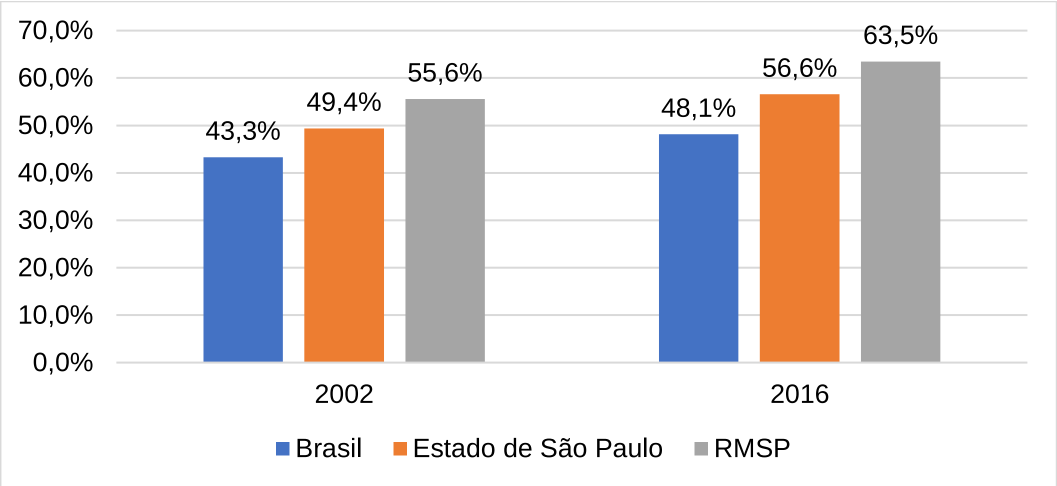
City	2016 GDP share	2002 GDP share	2016 Ranking	2002 Ranking	Ranking Change
São Paulo	62,0%	64,5%	1	1	0
Osasco	6,7%	4,2%	2	4	2
Guarulhos	4,9%	4,3%	3	3	0
Barueri	4,3%	3,8%	4	5	1
São Bernardo do Campo	3,8%	5,2%	5	2	-3
Santo André	2,3%	2,9%	6	6	0
Mogi das Cruzes	1,3%	1,2%	7	10	3
Mauá	1,3%	1,3%	8	9	1
São Caetano do Sul	1,2%	2,2%	9	7	-2
Diadema	1,2%	1,5%	10	8	-2
Cajamar	1,2%	0,6%	11	15	4
Suzano	1,1%	0,4%	12	20	8
Embu das Artes	1,0%	0,8%	13	12	-1
Cotia	0,9%	0,4%	14	17	3
Itapevi	0,9%	1,1%	15	11	-4
Santana de Parnaíba	0,8%	0,6%	16	16	0
Taboão da Serra	0,8%	0,7%	17	14	-3
Itaquaquecetuba	0,6%	0,4%	18	19	1
Carapicuíba	0,5%	0,4%	19	18	-1
Arujá	0,4%	0,2%	20	26	6
Poá	0,4%	0,8%	21	13	-8
Itapecerica da Serra	0,3%	0,3%	22	22	0
Jandira	0,3%	0,3%	23	21	-2
Franco da Rocha	0,3%	0,2%	24	23	-1
Caieiras	0,3%	0,2%	25	27	2
Ferraz de Vasconcelos	0,2%	0,2%	26	24	-2
Ribeirão Pires	0,2%	0,2%	27	25	-2
Vargem Grande Paulista	0,2%	0,1%	28	31	3
Santa Isabel	0,1%	0,1%	29	28	-1
Francisco Morato	0,1%	0,1%	30	29	-1

Guararema	0,1%	0,1%	31	32	1
Mairiporã	0,1%	0,1%	32	30	-2
Embu-Guaçu	0,1%	0,1%	33	33	0
Biritiba-Mirim	0,1%	0,1%	34	35	1
Rio Grande da Serra	0,1%	0,0%	35	37	2
Juquitiba	0,0%	0,1%	36	34	-2
Pirapora do Bom Jesus	0,0%	0,0%	37	39	2
São Lourenço da Serra	0,0%	0,0%	38	38	0
Salesópolis	0,0%	0,1%	39	36	-3

Source: IBGE, 2019

Companies that exclusively carry out logistics activities, such as storage, transportation, loading and unloading, among others, belong to the services category, although there are industries that carry out logistics services. To determine the GDP in the service sector, we exclude public services such as administration, defense, education, public health and social security, obtaining the results in Figure 9.

Figure 9 - Service sector GDP share in total GDP.

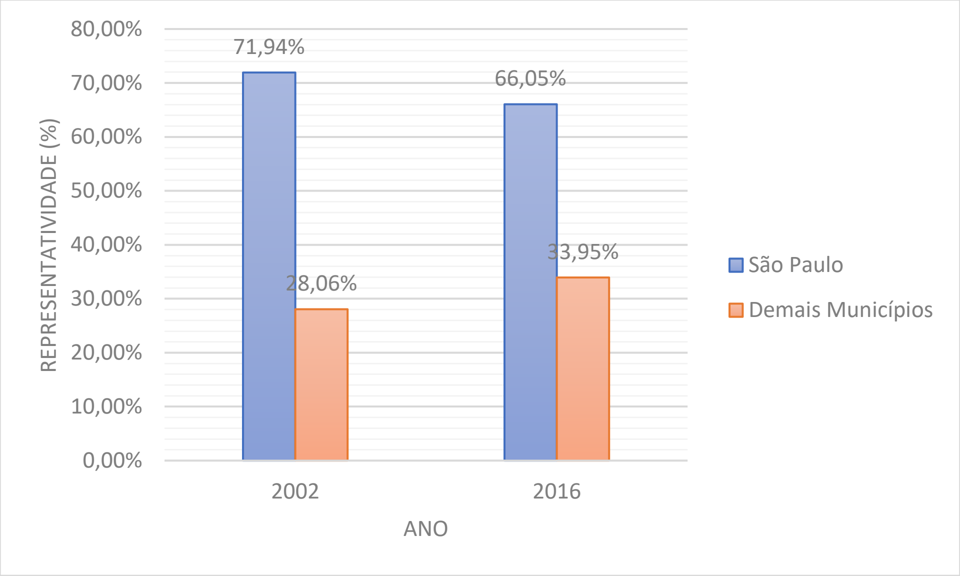


Source: IBGE (2020)

The participation of the services sector in the Brazilian economic activity was around 48% in 2016. In the State of São Paulo and in the SPMA it is even larger, as the GDP of services represents 55.6% and 63.5% respectively.

In SPMA, 66% of the services GDP was generated by the city of São Paulo. However, the contribution of the other cities increased between 2002 and 2016 towards a de-concentration (Figure 10).

Figure 10 – Services sector GDP share of core city.



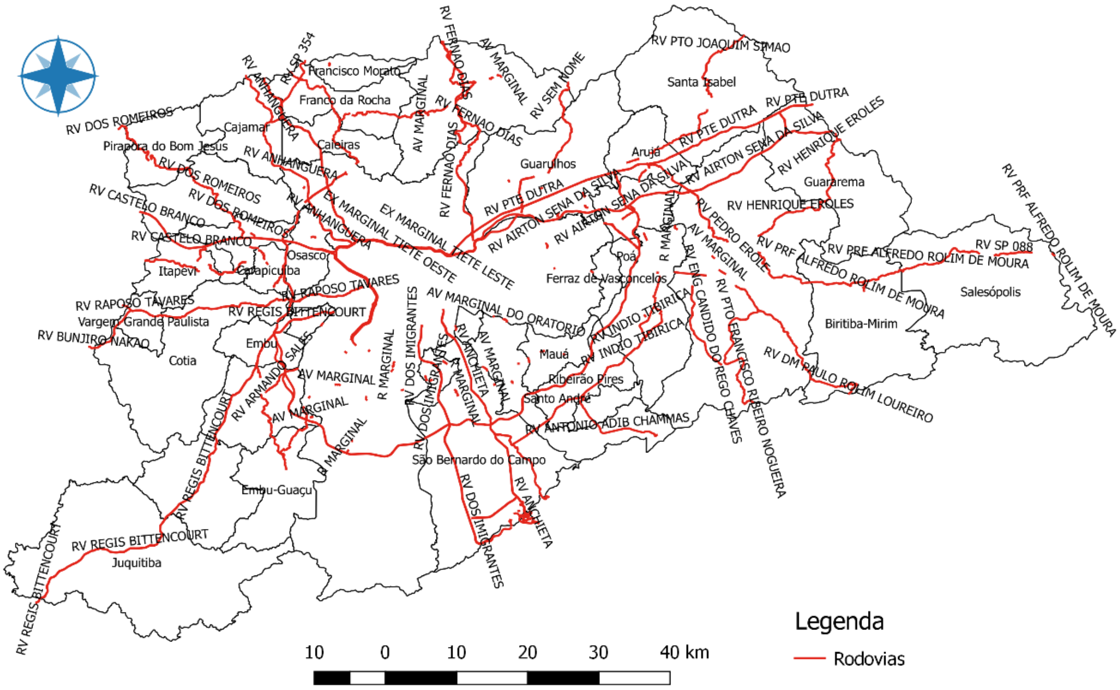
Source: IBGE (2020)

3.3. SPMA Logistic Infrastructure

3.3.1. Road Network

The road network of the SPMA is quite abundant and the 39 municipalities are integrated through it by federal and state highways of different sizes (duplicated or simple lanes) and types (federal or axis, according to the classification of the DER-SP), totaling 2 federal highways and 38 highways or stretches of state highways that cross SPMA cities, not considering interchanges and marginal roads. However, when considering the degree of importance of the highways, this number can be reduced to ten main highways in the region, in addition to the Rodoanel Mário Covas, totaling eleven roads. The road network is detailed in Figure 11.

Figure 11 - SPMA roads and highways, São Paulo main roadways (Marginal Pinheiro and Marginal Tietê), and Rodoanel (ring road).



Source: Guerin, 2019.

The flow of the main 10 freeways converges to São Paulo. To change the configuration from axial to annular, São Paulo State administration planned the Rodoanel Mário Covas (SP-021), or simply ‘Rodoanel’, a beltway around the city of São Paulo that crosses several cities in the metropolitan region. It is divided into four sections, three in operation, the West Section (since 2002), the South Section (since 2010), the East Section (since 2015) and the North Section, which is under construction. When completed, it will have 176.5 km and will connect the ten highways that lead to São Paulo (Government of São Paulo, 2018).

The ten main highways connecting the city of São Paulo with other regions of the state and with other states in the country can be grouped according to the classification of stretches of the Ring Road. In the west section, there are five highways: Rodovia dos Bandeirantes (SP-348) leads to the northwest region of the State of São Paulo and passes through important cities like Campinas and Jundiaí. The Anhanguera highway (SP-330) also leads to the northwest of the State of São Paulo and is parallel in its initial part of the route with the Rodovia dos Bandeirantes, in addition to also crossing important cities such as Jundiaí, Campinas and Ribeirão Preto. Both highways have access to Viracopos airport, which is an important air cargo and passenger terminal, located in the region of Campinas. The Castello Branco highway (SP-280) leads west of the State of São Paulo and crosses important cities such as Osasco, Barueri, Itu and Sorocaba. The Raposo Tavares (SP-270) highway, crossing cities such as Cotia, Sorocaba, Itapetininga, Ourinhos, Assis and Presidente Prudente, represents an important access to the extreme west of the state, being route to the city Campo Grande, capital of the State of Mato Grosso do Sul. The Regis Bittencourt Highway (BR-116) is the main highway that connects São Paulo to the south of the country, to the states of Paraná, Santa Catarina and Rio Grande do Sul. Within the State of São Paulo, it crosses important cities such as Taboão da Serra, Embu das Artes, Itapecerica da Serra and Registro.

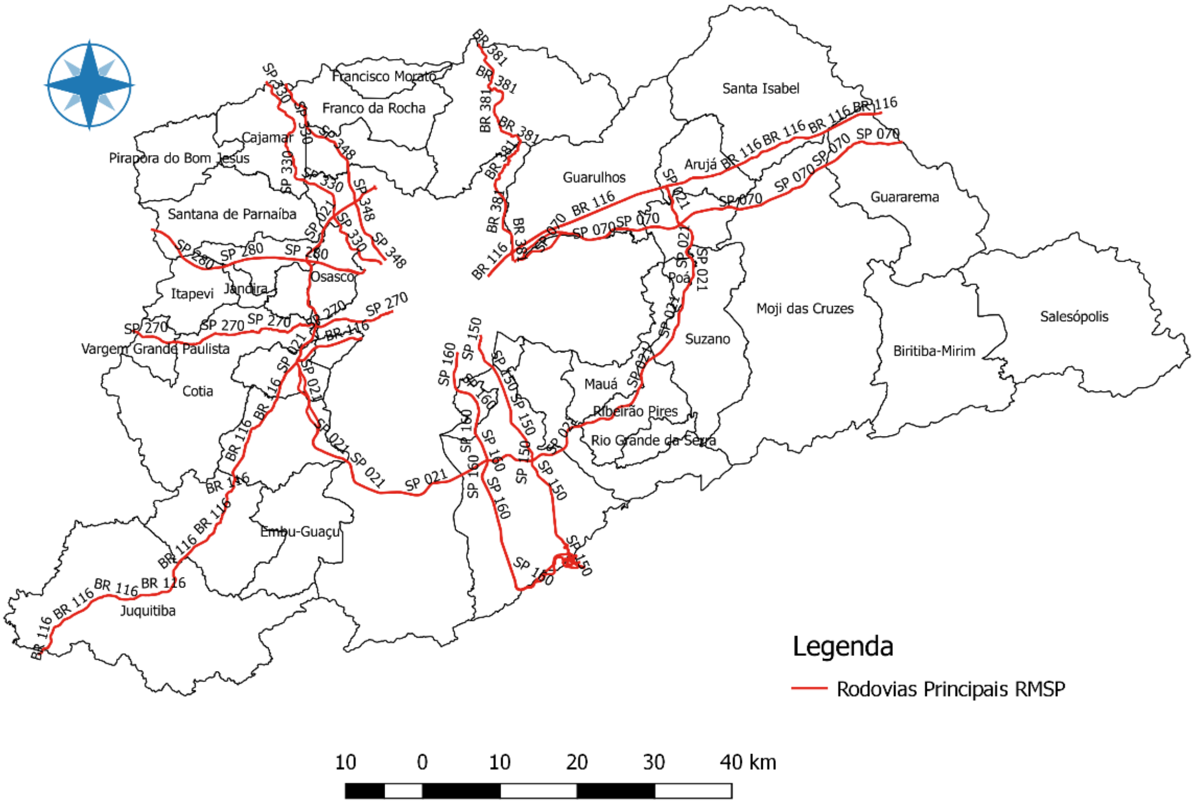
The South Section has two main highways. The first one is Anchieta (SP-150), connecting São Paulo to Santos, passing through São Bernardo do Campo and Cubatão. The Imigrantes Highway (SP-160) passes through cities such as São Bernardo do Campo, Cubatão and São Vicente. Both highways connect the capital of São Paulo to the coast, being the main access routes to the Port of Santos.

The Eastern Section also has two main highways. The Presidente Dutra Highway (BR-116) connects São Paulo to Rio de Janeiro, passing through Guarulhos, São José dos Campos. The Ayrton Senna Highway (SP-070) runs to the Paraíba Valley and is parallel to the Presidente Dutra Highway, with some access to it along the route. In addition, the Ayrton Senna Highway passes through important cities such as Guarulhos, Mogi das Cruzes and São José do Campos. Both highways are routes to Guarulhos International Airport, the main international passenger terminal. This road system leads to the Paraíba Valley, to the north coast of the São Paulo coast and to Rio de Janeiro, the second largest metropolitan area in Brazil.

Finally, the northern section has only the Fernão Dias highway (BR-381) that leads to the capital of Minas Gerais, Belo Horizonte. This highway is connected to the Presidente Dutra Highway (BR - 116).

Figure 12 shows the location of these highways and Table 7 summarizes the origin, destination and extent within the state of São Paulo.

Figure 12 - Main freeways.



Source: Guerin, 2019.

Table 7 - Main SPMA highways

Highway	Code	Origin	Destination	Length (km)
Rodovia dos Bandeirantes	SP - 348	São Paulo	Cordeirópolis	158,64
Rodovia Anhanguera	SP - 050	São Paulo	Igarapava	438,75
Rodovia Pres. Castello Branco	SP - 280	São Paulo	Santa Cruz do Rio Pardo	301,33
Rodovia Raposo Tavares	SP - 270	São Paulo	Presidente Epitácio	644,93
Rodovia Regis Bittencourt[1]	BR - 116	Taboão da Serra	Barra do Turvo	299,7
Rodovia dos Imigrantes	SP - 160	São Paulo	Praia Grande	58,54
Rodovia Anchieta	SP - 150	São Paulo	Santos	55,9
Rodovia Ayrton Senna	SP - 070	São Paulo	Taubaté	119,21
Rodovia Presidente Dutra[2]	BR - 116	São Paulo	Queluz	236,11
Rodovia Fernão Dias	BR - 381	São Paulo	Vargem	95,2

Source: DER - SP, 2018.

[1] Considering only the stretch under concession of Autopista Regis Bittencourt, with the final limit being the border between the State of São Paulo and Paraná;
[2] Considering only the stretch from São Paulo to Queluz, the limit of the State of São Paulo with Rio de Janeiro, under the administration of Nova Dutra.

Table 8 shows the number of kilometers of highway per municipality. It contains federal, state highways, interconnections between highways, marginal roads and accesses to highways.

Table 8 - Road mileage per municipality.

City	Mileage (km)	City	Mileage (km)	City	Mileage (km)
Arujá	28.65	Guararema	42.87	Poá	7.31
Barueri	30.65	Guarulhos	56.07	Ribeirão Pires	48.41
Biritiba Mirim	41.56	Igaratá	3.25	Rio Grande da Serra	4.0
Caieiras	20.78	Itapecerica da Serra	52.62	Salesópolis	31.19
Cajamar	22.76	Itapevi	26.59	Santa Isabel	44.68
Carapicuíba	8.9	Itaquaquecetuba	37.31	Santana de Parnaíba	19.01
Cotia	36.05	Jandira	7.91	Santo André	16.11
Diadema	17.8	Juquitiba	40.04	São Bernardo do Campo	124.36
Embu das Artes	17.09	Mairiporã	43.11	São Lourenço da Serra	18.13
Embu-Guaçu	39.84	Mauá	5.72	São Paulo	497.47
Francisco Morato	1.7	Mogi das Cruzes	144.58	Suzano	48.69
Ferraz de Vasconcelos	-	Osasco	38.53	Taboão da Serra	6.6
Franco da Rocha	34.78	Pirapora do Bom Jesus	19.21	Vargem Grande Paulista	15.45

Source: DER-SP (2020)

3.3.2. Airports

There are three airports in the São Paulo metropolitan area. Guarulhos International Airport (GRU), Congonhas Airport (CGH) and Campo de Marte Airport (MAE).

Guarulhos Airport, opened in 1985, is the only one operated by a private company, formed by a consortium of Invepar and ACSA. The airport is considered an international hub for Latin America, with 3 passenger terminals (GRU, 2018). The passenger flow in 2017 was 39 million (GRU, 2017). It is worth mentioning that there is an important logistics structure with cargo terminals and warehouses inside the airport, which is located in the city of Guarulhos, close to the Presidente Dutra and Ayrton Senna highways, being connected to them by the Hélio Smidt highway (SP-019).

Congonhas Airport, also known as Deputado Freitas Nobre Airport, is managed by Infraero and had its first flight in 1936. This airport is in a densely populated region in the southern region of the city of São Paulo, on Avenida Washington Luís, 8.7 km from the center and has the highest business traffic (Infraero, 2018). In 2017, more than 21 million passengers and 50 thousand tons of cargo passed through the airport (Infraero, 2017).

Campo de Marte Airport is the first in São Paulo, opened in 1929, but is now used only for business jets and helicopters. It is in the northern part of the city of São Paulo, close to the Tietê Bus Terminal and the Marginal do Tietê, which is an important access route to the Presidente Dutra, Ayrton Senna, Fernão Dias, Castello Branco, Anhanguera and Bandeirantes Highways and is managed by Infraero (Infraero, 2018a). The total number of passengers was 118,984 and had 69,137 flights in 2017 (Infraero, 2017). These numbers make it the smallest of the three airports (Table 9).

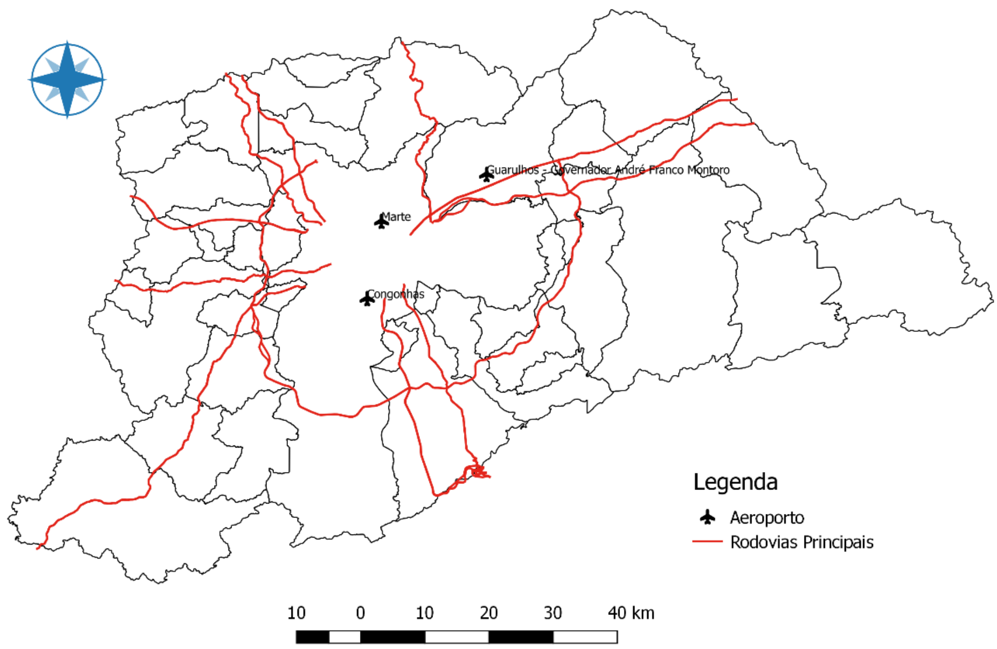
Table 9 - Dados sobre os aeroportos da SPMA

Airport	Opening	Location	Passengers (2017)	Cargo - ton (2017)
Aeroporto de Guarulhos	1985	Guarulhos	37.744.000	479.340
Aeroporto de Congonhas	1936	São Paulo	21.859.453	50.253
Aeroporto Campo de Marte	1929	São Paulo	118.984	0

Sources: (GRU, 2017; GRUCARGO, 2017; GRU, 2018; Infraero, 2017; Infraero, 2018; Infraero, 2018a).

Figure 13 highlights the highways connecting the airports with other regions.

Figure 13 - Freeways connecting airport.



Source: Guerin (2019).

Guarulhos Airport is the most used for cargo, having a volume 10-fold higher than Congonhas Airport.

Although the Viracopos Airport (VCP) is located outside the SPMA, just over 90 kilometers from the center of the São Paulo capital, it might influence some companies to install themselves on the main access roads to it. Viracopos Airport is located in Campinas and is an important passenger and cargo terminal, having transported 204,311 tons of goods in 2017, including post offices, that is, slightly less than half of what is transported by Guarulhos airport. Regarding the number of passengers, the number was 9,332,631 (Viracopos, 2017). To access this airport from the SPMA, the Anhanguera and Bandeirantes highways must be used.

3.3.3. Rail Network

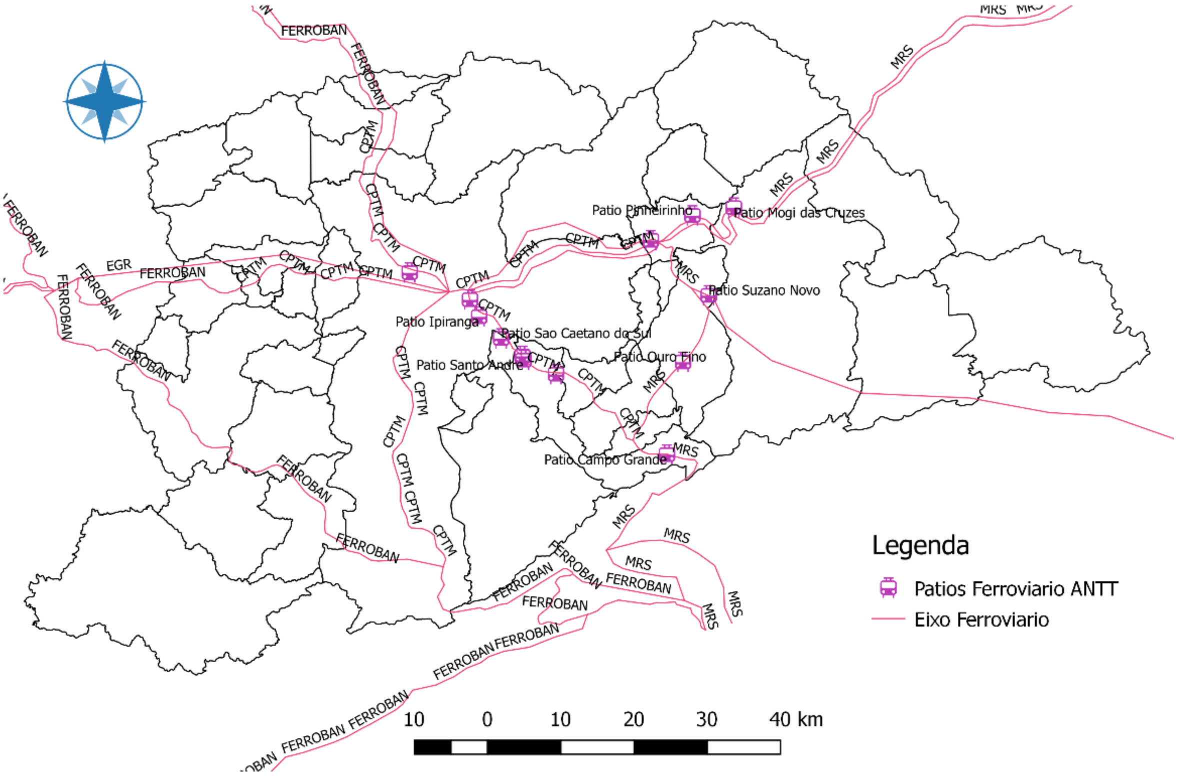
In the State of São Paulo, the freight rail network is operated by three private companies. The first of these is the FCA (*Ferrovia Centro-Atlântica* or Centro-Atlântica Railway*)* whose Central-East corridor encompasses the interior of São Paulo, in the northwest region of the state. This stretch is integrated with the states of Minas Gerais, Goiás and the Federal District, and integrates with Rumo to have access to the Port of Santos. The main products being transported are sugar, soy, corn, phosphate, sulfur and fertilizers (VLI, 2017).

Rumo is one of the companies that has a rail network through the southwest part of SPMA, however, it does not have terminals installed in the region. The main products transported are ethanol, fertilizers, corn, wheat, soybeans, bran, vegetable oil, sugar and industrialized products (RUMO, 2018; RUMO, 2018a). The Rumo network that passes through the SPMA is also known as the São Paulo network (RMP) and connects the cities of Santa Fé do Sul, Colômbia and Panorama to the Port of Santos, enabling the flow of production from the states of Mato Grosso and Mato Grosso do Sul (RUMO, 2018a)

The MRS network connects Jundiaí with SPMA, Vale do Paraíba, Rio de Janeiro and Minas Gerais. The company also has cargo terminals in the Metropolitan Region of São Paulo in Itaquaquecetuba (TMI Tora), Mogi das Cruzes (TINAGA), Água Branca - São Paulo (Transnovag), Santo André (AB Terminais) and two units in Suzano (CRAGEA, TMS TORA) (RMS, 2018). The length of the MRS railway is 1,643km and connects with five of the largest ports in the country, like Rio de Janeiro, Itaguaí, Sapetiba and Santos (RMS, 2018a). The railway network around São Paulo is in Figure 14.

Furthermore, for the use of the railways, it is necessary to have cargo terminals, so that the logistics companies can dispatch or receive their goods, showing the need for a more detailed survey of these yards and terminals in the metropolitan region of São Paulo. Most of the products transported are raw materials, such as sand, grains, steel products and cement, whose transport is directed to the processing industries or to the foreign market.

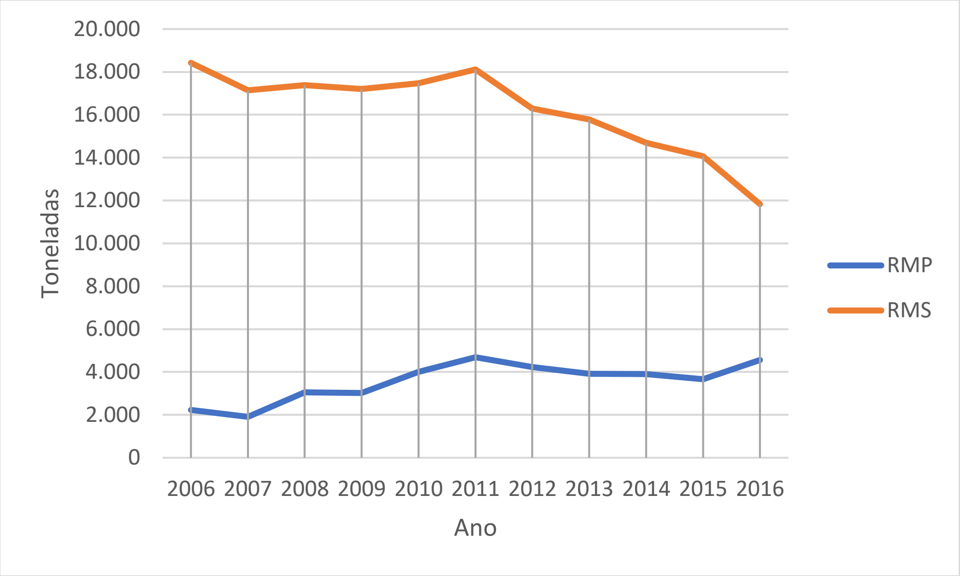
Figure 14- SPMA Railways.



Source: Guerín (2019).

The use of the railroads has been decreasing over the years, as shown in Figure 15, when adding the volume of the concessionaires MRS and Rumo Malha Paulista (MRP) between 2006 to 2016. It can be noted that MRS has a consistent decrease in volume, while RMP is in a slight upward trend.

Figure 15 - Railway cargo transportation between 2006 and 2016.



Source: Guerín (2019).

Finally, there is an ongoing change in the SPMA's railway structure. Ferroanel is a future project that consists of the construction of a railway ring around the SPMA, with two sections in its project. The Ferroanel Norte will be 53km long and will interconnect the Perus station, in the West Zone of the city of São Paulo, with the Manuel Feio station, in Itaquaquecetuba. The main objective is to have dedicated rails to cargo trains that currently share the passenger railway of the Companhia Paulista de Trens Metropolitanos (CPTM). The second objective is to transfer the demand for trucks to rail transport. São Paulo government estimates that the Ferroanel Norte project could remove around 7,000 trucks from São Paulo. There are other benefits arising from those mentioned above, such as reducing pollutant emissions, improving passenger transport on trains, reducing traffic on SPMA and reducing the final cost of products. As of 2021, the project is on the environmental licensing phase (DERSA, 2018).

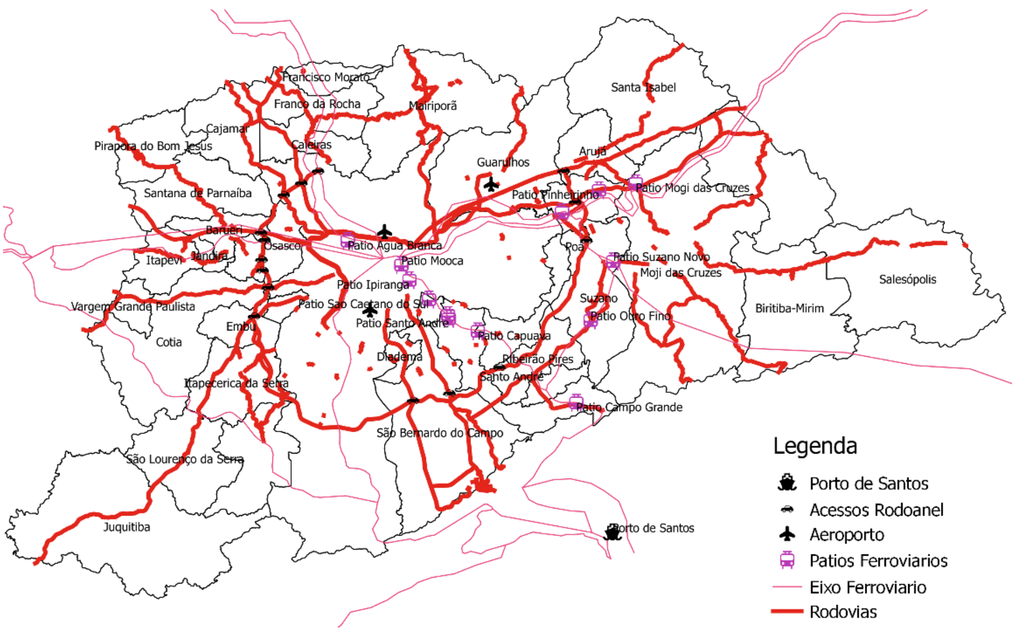
3.3.4. Santos Port

Despite being outside the São Paulo Metropolitan Area, the Santos Port has influence on the truck traffic at SPMA.

According to the company's website, this is the largest port complex in Latin America and accounts for a third of all Brazilian trade. In 2019, Santos Port handled around 134 million tons of cargo, from which 27% is transported by rail. It is managed by the São Paulo State Dock Company, which in turn belongs to the Ministry of Transport, Ports and Civil Aviation (Porto de Santos, 2020).

The port is about 85km from the city center of São Paulo. From the SPMA, the main access roads to the Baixada Santos and, consequently, to the Port of Santos are the Anchieta and Imigrantes Highways. However, with the Ring Road, companies located in other regions of the SPMA can reach these highways without crossing the city of São Paulo. Figure 16 shows the main logistics structures of the SPMA, considering the highways, airports, access to the Ring Road, Porto de Santos.

Figure 16 - SPMA logistics infrastructure.



Source: Guerin, (2019).

3.3.5. Urban Management e SPMA Master Plan

Regarding the planning of the Metropolitan Region of São Paulo, on January 12, 2015, it is pertinent to consider that the Brazilian government approved law 13.089 on the planning and management of Brazilian metropolitan areas, called the Metropolis Statute. This law establishes general parameters for the elaboration of an Integrated Urban Development Plan (Brazil, 2020).

In the case of the São Paulo Metropolitan Region, the plan is still under development, but for its conclusion there are four main axes that must be followed: (1) Economic, social and territorial development; (2) Housing and Social Vulnerability; (3) Environment, Sanitation and Water Resources; (4) Mobility, Transport and Logistics. According to the Preliminary Proposals Booklet, for Mobility, Transport and Logistics, the main guidelines are focused on passenger transport, infrastructure for transporting goods and articulation of distribution centers focused on metropolitan logistics. This last guideline can lead to future actions to minimize the impacts of logistics spread. The priority proposals for logistical improvements for SPMA are: (1) Development of an urban and rural network associated with the metropolitan transport and logistics system, considering the imbalance between concentration of jobs and housing; (2) Restructuring of the industrial territory with the strengthening of production chains and integrated logistics in the metropolis; (3) Implementation and expansion of logistics and cargo transportation in the metropolitan region of São Paulo (São Paulo City Hall - PDUI, 2017). The integrated urban development plan must be delivered by December 31, 2021 (PDUI, 2018).

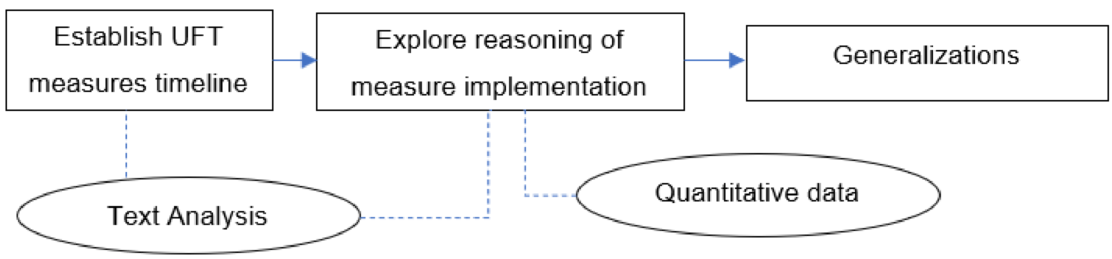
4. METHODOLOGICAL APPROACH

To achieve the proposed objective, we look at the phenomena under study as a process happening within a system, the urban area. The system evolves over time due to many simultaneous processes, which are evidenced by changes in the system characteristics that can be observed and measured as data.

The research draws insight from qualitative and quantitative data. Qualitative data corresponds to the presence and characteristics of UFT measures, while the quantitative part corresponds to variables that characterize a given city and its freight system, according to the model proposed by Kin, Verlinde and Macharis (2017).

The first part of the research consisted in finding information on UFT and classify it according to pre-established groups based on the literature review. The data resulting from this step is the timeline of initiatives in SPMA addressing UFT from 1960 to 2020, per city. In the second part, we present quantitative data to investigate how it relates to the measures, which consists in a qualitative-quantitative research design with a convergent parallel mixed method (Creswell and Clark, 2011). When resulting in incongruent findings, we proceed to find the explanations for the unexpected scenarios. The research steps are depicted in Figure *17*.

Figure 17 - research scheme.



Source: author.

4.1. Object of Study

This research focus on SPMA, comprising the 39 cities alphabetically organized in

Table *10* with sub-region, population and Human Development Index (HDI).

Table 10 - SPMA cities subject to the study.

City	Sub-region	Population (2018)	HDI (2010)
Arujá	East	86,746	0.784
Barueri	Northwest	259,793	0.786
Biritiba Mirim	East	31,571	0.712
Caieiras	North	97,763	0.781
Cajamar	North	74,910	0.728
Carapicuíba	Northwest	390,010	0.749
Cotia	Southwest	238,189	0.780
Diadema	Southeast	401,159	0.757
Embu das Artes	Southwest	264,787	0.735
Embu-Guaçu	Southwest	66,993	0.749
Ferraz de Vasconcelos	East	188,035	0.738
Francisco Morato	North	170,189	0.703
Franco da Rocha	North	148,126	0.731
Guararema	East	28,692	0.731
Guarulhos	East	1,325,750	0.763
Itapecerica da Serra	Southwest	166,229	0.742
Itapevi	Northwest	229,982	0.735
Itaquaquecetuba	East	360,462	0.714
Jandira	Northwest	120,523	0.760
Juquitiba	Southwest	30,040	0.709
Mairiporã	North	95,122	0.788
Mauá	Southeast	451,947	0.766
Mogi das Cruzes	East	423,912	0.783
Osasco	Northwest	677,750	0.776
Pirapora do Bom Jesus	Northwest	18,188	0.727
Poá	East	113,719	0.771
Ribeirão Pires	Southeast	117,917	0.784
Rio Grande da Serra	Southeast	48,648	0.749
Salesópolis	East	16,590	0.732

City	Sub-region	Population (2018)	HDI (2010)
Santa Isabel	East	54,191	0.738
Santana de Parnaíba	Northwest	132,317	0.814
Santo André	Southeast	690,551	0.815
São Bernardo do Campo	Southeast	803,771	0.805
São Caetano do Sul	Southeast	150,988	0.862
São Lourenço da Serra	Southwest	15,246	0.728
São Paulo	Not applicable	11,753,659	0.805
Suzano	East	285,257	0.765
Taboão da Serra	Southwest	275,988	0.769
Vargem Grande Paulista	Southwest	50,797	0.770
SPMA	Not applicable	20.856.507	Not applicable

Source: Author with data from SEADE (2020).

Considering the UN classification, all cities have a high HDI. However, it varies 22.6% in the region considering the highest GDP (São Caetano do Sul) and the lowest (Francisco Morato), reflecting the inequality in SPMA. Indeed, Caieiras, Francisco Morato and Franco da Rocha urbanization processes in the 1980s have been marked by the settlement of the low-income population and land occupation as commute-towns (EMPLASA, 2010). São Paulo ranks fourth in a tie with São Bernardo do Campo. The top three in descending order are: São Caetano do Sul, Santo André and Santana de Parnaíba.

4.2. Data collection

4.2.1. Identifying UFT Measures

To determine whether an action is an UFT measure, we decide whether a specific initiative meets the criteria of a given definition of UFT measure.

The two definitions provided in the section “UFT Measures” differ in whether there is an intention to address UFT or something can *be considered* to address a freight issue. In this thesis we consider the definition by Holguín-Veras et al (2015) because only recently UFT became part of urban planning, therefore the explicit addressing of it as a criterion would be too restrictive.

The literature review indicated that zoning and land-use are commonly adopted practices in urban planning. Warehouses, industries and service premises must follow rules established in such directives, thus resulting that zoning and land-use laws, in a way, address UFT. However, we do not consider comprehensive plans, land-use and zoning regulations *per se* as UFT measures, since they relate to urban freight issues in an indirect, unfocused fashion. However, they are sources of information if they mention parking requirements for loading and unloading or prohibitions to freight vehicles circulation.

So, how to find the existing UFT measures in SPMR? Taking as reference the framework of institutional ethnography, we chose as information source the formal publications by city councils, city executive administrations and local associations. Thus, we identified websites for each city council and executive administration, as well as the website of the Union of Cargo Transport Companies of São Paulo and Surroundings (SETCESP - *Sindicato das Empresas de Transportes de Carga de São Paulo e Região*) and the Traffic Engineering Committee website, which exists only in the city of São Paulo. The next step is to collect relevant information in these sources using search engines.

Quality and reliability of search engines (SE) results depend highly on indexing of information. Some services, like Google, have capabilities such as looking for occurrences of a term in both plural and singular form, as well as features that enhance user search. One of these features is the search within a specific web address, (*keyword* + site:<*site URL*>), but the practice showed that some official city websites did not have their regulations indexed to be found through Google, which would have allowed for a more automated collection of data. This may be due to the use of web forms requiring user input, so that a SE within the website will return the results according to input parameters. Some cities seem to have an agreement with a third-party website with its own search engine, namely *www.leismunicipais.com.br,* to which the user is redirected from the official web addresses. Not all SEs have the same capabilities, meaning that the user must employ workarounds to maximize relevant results. For example, searching for “caminhão” and “caminhões” when the singular/plural capability, previously mentioned, is not available in a city website search engine. Another issue is the poor indexing of some documents, meaning that only some words (for example, the ones in the title) are indexed for search, i.e., that a search cannot be performed in the whole extension of the document. In some cases, the *pdf* documents are not “readable”, consisting in a compilation of images. When this happens, OCR (Optical Character Recognition) capability is needed to scan through the content.

A crucial point is the appropriate keyword: a too general one brings along irrelevant information, a too specific one limits the results, and the context matters. In content analysis, this step corresponds to definition of *semantic units*. The term *UFT* is relatively new and originated in the academic environment, meaning that it is not of widespread use in the local sources. Thus, searching *UFT* (or similar terms, as defined in *2.2. Urban Freight Transport Definition*) would result in limited information. To circumvent that, we searched for terms related to urban freight transport, considering the most common word for each and common synonyms in the context of documentation by associations, city councils and administration. Finding the appropriate terms, although initially dependent on the user, may be refined by observing the results and other terms used within the same documents. To illustrate that, consider the Portuguese word *carga* (load or cargo), whose search has a large probability of comprising the desired information. Many unrelated results come along, as this word is part of an expression meaning workload, i.e., “*carga horária”*. We also observe that in the context of urban freight the term *carga* is almost exclusively used in the expression *“carga e descarga”* (loading and unloading). This improves time spent in the next step, which consists in inspecting each of the results to confirm it contains relevant content. All the search terms and their meaning in English are provided in Table 11.

Table 11 – Keywords indicating UFT measures.

Search Steps	Meaning of Keyword in English	Keyword in Portuguese used in SEs
Primary search	Truck/trucks “Cargo vehicle/vehicles” “Loading and unloading” Urban Mobility	Caminhão/caminhões, “veículo/veículos de carga”, “veículo pesado”/“veículos pesados” “Carga e descarga” Mobilidade Urbana
Secondary search	Master Plan/Comprehensive Plan Building Code Zoning Land-use Traffic Cargo	Plano Diretor “Código de Obras/Edificações” Zoneamento Uso e Ocupação do solo Tráfego Carga

Source: author.

The column “Search Steps” in Table 11 refers to the steps used maximize the detection of information considered to address UFT. To ensure that we find all the pertinent documentation, we examined specific documents that might contain relevant information, like the Building Codes, as suggested by Holguín-Veras *et al* (2018). Finally, when the primary search yielded too few results, we reran it using broader terms like *carga* and *tráfego* or filters for transport and traffic, if available in the city website SE. This allowed to find documents for which primary search terms were undetectable or not indexed.

To this point, we have collected documents with words related to the information we want to obtain. The next stages consist in extracting this information and validating if it corresponds to what we defined as an UFT initiative, then organizing it with year of publication and regulation identification for each city.

Information extraction required reading the documents. Many of the files involved parking spots for trucks licensed by municipalities as freight service providers, similarly to taxi licensing. A Python parser was used to accelerate identification of such cases, and thus they were removed from the set. The remaining files with more than two pages were parsed with Python to reduce the number of pages to be inspected to only those containing keywords. An OCR tool available as a Python library was used to handle files with images prior to parsing and/or reading.

After examining the set and extracting the potential UFT measures, they were classified in one of the groups in the second column of Table 12.

Table 12 - Measures analyzed in SPMA.

Type of Measure	Measure
Infrastructure	Ring roads or beltways
Infrastructure	On street parking and loading - OnSPL
Infrastructure	Off street parking and loading - OffSPL
Infrastructure	Pick-up points
Governance	Truck Traffic Restrictions - TTR: VER, ZMRC, time-windows
Governance	Preferred Routes
Governance	Urban Tolls
Equipment	Smaller Vehicles / VUC
Equipment	Alternative fuels

Source: author.

Data from each municipality, specifically population, GDP and accidents are available in the public database managed by the State System for Statistical Data Analysis (SEADE, in the Portuguese acronym). Fleet data has been gathered from the national traffic authority, DENATRAN. Table 13 presents the data considered and their sources.

Table 13 – Variables and Data Source

Variable	Source
Population	SEADE
GDP	SEADE
Fleet	SEADE
Accidents	DENATRAN

Source: author.

4.3. Data Analysis

The first part of the research involved the collection of UFT measures information. Since the study comprises more than 50 years, we divided the presentation of the data in two time periods: from 1960 to 1980 and from 1980 to 2020. We describe the initiatives that emerged in each period, and then the evolution of initiatives in each city.

The second part consisted in explore relationships among urban indicators and the emergence of UFT measures by using charts and tables. Since we do not have data available for the whole timespan of measures, we focus on restrictions to traffic of freight vehicles from 2002 to 2018 and discuss their surfacing considering demographics, GDP and fleet data according to the conceptual background proposed by Kin, Verlinde and Macharis (2017).

Since non-fatal accident data in SPMA is only available from 2019 on, we compared the mean values for the two populations, cities without restrictions to truck traffic *versus* cities with restrictions, using a t-test with unequal variance and 5% significance. A F-test showed that the variances are not equal.

5. RESULTS

The UFT measures adopted by SPMA cities are presented in Table 14. As the initiatives comprised mostly on and off-street parking and loading, we have these two initiatives in the columns, mentioning the year of their publication. The rows contain only cities that had explicit rules, also providing the regulation where the rule has been identified: building code, master plan, zoning or land use and occupation laws. A third column is added for occurrences of other measures.

Table 14 - Year of UFT measure adopted by SPMA between 1960-1980.

	Off-street parking and loading	**On-street parking and loading**	**Other**
Cajamar	1971: MP		-
Embu-Guaçu	1970: BC	-	-
Ferraz de Vasconcelos	1969, 1978: MP	-	-
Guarulhos	1974: *MP*	-	-
Itapecerica da Serra	1969, 1980: BC	-	1970: Truck Traffic forbidden in urban area
Juquitiba	1969: BC	-	-
Mauá	1970: BC, Z	1978	-
Mogi das Cruzes	1968: Z	-	-
Osasco	1971: BC 1978: LUO	-	-
Poá	-	-	1974: Traffic forbidden in urban area for loads above 10ton
Ribeirão Pires	1973: Z	1973	-
São Bernardo do Campo	-	1961	-
São Caetano do Sul	-	1977	-
São Paulo	1973, 1974, 1975	1979	1976: pedestrian-only streets in city downtown

Source: author.

MP: master plan; BC: building code; Z: zoning; LUO: land use and occupation.

From 1960 to 1980, only 14 cities had rules related to UFT, predominantly off-street loading/unloading, henceforth abbreviated to L/U. Regulations established that L/U should take place within the property for some specific land uses and/or types of buildings. When established in master plans, zoning and land use laws, this requirement came with exceptions for cases where the land use did not correspond to that allowed in the area. Some cities even modified a previous regulation to include such exceptions. Guarulhos is an example of these modifications. The city revised its 1971 master plan to allow small, non-nuisance industries in predominantly commercial areas if they had L/U capability inside the property. Ferraz de Vasconcelos established a similar exception in the residential zone in the city's 1969 master plan. In the 1978 revision, the city administration specified the size of the space for L/U as at least 20% of the built area for small industries in residential zones.

São Paulo's regulations are similar although with some added complexity due to more frequent changes to allow for flexibility. For example, the 1979 regulation in the column “On-street parking and loading” of Table 14 would dismiss the L/U area, if loading and unloading would take place during the night.

Five cities implemented OnSPL rules establishing the locations and time-windows where vehicles could conduct loading and unloading operations. Ribeirão Pires, for example, created the “System for Vehicles Circulation in the City Downtown Limits” in 1973, limiting parking for loading and unloading to 30 minutes on certain streets.

Other regulations addressed UFT in SPMA between 1960 and 1980. In 1970, Itapecerica da Serra became the first city to prohibit truck traffic. Truck drivers used city streets as a detour to avoid weight inspection when transporting goods to South Brazil, thereby causing excessive street damage. Poá forbade trucks with loads above 10.000 kg as a lesser restrictive measure to minimize wear and tear of roads and bridges.

Although other cities apart from those in Table 14 published urban planning laws around the same time, they do not mention freight operations in the form of the searched keywords. However, as municipalities would require licensing for some types of new premises, such as industries, it is possible that UFT could be addressed during the building approval processes. Thus, it remains unclear whether there were any concerns regarding UFT by those cities.

Table 15 displays UFT measures from 1981 to 2019, organized in 4-year periods according to the city presupposed mayor mandates for all the 39 cities of SPMA. Until the end of the 1980s, the pre-democratic federal government would appoint city administrators, which is the reason for the expression “presupposed mandates”. All the actions addressing UFT within the context of the coronavirus pandemic in 2020, such as temporary suspension of restrictions to trucks during lockdowns, have not been included.

Table 15 - Timeline of UFT measures in SPMA.

	1981-84	1985-88	1989-92	1993-96	1997-2000	2001-04	2005-08	2009-12	2013-16	2017-20
Arujá				*OffSPL*[1]	OffSPL,UT		OnSPL,TTR	TTR		
Barueri			OffSPL	OffSPL	OffSPL		OffSPL	TTR	OffSPL	OffSPL,OnSPL, VER
Biritiba-mirim						*TTR*		*TTR*		OnSPL
Caieiras				OnSPL		WR		OnSPL		*ADT*
Cajamar	TTR, PR						OffSPL		OnSPL, TTR, OnSPL	OffSPL, TTR, OnSPL, PR
Carapicuíba										
Cotia				OnSPL	OnSPL		OffSPL			*TTR*
Diadema					OnSPL		OnSPL	TTR		
Embu-Guaçu										
Embu das Artes		OnSPL	OnSPL	OnSPL						OffSPL
Ferraz de Vasconcelos			OnSPL		OnSPL	OnSPL			OffSPL	OnSPL
Francisco Morato		*WR*		WR						
Franco da Rocha		OnSPL,WR, OffSPL	OnSPL	OnSPL	OnSPL	OnSPL	OnSPL	OffSPL		OffSPL,*TTR*
Guararema								OnSPL,PR, TTR		
Guarulhos		WR, OnSPL	WR, OnSPL	WR, OnSPL		*TTR*	OffSPL			
Itapecerica da Serra					OnSPL	OnSPL	*RR*	OnSPL,TTR, OffSPL	OffSPL	
Itapevi				OnSPL				OnSPL	OnSPL,TTR	
Itaquaquecetuba			OffSPL	OffSPL			OnSPL, OffSPL			
Jandira										OnSPL
Juquitiba				OffSPL			TTR			OffSPL
Mairiporã					TTR		OnSPL,TTR	TTR	TTR	
Mauá					OnSPL			OnSPL		
Mogi das Cruzes		OnSPL, TTR			OnSPL		OnSPL, *TTR*			
Osasco						OnSPL		OffSPL, ZMRC	OffSPL	
Pirapora do Bom Jesus							TTR			

	1981-84	1985-88	1989-92	1993-96	1997-2000	2001-04	2005-08	2009-12	2013-16	2017-20
Poá	OnSPL			OnSPL	WR					
Ribeirão Pires	OnSPL, OffSPL	OnSPL,WR	TTR	OffSPL,TTR	OnSPL		OnSPL		OnSPL	
Rio Grande da Serra					WR					
Salesópolis							OffSPL			
Santa Isabel							OnSPL	OnSPL[2]		
Santana de Parnaíba			OnSPL, OffSPL	OffSPL			WR	TTR	OffSPL	OffSPL,WR
Santo André										
São Bernardo do Campo							OffSPL	OffSPL		OnSPL
São Caetano do Sul	OnSPL		TTR,OnSPL		Plate rotation	OnSPL	OnSPL			
São Lourenço da Serra										
Suzano						*RR*				OffSPL,TTR
Taboão da Serra				OffSPL				OnSPL, OffSPL, TTR		TTR
Vargem Grande Paulista										OnSPL
São Paulo	***ZMRC***	***UT, VER***	***ZMRC***	***VUC, ZMRC***	***RR***		ND	***VER, RR***	***RR***	COMFROTA Urban Lockers

ADT: alternate-day travel; OnSPL: on-street parking and loading; OffSPL: off-Street parking and loading; UT: urban toll; TTR: truck traffic restriction; PR: preferred route; VER: Restricted Arterial Road; WR: weight restriction; ZMRC: truck traffic restricted area; RR: ring road; VUC: Urban Cargo Vehicle; ND: night deliveries. Red font: no longer in force. *Gray, italic:* legal ground requiring further action. [1]regulation is unclear; [2]no change from previous measure of this type.

Table 15 shows that during the 1980s more cities, including São Paulo, implemented the first restrictions to truck traffic by either limiting the weight or areas and time of circulation. On-street L/U rules were also adopted by more municipalities while off-street requirements lost their predominance. By the end of the decade, when the SPMA had its current configuration, almost 50% of its cities had adopted some regulation affecting UFT. In 2000, this number had raised to 30. In 2020, the number of municipalities that had at some point a rule related to freight in the urban area reached 37. This is consistent with urban change and the emergence of state and federal laws, with highlight to Law 10.257/2001, the Urban Policy Enabling Act ("*Estatuto das Cidades*"). Carapicuíba and São Lourenço da Serra are the cities that seem to never have implemented any initiative directed to freight vehicles. Some cities might have revoked regulations or never having them effectively in force.

Further analysis of Table 15 indicates that the most common initiative addressing UFT is the establishment of rules for on-street loading and unloading, adopted over time by 27 of the 39 municipalities. The number is slightly above that of cities that have or had some truck circulation constraint, whether establishing it based on the vehicle weight or other rules such as time windows or restricted zones and roads. That amounted to 23 cities in 2020, with most of them implementing them in the 1980s (eight cities) and in the 2000s (five) and the last four in the 2010s. The timeline of measures also shows that loading and unloading rules antedate those constraints to truck traffic, except in some cases, like Pirapora do Bom Jesus and Biritiba-Mirim.

Among the 24 cities that had or currently have some restriction to truck circulation, 8 cities refer to weight restrictions. More constraining circulation rules substituted the weight limits in five of them. Santa Isabel, Rio Grande da Serra e Poá, the cities for which rules intensifying restrictions were not identified, created their WRs within the urban perimeter before the year 2000. A publication by SETCESP (2018) does not include these 3 cities among those with restrictions in place, although Santa Isabel reports this regulation as "in force" and there is no evidence of cancellation of the ordinances in Poá and Rio Grande da Serra.

Urban tolls existed in Arujá and São Paulo. In Arujá, the first regulation on it emerged in 1998 with the preamble "charge for streets resurfacing". Citizens' formal requirements to remove remaining infrastructure in 2005 and 2006 evidenced that the tolls operated for some time. In at least one of the locations, the toll had been replaced by a prohibition to truck traffic, according to a city ordinance from 2008 that aimed to exempt truck owners living in the area. In São Paulo, toll charging was established in 1987 for loading and unloading in pedestrian-only streets located downtown. This initiative is still in force: vehicles up to seven tons are allowed to access such pathways by purchasing coupons that grant a 30-minute time-window for loading and unloading. The operation must be carried on between 8p.m. and 7a.m. due to pedestrian safety.

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The last row of Table 15 shows that São Paulo has the largest number of initiatives addressing UFT. The early need to implement plans and policies for traffic resulted in the creation of the Traffic Engineering Company (CET) back in 1976 to monitor congestion and participate in the development and implementation of traffic control policies. In contrast to it, by 2020 Pirapora do Bom Jesus did not have any local government entity addressing transportation or traffic reporting directly to the main administration.

On-street parking and loading addressing UFT in SPMA is in many cases related to the management of curbside parking by limiting and charging its use, which became known locally as “Blue Zone”. Deliveries to premises such as small stores located in commercial areas might be impacted by such rules if parking for loading and unloading is prohibited or limited. For example, the parking charging system instituted in Cajamar in 2013 required loading and unloading out of parking meter operating hours. Thus, deliveries in regulated streets could only be carried on after 5p.m and before 8 a.m. in weekdays and after 12 p.m. on Saturdays. Ferraz de Vasconcelos created in 2015 a rule with similar effects, although focusing on loading and unloading, requiring it to be performed from 9:30 p.m. to 9:30 a.m. and allowing freight vehicles to park in metered bays during the day with loading and unloading explicitly forbidden except for signaled dedicated bays. São Caetano do Sul and São Paulo created dedicated spots for loading and unloading while also allowing operations to take place outside the parking meter operating hours, which can be beneficial if the number of bays matches the demand of freight vehicles. Caieiras and Diadema are examples of municipalities that created rules for on-street loading and unloading outside the background of curbside parking management, the former establishing time windows for loading and unloading in central streets and the latter forbidding such operations at peak hours in some roadways. During the 2000s, new urban mobility regulations started to mention urban loading and unloading facilities within the urban perimeter as a policy, as illustrated by São Caetano do Sul Mobility Plan in 2016.

Off-street rules have been revisited to establish more comprehensive requirements over time. New regulatory paradigms arouse with concepts like Traffic Generators and Surroundings Impact Report, with acronyms PGT and EIV in Portuguese, respectively, for *Pólo Gerador de Tráfego* and *Estudo de Impacto de Vizinhança*. In Guarulhos, the Building Code regulation of 2005 defined different types of PGTs according to building size, establishing the need for loading and unloading areas according to land use by the traffic generator. As an example, shopping centers sized between 1000 and 2000 m² were considered *minigenerators* and required to have 2 bays for freight operations. Land uses considered non-impacting (non-generators of traffic) could also be bound to allocate space for loading and unloading, as illustrated by the requirement of truck freight yards, with unspecified dimensions, for commerce and service facilities sized above 500 m². Cajamar, Barueri and Franco da Rocha had similar requirements for truck parking necessary in industries, warehouses, non-retailer commercial activities and similar uses, establishing the need of one loading and unloading bay in premises with less than 400m² occupied by buildings, with the minimum of one bay for any premises below 400m². Barueri published this rule in 1993, while Cajamar and Franco da Rocha included it in their Building Codes in the 2000s.

5.1. Development of UFT Initiatives per City

This section delineates the evolution of measures in each city. There are usually vehicles exempted from prohibition, like emergency attendance, perishable food and waste collection trucks, however we will not detail those exemptions for each municipality. Thus, unless otherwise noted we assume that pertinent exemptions are in place.

The area where Aruja is located has a road toll in operation at least since 2001, with a new toll starting to operate in 2014 as part of the São Paulo external ring road. Initiatives in Aruja concerning truck traffic are at least partially related to it, as showed by a reference to overweight or oversized vehicles, evasion to tolls and weight inspection and damages to roadways in one of its regulations. The 2008 regulation on truck traffic pointed out that the local roads could not accommodate truck traffic, thus the circulation restriction aimed to organize the traffic, stopping misuses that had motivated the prohibition required by the community. Since there were dwellers in the area that own trucks, working in the transportation sector, the Decree 5144/2008 created an exception for their vehicles in Jardim Emilia. In 2010, Law 2295 restricted traffic in 11 streets, calling it Maximum Restriction Zone (ZMR). This denomination, however, differs from the definition of "restriction zone" adopted by São Paulo, since traffic would be supposedly allowed in other streets in the area. The same regulation established a type of permit to allow circulation when the vehicle needs access to the urban area with specific purposes such as transport of perishable food, waste removal and owned parking area access. Law 2808/2016, that did not come into effect, tried to forbid truck restrictions by the city mayor as it they would be negatively impacting local agriculture businesses. The complete set of regulations in Arujá matching search criteria as described in "Methodological Approach" are depicted in Table 16.

Table 16 – Regulations analyzed for Arujá.

Year	Description	Regulation	UFT Measure
1995	Law defines city zones according to main use: "c) predominantly industrial, the service zones, which buildings must be designed [...], contemplating parking, access loading and unloading." *Possibly missing a comma between "access" and "loading and unloading"*.	Law 1124	OffSPL
1998	All public administration vehicles subject to restriction imposed by State Law 9690/1997.	Decree 2525	-

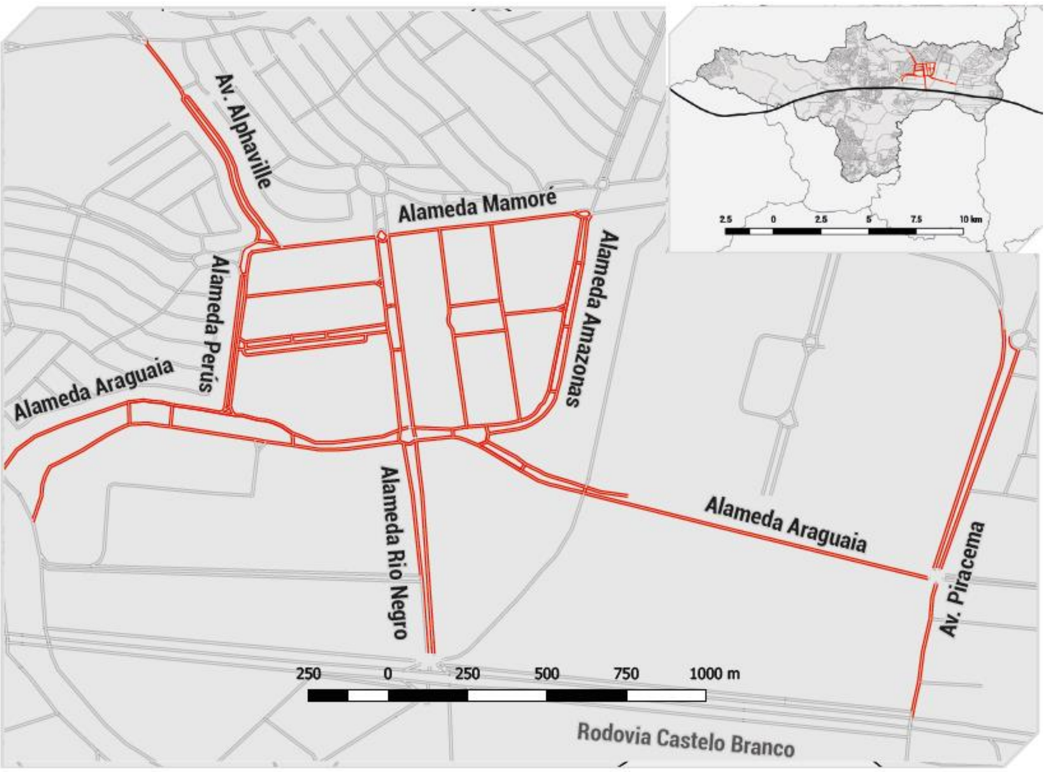
1998 1999	City tolls in 2 locations: Rua Oscar Schiavon, in Jardim Emília; Estrada dos Vados, in Bairro dos Fontes, initially to operate for 12 months. Exempted: vehicles with Arujá plate, vehicles loading and unloading in Arujá. Law refers that the charge must be in the same amount as the toll in federal road Presidente Dutra. Regulating Decree stated the charge.	Law 1341 Decree 2677	UT
2000	City tolls in 2 locations: Rua Oscar Schiavon, in Jardim Emília; II - Rua Adília Barbosa Neves, s/n, Centro Industrial;. Same exceptions. Law refers to a regulating decree that either was not published or is not available.	Law 1410	UT
2000	Loading and unloading yard required for large commerce retailers, wholesalers, diversified and special services that by itself or located in the same estate occupy more than 1000m². “Diversified” is used in opposition to local commercial and service facilities.	Law 1472	OffSPL
2006	Law authorizing the city to keep the parking meter system in urban roads for passenger and freight vehicles with maximum capacity of 4000kg. L/U allowed without charge between 8 a.m. and 10 a.m. and after 6 p.m.	Law 1919	OnSPL
2007	Parking meter ("Blue Zone") to operate out of previously established places and times for loading and unloading. All other metered street bays can be used for L/U until 9 a.m. free of charge. Not clearly revoked by following regulations.	Decree 4761	OnSPL
2007	Review of "Plano Diretor" acording to the City Statute Law; urban mobility and freight transport mentioned.	Suplemental Law 6/2007	-
2008	Trucks owned by local dwellers not subject to previously established restriction. Law draft stated that local roadways were not compatible with truck traffic; therefore, the restriction had aimed to organize the traffic, stopping misuses that made dwellers unsatisfied and that motivated the prohibition in the first place, required by the community itself; that there were dwellers in the area that owned trucks for work activities.	Decree 5144	Truck Traffic restriction
2010	Truck restriction: reference to Brazilian Traffic Code of 1997 on the penalties to overweight or oversized vehicles, evasion to tolls and weight inspection and damages to roadway. Maximum Restriction Zone (ZMR) – truck traffic restricted in 11 streets.	Law 2295 Decree 5557 Ordinance 11829	Truck Traffic restriction
2013	Proposed L/U regulation	Law draft 24	-
2013	Proposed to include new areas (or streets) to the truck restriction, but was withdrawn by the proponent	Law draft 18	-
2015	Parking meter regulation. L/U allowed without charge between 6 p.m. and 8 a.m. During parking meter operating hours, bays can only be used for L/U by vehicles with maximum capacity of 1500kg.	Law 2765 Decree 6463	OnSPL
2016	Law prohibiting the municipality of imposing restrictions to trucks with less than 14m in road located in rural area, later deemed non-constitutional	Law 2808/2016	-
2016	Changes in road network	Suplemental Law 34	-
2019	Parking meter regulation. L/U allowed for 30 minutes without possibility of extra time, for vehicles with a maximum load of 1500 kg and length of 10 m.	Law 3106	OnSPL

2019	LUO alterations: loading and unloading yard required for trucks, 1 bay/2.000m² built area, minimum of one bay for built area up to 1.000 m². Some types of premises must design the L/U space according to the sketch provided in the law.	Suplemental Laws 42 and 45	OffSPL

Source: author.

Barueri had a pilot truck restriction program for 90 days in 2011, turning it into a permanent rule in the beginning of 2012. Trucks were forbidden to drive in some streets during evening peak hours to reduce congestion because there was an excessive number of them, according to the city ordinance. In 2014, Decree 7844 extended the prohibition to the morning peak hours and added one hour the evening restriction in weekdays, with exemption to VUCs and other vehicles portraying Traffic Special Authorization (AET, in the Portuguese acronym). In 2018, an ordinance suppressed the restriction in the mornings in weekdays and included more streets in the restriction, expressly revoking Decree 7844/2014, granting VUCs free traffic all day with no mentions on permits. Again in 2019 more streets became part of the restriction, depicted in Figure 18.

Figure 18 – Barueri streets with restrictions to truck traffic.



Source: edited by the author from IPTC, SETCESP (2019).

Biritiba-Mirim did not implement any restrictions enforced by ordinances, however, at least two requirements have been presented so far by the city council or citizens to demand that traffic of trucks and/or buses is forbidden in two roadways. Parking meters are implemented or about to and L/U is allowed in metered bays following the rules applicable to passenger vehicles, as evidenced by a public bid for the parking system management.

Caieiras has disciplined L/U in 1995 by establishing two time-windows for operations (5- 8 a.m. and 7 p.m.-12 a.m.) in some streets. In 2002 vehicles carrying waste, except for the public waste collection, were forbidden to traffic in the central area of the city. Implementation of parking meters was regulated in the same year with no mention to L/U. Two years later, an ordinance established maximum dimensions of weight (12 t) and length (12 m), requiring AETs for dangerous goods vehicles within these limits that, without the authorization, would not be allowed to traffic in the city streets and avenues. In 2010, a new city law limited L/U to 6 a.m. to 11:30 p.m. in residential areas. A city ordinance in 2012 evidenced the need for infrastructure connecting the east-west axis of the city and other improvements in urban mobility. Finally, in 2019 an alternate-day travel by plate has been created to operate between 6 a.m. and 8 p.m., depending on further regulation of area or streets where it shall be required.

In Cajamar, a city ordinance specified the roadway (Cajamar Ano 2000 Avenue) to access the city back in 1982, explicitly forbidding the use of the alternative Brasil Avenue, which gave access to the city central area. Only in 2015, more than 30 years after establishing a preferred route, Cajamar identified the need to constrain truck traffic in a street on weekdays, in time spans throughout the day (7 - 9 a.m., 11 a.m. - 1 p.m. and 4 - 8 p.m.). Three-axle tractors had their circulation even more constrained (6 a.m. - 8 p.m), being allowed to load and unload if registered and space within the destination premises to perform the operation. L/U on the street could be carried out during the night for the latter type of vehicle. VUCs were exempted. In 2019, the rule was extended to more streets and the constrain to 3-axle tractors and larger vehicle became more flexible in one hour (7 a.m. - 8 p.m). A new flexibilization of the rule time span happened in 2020, with the prohibition only from 6 a.m. to 8 a.m. and 4 p.m. to 8 p.m., although with more streets in the restriction domain. The search for the keyword “traffic” within the city regulations collection results in many decrees for properties expropriation to give place to public work aiming to increase traffic fluidity.

Carapicuíba did not establish measures addressing UFT comprehensively in its regulations. Therefore, all types of vehicles can access any area in the city, originating occurrences such as that showed in

Figure *19*. The city master plan of 2011 established an urban mobility policy with the following highlights: improve traffic by avoiding accidents and congestion, through specific measures like disciplining heavy vehicles traffic with preferred routes and time windows; improve and create new accesses to the city, revisiting the sharing of resources generated by the tolls located in the area, since it has significantly increased the traffic within the city. In 2019, the Municipal Urban Mobility Plan mentioned policies for freight transport, including the plans of defining a “Basic Road Network of Goods Transport Concern”, establishing partnerships to develop urban freight solutions, and fostering the use of environmentally friendly vehicles. The PlanMob contained a comprehensive analysis of the city and its mobility scenario.

Figure 19 - Truck damages supermarket in Carapicuíba in 2020*.*

Source: https://www.r7.com/WqSG. Access: May, 24 2021.

Cotia has regulated loading and unloading in streets in its central area in 1998, restricting them to nighttime on weekdays (8 p.m. to 6 a.m.). The rule was adjusted in 1999 to allow L/U from 8 a.m. to 10 a.m. In 2009 the city published a Road Network Plan indicating that freight transport of goods produced in the city should be prioritized along with public transportation and requiring the traffic generators should be only built on locations directly connected to the Federal Highway Raposo Tavares; although not using the denomination freight generator, the guidelines provided can be considered compatible with such a definition, that was adopted later in a 2013 ordinance. In fact, a city ordinance from 1986 already mentioned freight transport in the planning process of the municipality, which is consolidated by the mentions to it in the 2018 PlanMob: road network changes are to consider fluidity for freight transport, areas where physical configuration do not allow heavy vehicles must be identified and regulated by city ordinances, future transshipment facilities may be planned by the municipality are some examples. In 2015 a city resolution indicated the need to address the congestion in the highway crossing the city area along with public transportation around it. Finally, a restriction not found in regulations is in place according to a media publication highlighting the restriction-breaking behavior by truck drivers. According to Giro S/A, the city hall informed that long vehicles (above 3.6 kg – probably a typo) are not allowed to circulate in the central area from 8 a.m. to 8 p.m., but that for loading and unloading the restriction starts at 10 a.m.

Diadema prohibited truck L/U in weekdays, from 7 a.m. to 9 a.m. and 5 p.m. to 7 p.m., in 11 street stretches (2005). A city ordinance from 1999 showed that there must have been some incompatibility in the urban space use by trucks and buses, since it forbid trucks to perform L/U in streets belonging to buses' routes. The city prohibited truck traffic in some central area streets in 2011 from 6 a.m. to 8 p.m. in weekdays and on Saturdays between 6 a.m. and 2 p.m., exempting VUCs.

Embu-Guaçu revoked its 1970 requirement for L/U yard within premises according to the land use and location in 2002, establishing licensing for some land uses by the city environmental entity in 2007. Two of the city master plans (2007 and 2019) mentioned that the city would establish a Transport/Urban Mobility program, the need to connect the municipality to the beltway and suggested that further investigation was necessary for accidents in the rail crossing the municipality. To address this need, the relations with the national administration of the rail system should be improved, thus this entity could request actions from the third-party administration of the railroad.

Embu das Artes has established parking-meters in the 1988, allowing L/U outside meters' operating hours. A 1996 ordinance on the matter indicated that some metered zones operated in the weekends as well, however the concession to the third-party was revoked as resources were not being directed as due to the city hall and it is not clear in the regulations if the parking meter were kept in operation. The master plans of the city in 2003, and 2012 and its modification in 2015 manifested the intention to regulate freight transport in the urban area, reducing the crossing traffic in residential areas, while providing an extensive plan of infrastructure actions to be approached in a future PlanMob, including improvement of the city access to Federal Highway 116. In 2017, the city created a committee to address urban mobility that should address the use of less-pollutant technologies, among other requirements.

Ferraz de Vasconcelos established its first UFT initiative after the 1970s in 1991, limiting L/U in central areas (5-9 a.m., 5-10 p.m.), changing the rule in 1997 two times. In practice, the two changes referred to night deliveries, since L/U was restricted to 7 p.m to 7 a.m., with the flexibilization in the second ordinance allowing L/U until 10 a.m. This was revoked in 2001, when a new ordinance further constrained the time window for loading and unloading (9 p.m. to 7 a.m.). The Law 3.320/2017 allows loading and unloading in central areas between 9:30 p.m. and 9:30 a.m. Off-street requirements of space had been revoked in 1994 and were adopted again in 2015. Restriction for L/U on-street changed again in 2017 (9:30 a.m. to 9:30 p.m.), being allowed during the day in established, signaled L/U spots and being strictly forbidden in metered bays.

Francisco Morato and Franco da Rocha restricted truck weight to 15 metric tons in city streets since the 1993 and 1986, respectively. Francisco Morato first prohibited circulation in a central street in 1988. Then, the broader weight restriction was established in a 1990 law, although in need of further regulation by a Decree, which was revoked by the 1993 rule. Even though the latter has not been explicitly suppressed, according to the SETCESP publication currently there is no rule in place. The city's master plan from 2006, in its chapter on urban mobility policy, mentioned the creation of a beltway around its expanded central area, as well as the implementation of rules on UFT specially in that region. Francisco Morato's 2019 PlanMob included a chapter on UFT remarkably alike to Cotia's, including the mention to future transshipment facilities.

Besides the weight restriction, Franco da Rocha established loading and unloading rules altogether with its parking meter regulation, as showed in Table 17. Over time, the city limited L/U in some central area streets while also restricting it in the metering regulations, and changes happened on many occasions. Franco da Rocha published its Urban Mobility Plan in 2019, one year after establishing more comprehensive rules for freight vehicles in Law 1368/2018. The latter established rules according to the type of vehicle as defined by the National Land Transportation Agency, CONTRAN and DENATRAN. In summary, light freight vehicles (VLC, in the Portuguese acronym), e.g., those with weight up to 7.99 t did not have any access restrictions except for those indicated in traffic signs. Vehicles above that capacity designated as VCP (heavy load vehicles) could circulate in Heavy Load Routes with a special authorization needed for traffic and parking out of that route. Single trailer vehicles also can only circulate in Heavy Load Routs if previously licensed for it, and both them and multi-trailers had their circulation forbidden in the city. The law established time-windows for loading and unloading (from 9 a.m. to 3 p.m. on weekdays and 2 p.m. on Saturdays) in areas reserved for it according to the traffic signs, with the possibility to use the parking meters spots out of those time spans. The law required further regulation that might not have been issued, since the COVID-19 crisis started soon after it.

Table 17 - Regulations analyzed for Franco da Rocha.

Year	Description of Measure	Source
1985	Addition to Law 708/1974: “Commercial premises to be installed in the municipality, from the promulgation date of the present law, shall keep appropriate area for parking vehicles owned by customers, as well as for loading and unloading of the goods sold"; such commercial premises comprise supermarkets and shopping-centers.	Law 1422
1986	Parking meters operating on weekdays (8 a.m. – 6 p.m.) and Saturdays (8 a.m. – 12 p.m.), not allowed for large sized vehicles (trucks); loading and unloading allowed out of paid parking operation hours or in times and locations indicated by signs. List with nine streets.	Decree 1864
	PROIBIÇÃO do traffic DE vehicles PESADOS COM CARGA ACIMA DE 15 TONELADAS. Excetuam-se quando for de necessidade premente, com a devida autorização expressa de autoridade municipal competente.	Law 1529
1987	Regulamenta Lei 1529/1986. Expressamente proibido o traffic de vehicles em todas as vias públicas do município de Franco da Rocha, com carga acima de 15 toneladas. Excetua-se desta proibição se o fato ocorrer com autorização do setor competente, e devidamente justificado, da Diretoria de Transportes e Serviços Urbanos.	Decree 1922
1989	L/U: 6 a.m. to 9 a.m. and after 6 p.m.	Law 214
1994	Parking meters: Mon-Fri 8-18h; Sat, 8-12h, not allowed for large sized vehicles (trucks); loading and unloading in times out of the range defined by specific signs; list with 11 streets.	Decree 779
1997	Parking meters: Mon-Sat, 8-18h, not allowed for large sized vehicles (trucks); loading and unloading in times out of the range defined by specific signs; list with 12 streets.	Decree 130
1998	L/U in commercial and industrial premises in some streets (already mentioned in metering rules) allowed only 6-10 a.m. and after 6 p.m.	Law 048
2000	L/U in Rua Coronel Domingos Ortiz and Rua Azevedo Soares 6-8 a.m. and 6-8 p.m.; L/U by all types of freight vehicles prohibited any	Law 110

	day in Avenida 7 de Setembro, between Rua Azevedo Soares and the Community Center.	
2003	Parking meters; Mon-Fri 8-18h; Sat, 8-12h, not allowed for large sized vehicles (trucks); loading and unloading in times out of the range defined by specific signs. List with 14 streets.	Decree 544
	Law 110/2000 changed to be applicable in the whole city, with L/U allowed only 6 – 9 a.m., 6 – 9 p.m., all days of the week.	Law 293
	Time-windows from previous regulation are valid only for weekdays instead of any day. for L/U only on weekdays according to signs. L/U free on weekends regardless of street signs.	Law 324
2006	Parling Meters; Mon-Fri 8-18h; Sat, 8-12h, not allowed for large sized vehicles (trucks); L/U allowed in places and times informed in traffic signalization.	Decree 1074

Source: author.

Guararema forbade traffic within the city and in some city access for trucks going to the industrial area, establishing a route for such vehicles in 2011. The city also has parking meters where L/U is allowed for 30 minutes in designated spots since 2009. Its master plans mentioned goods transport since 2006, as well the potential use of rail that crosses the city.

Guarulhos had its first restriction for vehicles with gross weight above 2 t (traffic and L/U) in the area limited by four streets in the central region in 1986, changing the locations and/or time-windows two times in 1989, once in 1991, two times again in 1992 and then in 1993. The regulations mentioned damage to roads inflicted by vehicles evading tolls in nearby roads. The city has parking meters, however L/U might have been kept out of the scope of those regulations, as evidenced by requests to implement L/U spots in some locations over the city in the 2000s.

Itapecerica da Serra, although having had implemented a restriction as early as 1970, only addressed UFT again in the 2000s. During that period, there was only a rule related to L/U within the premises in commercial uses, in 1980. In 2002, the city created a “distribution area” by designating one block as a truck parking space, while restricting L/U in other areas from 6 a.m. to 10 a.m. and 5 p.m. to 22 p.m. In 2004, an ordinance forbade L/U in the parking metered spots, except for deliveries. In 2010, L/U was limited to nighttime and early morning (9 p.m. to 10 a.m.) in some streets. In the same year, the circulation of trucks was forbidden on weekdays 5 a.m.-9 p.m. and Saturdays in the morning and early afternoon, unless the vehicle had the city as destination and having proved it, had a previously granted authorization. In 2012, an ordinance added more streets in the prohibition. It indicated the odd-even rationing in São Paulo as the reason, since trucks would access the city and damage its roads without any compensation by the state or the city of São Paulo. Itapecerica da Serra published its PlanMob in 2016, planning for a local beltway to redirect the traffic crossing the street, among other initiatives.

Itapevi had in its 1972 master plan a distinctive way to limit the installation of industries in residential areas, admitting the maximum of 10 L/U operations a day within premises. The city has had on-street parking spots dedicated for L/U in the context of parking meters since at least 1993 and manifested the possibility of a route for trucks and transshipment facility in its 2008 master plan. In 2013, Itapevi restricted truck traffic in central area streets during peak hours (7-9 a.m. and 4-8 p.m) with exception for VUCs.

Itaquaquecetuba had its first regulation addressing UFT in 1991, also including UFT policies in its 1991 master plan to redirect through traffic from central areas by perimeter connections and foster cargo terminals in locations with easy access to the main roads, among other directives. In 2005, the city created L/U Operations Zones, allowing parking meter spots to be used for L/U by freight vehicles with capacity up to 1350kg and limiting L/U in the central area to the 8 p.m.-9 a.m. time span. The most recent ordinance, in 2019, forbade trucks to park in the metered spots during its operation times.

Jandira has only addressed UFT in the 2000s, having published in 2017 an urban mobility plan with mention to traffic restriction and regulations for load and unloading operations as measures to improve mobility. In 2019 the city regulated on-street parking management, including areas dedicated for L/U of vehicles with net load weight up to 5 t.

Juquitiba addressed off-street parking and loading in 1969 and 1994, only regulating other aspects of urban freight in the 2000s. In 2006, an ordinance forbade vehicles with 4 axles or more to use the paved accesses to the city urban area.

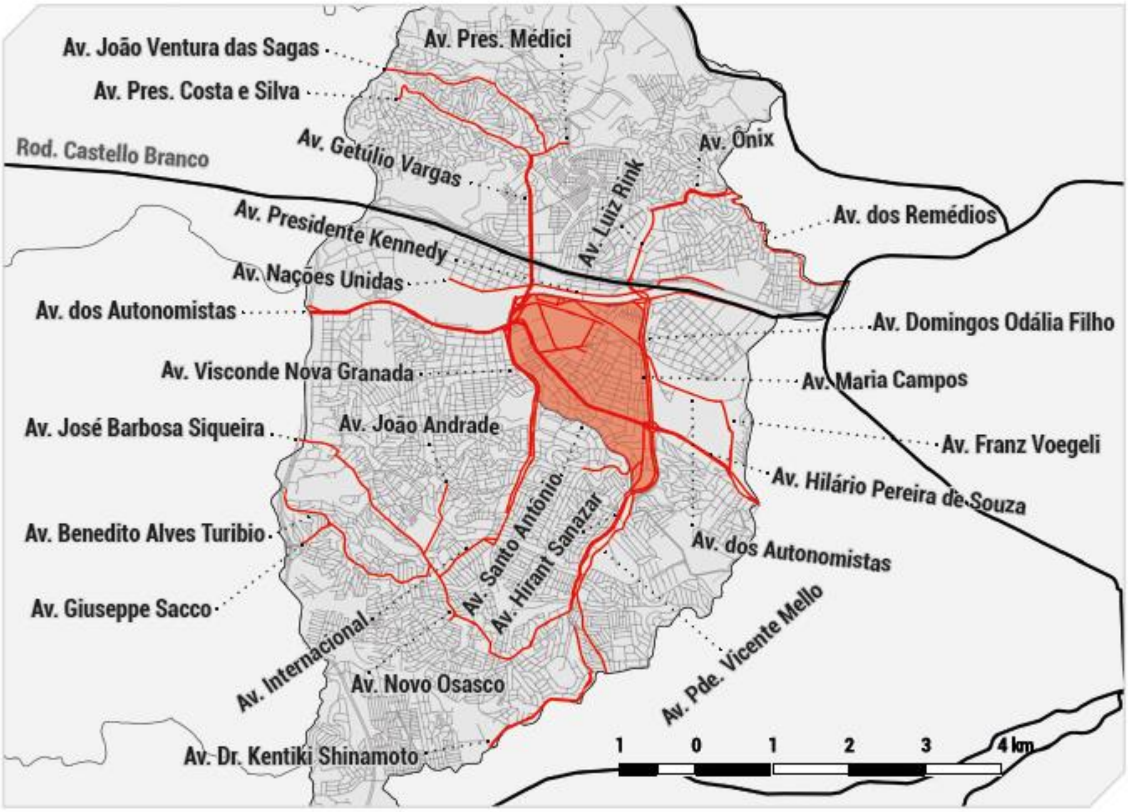
Mairiporã's first UFT measure consisted in the prohibition of trucks with more than 3 axles in 1997. A requirement for flexibilization indicated that vehicles' owners had their access to their homes hindered by the rule. Then the city regulated on-street parking in 2005 with spots reserved for L/U. In 2008, one 3-axled trucks and larger compositions had their traffic prohibited in one more street, and a different ordinance created an odd-even rationing for trucks of 2-axles and above from 5 a.m. to 9 p.m. in the central area. A new ordinance changed the time-window one year later (weekdays 6-11 a.m. and 3-8 p.m.) and added an exception to local plates, and in 2010 another rule overlapped with the existing ones, by restricting completely the traffic. Still in 2010, both were revoked, and the 2008 ordinance was reinforced with changes (weekdays 7-11 a.m. and 4-8 p.m.). The latter was finally replaced in 2013, which prohibited truck circulation on weekdays from 6 a.m. to 8 p.m., except for vehicles to deliver within the city as showed in the shipping documents. The city PlanMob was published in 2020, again with the same phrasing as Cotia's.

Mauá established time windows for L/U in its central area (4-8 a.m. and 8 p.m.-12 p.m.) in 1998. On-street parking for L/U has been found to be part of a 2009 *Blue-Zone* regulation (some parking spaces to be allocated for L/U) and a pedestrian-only area in the city center (access allowed for delivery trucks from 9 p.m. to 6 a.m.). No restriction to traffic has been observed in city ordinances.

Mogi das Cruzes prohibited the traffic of heavy vehicles in the central area from 6 a.m. to 10 p.m. in 1985, and new regulations related to UFT emerged again only in the 2000s. In 2008, the city authorized the implementation of specific times and locations in the central area for L/U by visual signs, if needed to improve the traffic flow. In 2009 the city published a Transportation and Traffic Plan with directives for the management of the road network and UFT, including the need to "promote traffic flow improvements, altogether addressing goods movement and storage, decreasing traffic congestion", and the intention to further restrict truck traffic and create routes after expanding the road network infrastructure. The PlanMob (2018) had similar directives.

After addressing off-street L/U in the 1970s, Osasco regulated UFT in the context of on-street parking management in 2003, having L/U authorized from 7 p.m. to 7 a.m. without charge but allowing it to take place in metered spots if following "Zona Azul" rules. In 2012, two ordinances in the time span of one month created zones restricted to truck traffic with a structure alike that of São Paulo, comprising both a Maximum Circulation Restriction Zone - ZMRC, limited by a polygon, and Restricted Structural Roadways - VER. In the ZMRC, the traffic of trucks is prohibited from Monday to Friday, from 5 am to 9 pm, and on Saturdays, from 10 am to 2 pm, as well as in some streets mentioned in Decree 10676/2012 (Figure 20). VER are lanes where trucks are prohibited from traveling from Monday to Friday, from 7 am to 9 am, and from 5 pm to 7 pm, except for Saturdays, Sundays and holidays, and comprise 46 streets. Vehicles under 7.20 m in length and 2.30 m in width are exempted from such restrictions, as well as essential services, moving and street fair trucks. The city published a PlanMob in 2016.

Figure 20 - Osasco streets with restrictions to truck traffic.



Source: IPTC, SETCESP (2019).

Ordinances on UFT have not been observed in Pirapora do Bom Jesus, although the State Road Management has a restriction for dangerous goods in a road located by the city (SP-312). Many city regulations are not available in the world wide web. In 2019 the city pointed out the need of Surroundings Impact Assessment for some types of new premises.

Poá restricted trucks according to their weight in 1974 (load above 10000 kg) and then again in 1997 (above 8 t per axle). The latter contained the streets where traffic was allowed for vehicles with up to 8 t per axle. Concerning L/U, the city ruled in 1981 that it should be carried on from 7 p.m. to 8 a.m the next day in some central avenues. Finally, its mobility plan (2018) points to the intention to create rules for heavy vehicles in the city central area and implement a beltway.

Ribeirão Pires has concerns with transit of heavy vehicles in central areas since 1983, the year when the first regulation was put in place to limit load and unloading until 9:00, from 12:00 to 2 p.m. and after 7 p.m. in weekdays and Saturdays in streets of its central zone. The current restriction forbids truck with total gross weight above

18 metric tons to drive in the defined central zone at all circumstances, allowing vehicles from 2 to 18 metric tons to load and unload in the area from 8 p.m. to 9 a.m.

Rio Grande da Serra restricted vehicles above 30 t gross weight (vehicle and load) in 1997; the city had by then already established routes in its central area for dangerous goods transport, in 1991.

Ordinances on truck circulation in Santa Isabel have not been observed, however the city PlanMob (2016) mentioned the need to adopt measures for reducing the number of freight vehicles passing through the urban area, indicating that those vehicles use the city streets as a shortcut or to avoid tolls in roads.

Santana de Parnaíba prohibited heavy vehicles in its central area in the context of preserving historical areas in 1990, limiting the time and days for L/U in the region. In 2005, Decree 2693 pointed out that a pilot program had been successful in decreasing the number of accidents by limiting the circulation of heavy vehicles in the city, therefore turning the restriction permanent. Two categories of restrictions existed for vehicles with gross weight of 15 t and heavier: in Estrada Tenentes Marques, traffic was forbidden from 6 to 9 a.m. and 4 to 7 p.m. daily; and in other three streets the prohibition had place every day, all day. Exceptions existed for deliveries to the restricted streets as proved by transport manifest or invoice. The restriction was extended to more streets two times in 2009, and then reedited in the same year. In 2011 there were two ordinances modifying it, as well as a decree for improvement in the Program of Restriction to Commercial Freight Vehicles in Santana de Parnaíba, to comprise the expanded city center. New streets became part of the 2011 regulations in 2012. In 2019, alterations kept only the afternoon time-window in Estrada Tenentes-Marques and removed Av. Alphanorte from the list of every-day, all-day prohibition while keeping 11 others. The last change, in 2020, included one more street.

Santo André does not seem to have initiatives belonging to the considered categories. However, the city created in 1989 the definition of LET, from the Portuguese *Logradouros Especiais de Tráfego*, meaning traffic designated roadways and referring to streets operating above their capacity. The ordinance had requirements for traffic generators and licensing for projects in the LETs. Although Law 8247/2001 revoked this ordinance, there are still references to some articles as valid.

São Bernardo do Campo planned for on-street L/U in its parking meter system, having only addressed the need for parking within premises in the 2000s. Concerning truck circulation, the city has marked the intention to regulate it in its 2006 master plan.

However, trucks cannot access Marechal Deodoro St. in the city center, according to the IPTC/SETCESP publication (2019).

São Caetano do Sul regulated L/U in its central area in a distinctive manner, linking it to the circulation of trucks in that region, already in 1989. Two years later, an ordinance prohibited the traffic for L/U in the whole city from 10 p.m. to 6 a.m., allowing circulation from 6 to 8 a.m. and 7 to 10 p.m. When regulating its on-street parking, since 1977 and with modifications in 1983, 2003 and 2007, spots for L/U were free of charge as well as the use of bays outside of parking meters operating hours. In the last two rules, the metered parking spots could be used for L/U of vehicles weighting up to 4000 kg for 30 minutes. In 1998, the city implemented an odd-even rationing for all vehicles from February to June and August to December to reduce traffic congestion in peak-hours – in fact, the odd-even rationing had been established by the State of São Paulo in 1997 to reduce critical atmospheric pollution episodes in SPMA (Law 9690 of June 2nd, 1997). IPTC/SETCESP (2019) indicates that, although not part of the regulations set, freight vehicles are forbidden in some streets in the city.

Santo André, São Bernardo do Campo and São Caetano do Sul comprise the group of cities named *ABC Paulista.* With the municipalities of Diadema, Mauá, Ribeirão Pires and Rio Grande da Serra they form the *Greater ABC*, a public association created in 1990 to advocate regional policies and programs with the federal government (Consórcio Intermunicipal Grande ABC, 2021). In 2011, the consortium discussed the shared management of the peak-hours traffic in streets connecting the cities, also planning to restrict cargo vehicles and eliminate parking in selected roadways in the scope of the shared management. In the same discussion, some authorities pointed out that some truck drivers “flee” the Rodoanel (avoid it, possibly due to distances and tolls); that plate rotation may not be efficient to decrease congestion; and that traffic operators should work faster to inspect accidents for investigation purposes, this being a possible cause for the frequently observed congestion. The proposed restriction and parking prohibition generated protests by commercial and industry associations and did not follow through to full implementation.

In Suzano, we did not observe ordinances addressing UFT. However, the city had a restriction to trucks in the central area before 2017, according to the administration news page on the expansion of the time-window of prohibition from 9 a.m.-7 p.m. to 7 a.m.-9 p.m.

Taboão da Serra published a Mobility Plan in 2019, having already had in its 2006 master plan a mobility policy that marked the intention to establish routes for trucks accessing its industrial areas. A 2010 traffic department ordinance implemented a prohibition to trucks from 5 a.m. to 9 p.m. on weekdays and from 10 a.m. to 2 p.m. on Saturdays, due to the hindrance caused by vehicles avoiding São Paulo restrictions.

Vargem Grande Paulista has only addressed on-street L/U in its parking management regulation of 2019, indicating that some spots are reserved under parking payment for vehicles up to 10 m. Until then, the city had licensing requirements that referred to impact on traffic, first established in 1996.

5.1.1. São Paulo

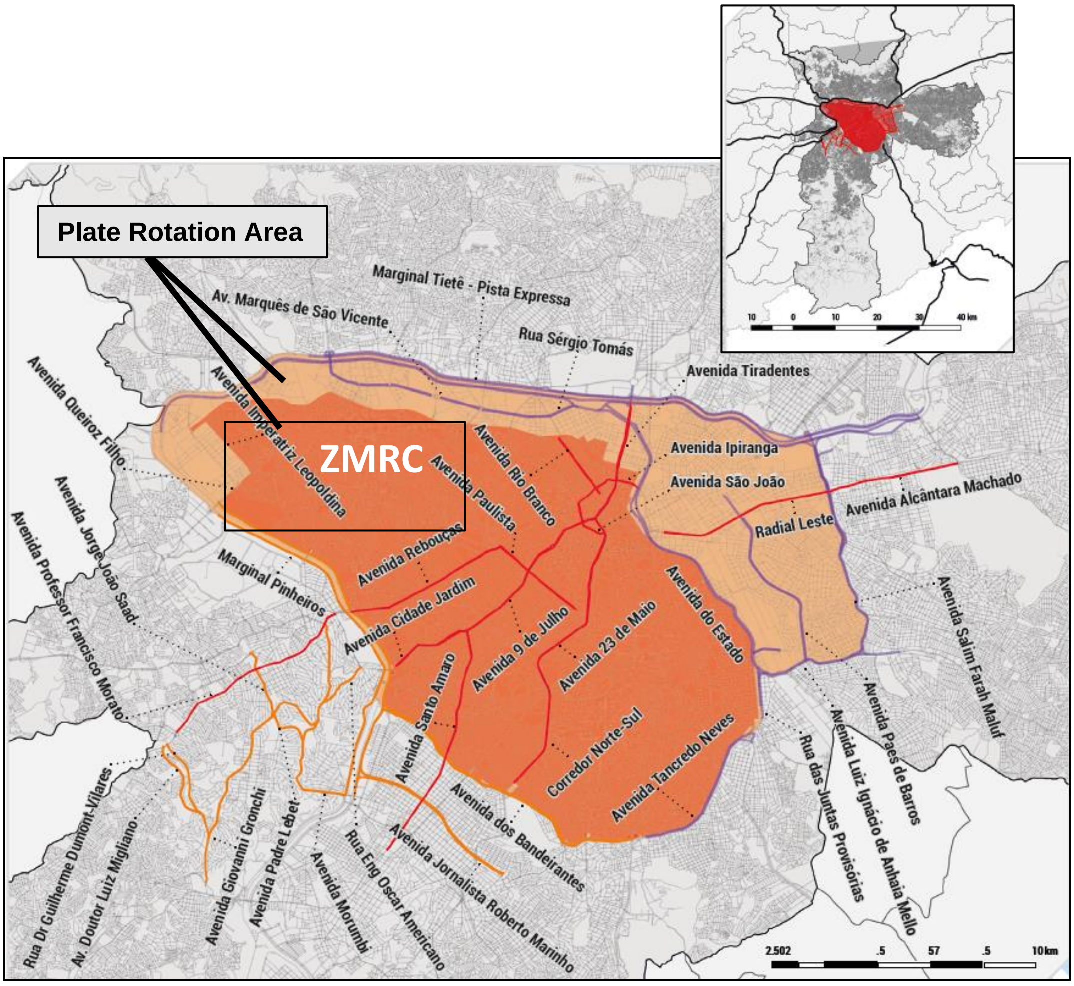
In 1982, an ordinance by the DSV - Road System Operation Department Ordinance (Departamento de Operação do Sistema Viário or DSV, in the local acronym) instituted a restriction zone where trucks above to 15 t (gross weight) had their circulation prohibited, although it did not have any effect, as there were no inspections or practical actions to enforce it (SILVA, M.R.M., 2011). In 1986, the first Circulation Restriction Zone (Zona Máxima de Restrição de Circulação, or ZMRC, in the local acronym) was established as part of an emergency plan to improve traffic in a commercial and services area. Load and unload could only happen in specified time windows in that area, with some exceptions for which permits were granted as applicable. Two regulations in the same year modified the limits of the restriction zone. In 1987, new restrictions to truck traffic in structural routes (Vias Estruturais Restritas – VER, in the Portuguese acronym) emerged.

The ZMRC was revisited by public agents for changes, establishment of legal ground and clarification of exceptions eight times between 1988 and 1996. In 1997, VUCs and VLCs (light freight vehicles) emerged as a collective solution involving government, vehicle manufacturers and local commerce representatives to address the need for vehicles appropriately sized to access UFT restricted areas. In 2007, the distinction between VUCs and VLCs was extinguished. Urban freight vehicles with lengths up to 6.3 meters are designated solely as VUCs, decreasing regulation complexity.

In 1998, the city central area became a ZMRC from 9 a.m. to 7p.m. in weekdays, and from 9 a.m. to 1 p.m. on Saturdays and Paulista Avenue, one of the main business locations in São Paulo, was set as structural restricted roadway within determined time windows from Monday to Saturday. In 2002, a new ordinance standardized all existing restriction exceptions, with other regulations modifying the two existing restriction zones (the first one, referred as ZMRC-quadrangle, and the city center ZMRC or ZMRC-center). In 2005, night deliveries became a requirement in large commercial and service facilities with penalties for operations happening out of legally allowed hours. This measure was revoked in 2007. In 2015, the city traffic authorities in collaboration with the University of São Paulo conducted a pilot program to assess impacts of night deliveries, pointing advantages such as 40% higher speeds to reach destinations, as well as mitigative actions to avoid noise complaints (ANTP, 2015).

Until 2007, there were two ZMRCs. Municipality Decree No. 48.338/2007 redefined the scenario, expanding the restricted area to a 25km² zone comprising both ZMRC-quadrangle and ZMRC-center. In the same year, limits and time windows suffered adjustments. These, however, were in force just until 2008, when the ZMRC was expanded to a 100km² area, with circulation restricted from Monday to Friday from 5a.m. to 9p.m. and Saturdays from 10a.m. to 2p.m. In the same year, 9 other regulations established exceptions, a commission to analyze exceptions, and temporary allowance for VUCs. In 2009 and 2010, new ordinances extended the transitory permission of VUCs traffic until, in 2010, Municipality Decree regulated their access to ZMRC allowing traffic from 10a.m. to 4p.m. They are currently allowed in the ZMRC with no time restriction, as established by Decree 53.149/2012. Finally, in 2018, a Mobility and Transports City Department (SMT) Ordinance provided a new specification for VUCs, that now can have lengths up to 7,20m, keeping width as 2,20m. The same Ordinance establishes times windows for trucks from 5 a.m. to 9 p.m. in weekdays, and from 10a.m. to 14p.m. on Saturdays. In 2016 some areas or streets were designated as ZERCs, exclusively residential zones, aiming to promote safety or environmental quality.

Figure 21 – ZMRC and plate rotation areas in São Paulo.



Source: IPTC, SETCESP (2019).

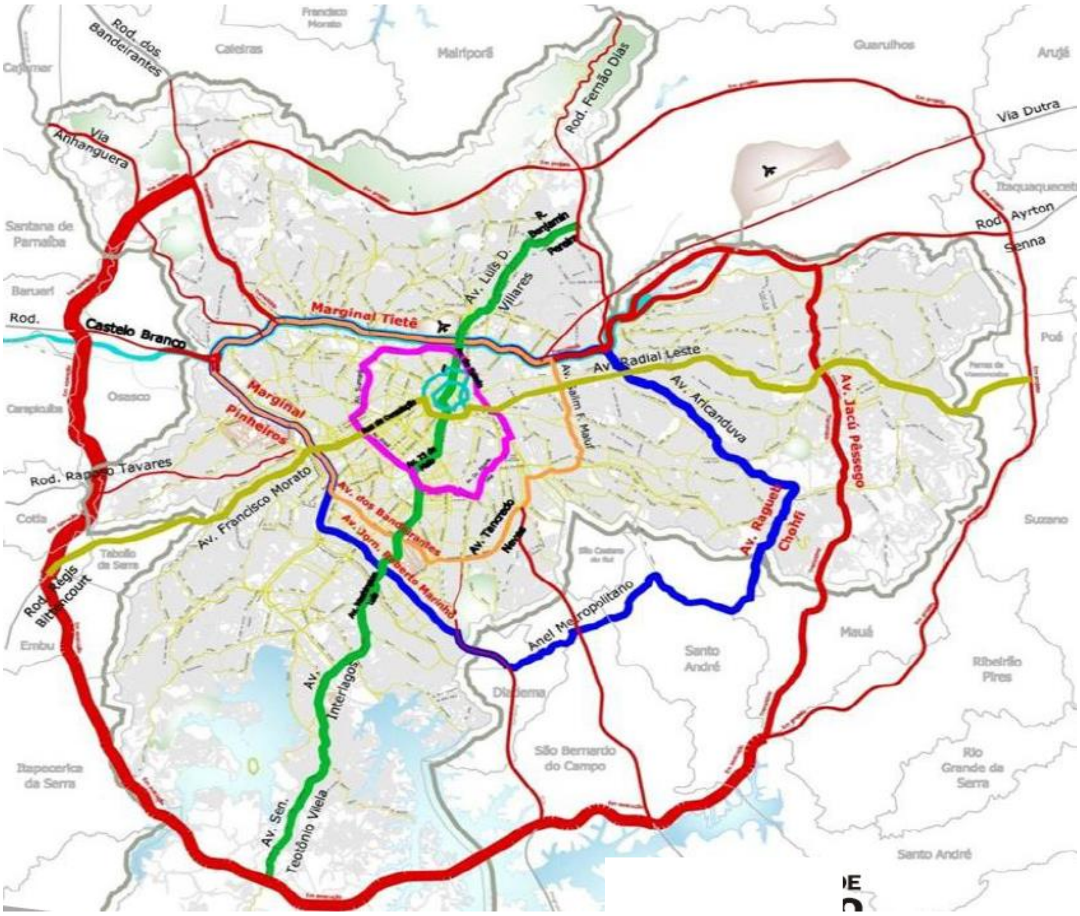
In 2017, city Law 16082 created the Cleaner-alternatives Fleet Substitution Program (*Substituição de Frota por Alternativas Mais Limpas*), also referred to as COMFROTA. However, the substitution is only required of selected public suppliers.

The city of São Paulo has 1,868 spots for on-street parking and L/U of trucks, pickup trucks, and mixed-use vehicles, corresponding to 4.8% of the total 43,875 public parking places (CET, 2020). Freight vehicles can also park in any of the 38,823 regular parking spots available if there are no signs prohibiting it. According to the Traffic Engineering Company (CET), the dedicated parking aims to ease and speed up the loading and unloading of goods to ensure supplies for the city. Trucks and other beforementioned vehicles are allowed 30 minutes in São Paulo loading and unloading zones, extensible for more 30 minutes, and must follow the rules of regular spots when parking in such places. The parking period is granted by purchasing a card where date and time are noted and subject to inspection.

As a megacity, São Paulo is the largest on-line purchasing market in Brazil, and as such is the first city in the country where a given service is available. That is the case of pick-up lockers, tested by Via Varejo, one of the largest retailers in Brazil, in 2018. Stores managed by the retailer, like *Casas Bahia,* have also been available as pick-up location for goods purchased on-line (TECMUNDO, 2018). The installation of *smart cabinets* in public transport terminals has also been announced by a private initiative (UOL, 2019).

The most relevant infrastructure measure in the region is the Rodoanel, the beltway around São Paulo corresponding to the outer ring in Figure 22 and item *3.3.1 Road Network.* The Ferroanel (item 3.3.3 *Rail Network*) should also be highlighted, as it increases the cargo capacity that can be handled without interfering with the road network.

Figure 22 - Annular Road Systems in SPMA; the outer ring corresponds to Rodoanel.



Source: JUNQUEIRA, 2011.

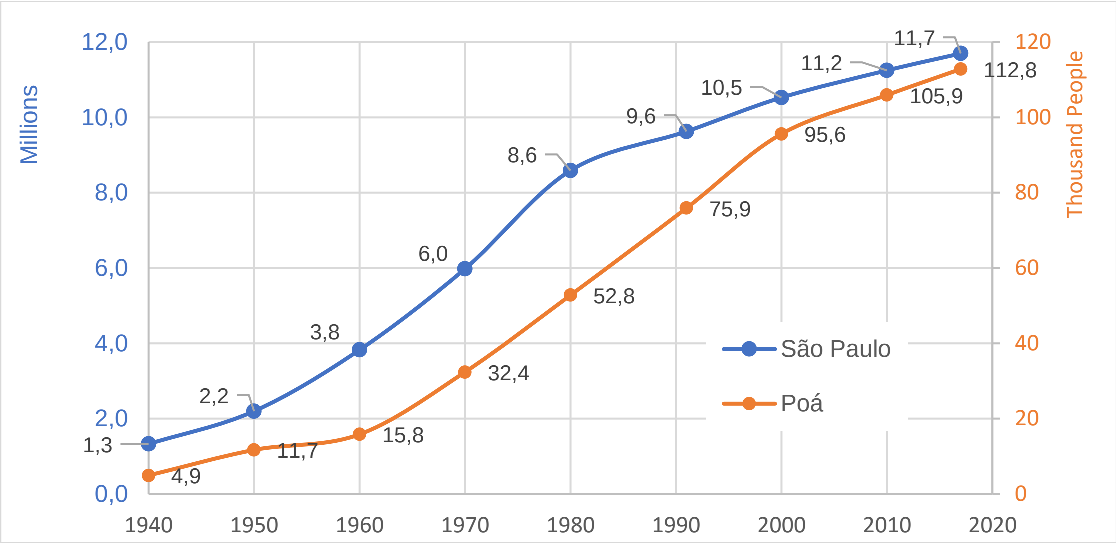
Rodoanel East has a flow of around 24 thousand vehicles, from which 60 to 70% are of heavy vehicles, and connects the Santos Port to Guarulhos Airport. The

West and South sides allow to divert through traffic from São Paulo by connecting South and Central Brazil and the latter to the Santos Port (Government of São Paulo, 2021).

5.2. Relation of Urban Environment and UFT in SPMA

The development of UFT measures in São Paulo, previously described, is more complex than that observed in the other cities, ultimately culminating in the development of a cargo vehicle that could simultaneously allow transport activities while also complying with the urban environment constraints as viewed by authorities. Truck restriction zones emerged in the 1980, much earlier than similar measures in other cities, which is consistent with the city economic development. By 1980, São Paulo population was 16 times the size of the second ranked city in SPMA, Guarulhos. Before São Paulo, Poá, occupying an area of roughly 17 km^2, restricted trucks above 10 t in its main streets in 1974. The city is in the route of the railroad that had been the most important connection between Rio de Janeiro and São Paulo before the main modal shifted to road transport. As São Paulo grew 62% between 1960 and 1970, Poá more than doubled its population. Figure 4 shows that the area corresponding to the city had been somewhat urbanized until 1970, and that by 1980 most of it characterized an urban area, reaching an urbanization above 99% (SEADE, 2020). According to Poá's commercial association, the city had 28 industries in 1950 with 507 employees, reaching 61 industries with 2400 people by 1975. Therefore, an increase in truck traffic is likely for that period since both demand and supply of goods rapidly increased, resulting in the reactive rule by the city administration, allegedly to limit road damage.

Figure 23 - Trends comparison between city populations, reflecting urban sprawl.



Source: author with data from SEADE (2020).

During the decade of 1980, truck traffic and weight restrictions emerged in Cajamar, Francisco Morato and Franco da Rocha, in the SPMA north sub-region, Ribeirão Pires and São Caetano do Sul, in the Southeast, and Guarulhos and Mogi das Cruzes, in the East sub-region. The population of these cities from 1950 until 2010 is presented in Figure 18, as well as their percentual change.

Table 18 – Population evolution from 1950 to 2010 for cities with either TTR or WRs in the 1980s.

	1950	1960	1970	1980	1991	2000	2010
Cajamar	-[1]	6,438	10,440	21,941	33,495	50,568	63,989
%growth	-	-	62%	110%	53%	51%	27%
Francisco Morato	26,262[2]	27,930[2]	11,210	28,462	82,276	133,143	154,287
Franco da Rocha			36,391	50,710	84,912	107,883	131,389
Combined %growth[2]	-	6%	70%	66%	111%	44%	19%
Ribeirão Pires	-[3]	21205	29,117	56,487	84,529	104,305	112,994
%growth	-	-	37%	94%	50%	23%	8%
São Caetano do Sul	60,200	114,421	150,171	163,030	149,436	140,241	149,185
%growth	-	90%	31%	9%	-8%	-6%	6%
Guarulhos	35000	101000	237000	532726	781895	1069609	1220653
%growth	-	189%	135%	125%	47%	37%	14%
Mogi das Cruzes	30243	100194	138749	198081	271981	329653	387260
%growth	-	231%	38%	43%	37%	21%	17%
Santana de Parnaíba	10,556	5,244	5,428	10,070	36,848	74,343	108,474
%growth	0%	-50%	4%	86%	266%	102%	46%

Source: IBGE.

[1] Cajamar became an autonomous city in 1959.
[2] Franco da Rocha had Francisco Morato as a district before its emancipation in 1964.
[3] Ribeirão Pires was emancipated in 1953.

Table 18 shows that Cajamar population more than doubled during the 1970s, growing in a slower rate in the 1980s. The city is on the route of Anhanguera Highway, which operation in that area started in 1948. Therefore, although the proximity to roadway contributed to Cajamar urbanization (EMPLASA, 2010), the restriction to truck traffic within the city jurisdiction happened much later, in 1982, after a population boom. There may have been influence from Santana de Parnaíba populational growth as well because it can be accessed by exiting Anhanguera Highway in one of the entries to Cajamar. Besides that, the south district of Cajamar, named *Polvilho*, could not be accessed directly from the road until at least 1983. Currently there is an additional access to the city by entering Polvilho, which might be considered an infrastructure measure, however concerning traffic management as a whole and not solely focusing UFT.

Most cities in Table 18 show an elevated growth in the context of São Paulo urban sprawl, increasing demand to UFT, which led to restrictions mostly regarding large vehicles in the city center (Cajamar, Francisco Morato, Guarulhos and Mogi das Cruzes) or in city streets in their entirety (Franco da Rocha and later Francisco Morato). Ribeirão Pires restriction to trucks above 10 t in 1986 emerged from the use of its streets to deviate from a blocked section of SP-31, that intersects the city close to its central area. In the early 1990s, the municipality prohibited circulation of trucks with net loads over 2 t. Truck loading and unloading had already been restricted in some city center streets in 1973, with changes during the 1980s to implement OnSPL management while keeping dedicated bays for L/U.

São Caetano do Sul had a decrease in its population between 1980 and 1991, linked to deindustrialization. Therefore, the TTR in the central perimeter in 1989, published as an extra requirement to the establishment of L/U windows, cannot be connected to an increase in demand for UFT due to population growth. Since previous regulations (1977 and 1983) mentioned that there were spots for L/U within the parking metered areas, it is possible that the city administration sought to compensate the loss of tax revenue following the reduction of industrial activity. The increased relevance of the service sector may also have led to more intense traffic of people and goods in the city, resulting in the need of controlling freight vehicle traffic.

The highest population growth in this set of cities is in Santana de Parnaíba, from 1980 to 1991. The only regulation on heavy vehicles consisted in L/U time-windows in created in 1990 to, informedly, comply with historical site preservation requirements. The city kept growing in a fast pace during the 1990s and, by 2005, started a new set of rules to restrict truck circulation.

During the 1990s, Mairiporã, Poá and Rio Grande da Serra restricted large-sized vehicles in the same year of the publication of the Brazilian Traffic Code, 1997, and São Caetano do Sul had an experimental plate rotation program in 1998. The population increased 56% in Mairiporã and around 30% in Poá and Rio Grande da Serra between 1991 and 2000, years of the census. In the previous decade, all of them had a population growth of around 45%, except São Caetano do Sul. The increased number of inhabitants is aligned with a growing UFT demand, but as the case of São Caetano do Sul shows, it is not the only factor involved in the emergence of UFT measures.

Thus, we consider other data for the periods of 2002 and 2018 that are not available in the previous years. Kin, Verlinde and Macharis (2017) model enumerates GDP as an indicator related to the demand side of UFT model. Therefore, we select the cities with highest growth rate of GDP, showed in Table 19.

Table 19 – Top 10 cities by GDP average annual growth between 2002-2010 and 2010-2018.

2002-2010		**2010-2018**	
City	GDP growth/yr	City	GDP growth/yr
Itapevi[(1)]	23%	*Arujá*[(1)]	16%
Pirapora do Bom Jesus[(1)]	20%	*Cajamar*[(1)]	15%
Ferraz de Vasconcelos	19%	Embu das Artes	15%
Arujá[(1)]	17%	*Itapevi*[(1)]	11%
Osasco[(1)]	17%	Vargem Grande Paulista	11%
Embu das Artes	17%	Biritiba Mirim	11%
Cajamar[(1)]	16%	Itaquaquecetuba	11%
Cotia[(1)]	15%	*Caieiras*[(1)]	10%
Caieiras[(1)]	15%	*Santana de Parnaíba*[(1)]	9,5%
Itapecerica da Serra[(1)]	15%	Jandira	9,2%

Source: SEADE.

[(1)] Cities that limited circulation of heavy vehicles between 2002 and 2018.

Seventeen cities created regulations to control heavy vehicles circulation during the 2002-2019 period (and possibly more). Table 19 shows nine of them among the highest growing economies of SPMA either from 2002 to 2010 or from 2010 to 2018, with five making the top 10 list in both time spans. In the first period, only two cities among the fastest growing did not restrict truck traffic: Ferraz de Vasconcelos and Embu das Artes. In the second period, five cities form the group without The difference between the number of cities with measures in each group suggests a lag between what causes the elevation in the indicator and the emergence of UFT initiatives. Embu das Artes absence of regulations would point to the influence of other factors affecting administrator's decision to constrain freight vehicles circulation. However, IPTC (2019) mentions that some restriction exists in the city, although not pointed in regulations.

The fleet and fleet composition are relevant factors in Kin, Verlinde and Macharis (2017) model. An increase in the truck fleet without improvements in the infrastructure can lead to accelerated wear and tear and motivate restrictions, therefore we present truck fleet growth in Table 20. The total fleet size is presented in the Appendix (Table 23).

Table 20 – Top 10 cities by average growth/year of truck fleet per 100 people.

2002-2010		**2010-2018**	
City	Growth/yr	City	Growth/yr
Ribeirão Pires	20,4%	Rio Grande da Serra	10,9%
Juquitiba[1]	12,0%	Itaquaquecetuba	6,6%
Carapicuíba	11,2%	Embu-Guaçu	5,7%
Guararema[1]	11,2%	Ferraz de Vasconcelos	5,4%
Barueri[1]	10,1%	*Guararema*[1]	5,1%
Ferraz de Vasconcelos	9,8%	Salesópolis	4,8%
Embu-Guaçu	9,3%	*Pirapora do Bom Jesus*[1]	4,7%
Embu das Artes	8,7%	*Suzano*[1]	4,4%
Osasco[1]	8,6%	Biritiba-Mirim	4,4%
Santa Isabel	7,8%	*Mairiporã*[1]	4,2%

Source: SEADE.

[1] Cities that limited circulation of heavy vehicles between 2002-2018.

Table 20 indicates that truck fleet grew in a slower pace from 2010 to 2018 when comparing to the previous period. Seven cities among the 17 presented in Table 20 restricted heavy vehicles in their roads between 2002 and 2018, and Biritiba-Mirim had requirements to do so that have not been promulgated as regulations. However, most cities with the fastest growing truck fleet did not have prohibitions until 2019 or they seem not to be in force, which is the case of Ribeirão Pires and Rio Grande da Serra. That suggests a preference for cities without restrictions to install transportation premises. Indeed, data by Guerin (2019) shows that many cities in Table 20 attracted warehouses and/or carriers, which may account for at least part of the truck fleet increase. That is not the case, though, for Juquitiba and Ferraz de Vasconcelos, for example. A share of the fleet increase is due to individual contractors or *motoristas autônomos* – although data specific for SPMA is not readily available, in December of

2020 almost 77% of registered carriers corresponded to individual contractors, owning around 38% of the transport vehicles fleet (RNTRC, 2021).

It may also be the case that the competing car fleet is a more relevant factor influencing UFT measures, thus we show the largest fleets of SPMA in Table 21 in two moments during the considered time span. Franco da Rocha, Itaquaquecetuba and Francisco Morato had the smaller fleet in SPMA in 2018, under 26 cars per 100 people.

Table 21 – Top 10 cities by car fleet per 100 people.

2010		**2018**	
City	Car Fleet	City	Car Fleet
São Lourenço da Serra	59.2	São Lourenço da Serra	67.1
São Bernardo do Campo	45.0	São Bernardo do Campo	53.8
São Caetano do Sul	41.3	São Caetano do Sul	50.3
Suzano(1)	41.0	*Suzano*(1)	48.8
Ribeirão Pires	35.3	Ribeirão Pires	43.7
Rio Grande da Serra	31.7	*Barueri(1)*	42.4
Osasco(1)	31.2	*Osasco*(1)	41.8
Santo André	31.0	Rio Grande da Serra	40.2
Barueri(1)	30.9	*Cotia(1)*	39.8
Arujá(1)	30.7	*Arujá(1)*	39.5

Source: SEADE.

(1) Cities that limited circulation of heavy vehicles between 2002-2018.

Size of the car fleet shows must be a contributing factor. However, it does not reflect the actual flow of vehicles in cities. Taking Barueri as an example, the city received daily a high volume of people that commute from São Paulo due to the high density of corporate facilities.

To obtain further insight on the consequences of UFT measures, we examine accidents in the SPMA. Table 22 presents the data available.

Table 22 – Accidents involving trucks per 1000 people in 2019.

Cities with restrictions		Cities without restrictions	
City	Accident index	City	Accident index
Arujá	0,317	Biritiba Mirim	0,156
Barueri	0,179	Carapicuíba	0,069
Caieiras	0,202	Embu das Artes	0,194
Cajamar	0,407	Embu-Guaçu	0,030
Cotia	0,194	Ferraz de Vasconcelos	0,026
Diadema	0,104	Francisco Morato	0,023
Franco da Rocha	0,107	Guararema	0,585
Guarulhos	0,163	Itaquaquecetuba	0,063
Itapecerica da Serra	0,202	Jandira	0,057
Itapevi	0,081	Mauá	0,070
Juquitiba	0,463	Ribeirão Pires	0,177
Mairiporã	0,289	Salesópolis	0,120
Mogi das Cruzes	0,098	Santa Isabel	0,275
Osasco	0,119	Santo André	0,068
Pirapora do Bom Jesus	0,054	São Bernardo do Campo	0,121
Poá	0,079	São Caetano do Sul	0,073
Santana de Parnaíba	0,067	São Lourenço da Serra	1,363
São Paulo	0,077	Vargem Grande Paulista	0,251
Suzano	0,115		
Taboão da Serra	0,061		
Mean	**0,169**		**0,207**

Source: author.

The index for cities that had not constrained truck traffic is 22% higher, due to the elevated number of accidents per one thousand inhabitants in São Lourenço da Serra. Removing it, the mean drops to 0,139. Considering the means with the complete set, a t-test shows that there is no significant difference between the two groups.

5.3. Further Considerations

The rules organizing truck traffic and, therefore, impacting UFT in SPMA highly change among cities. Only three cities adopted aligned rules: Osasco, Taboão da Serra and São Paulo. The city ordinance in Taboão da Serra made public the need to address the effects following restrictions imposed in São Paulo. In fact, the first prohibition in SPMA, in 1970, sought to avoid the damage caused by trucks that deviated weight inspections after leaving São Paulo; Arujá implemented urban tolls operated in to charge the vehicles that would leave the main highway to avoid the interstate toll. These are examples of the issue mentioned by McLeod *et al.* (2019): freight transport policies reach beyond local planning jurisdiction limits.

In most cases, however, initiatives on UFT are conditioned to the urban planning paradigm and to the perception of nuisance. That is demonstrated by the fact that most cities constrain L/U and/or circulation in central areas, as they are concentrate people movement during the day and are most densely occupied, although there is no data to confirm whether safety is increased by this initiative. There are various mentions to prohibiting cargo vehicles to decrease congestion, although passenger vehicles highly contribute to traffic-jams. On the change of paradigms, the recent urban mobility plans include goods transport in their texts; however, this does not mean that cities evaluated their current situations and created plans to effectively address issues, as there is an example of a set comprising 3 cities that have the exact same writing in their PlanMobs.

Considering Lindholm (2012) approach to UFT measures as “tested solutions”, only 4 cities would have indeed adopted UFT measures: Santana de Parnaíba, Barueri, Arujá and São Paulo. They had pilot programs before enforcing rules, although only São Paulo published ex-post evaluations presenting trial data. These three cities exemplify the relation between measures and economic development, as we observe the emergence of regulations associated to GDP growth.

Finally, we consider that demographic and economic characteristics are necessary, but not sufficient, to the emergence of UFT measures. They need to be politically supported to be put in place.

6. CONCLUSIONS

This study aimed to provide insight in the emergence of UFT management measures in large cities and adjacent areas, deriving generalizations from a detailed account of UFT measures in the 39 SPMA cities from 1960 to 2019 and changes in population, GDP, fleet and accidents. We devised three propositions, from which we address the first two together since they complement each other:

a) Observable and measurable <u>*externalities*</u> *of truck traffic in urban areas are the reason for governance measures restricting their circulation.*

b) Observable and measurable <u>*characteristics*</u> *of the urban area, such as demographics, are the implicit drivers behind emergence of governance measures restricting truck circulation.*

Public authorities historically did not use data in SPMA cities, nor discussed with stakeholders to adopt measures, except for São Paulo and other cities in the recent years. Although Holguin-Veras et al. (2018) pointed out that public decision-makers have difficulties in identifying effective measures due to the lack of data, we risk saying that they do not try to objectively assess the situation before creating rules. This is supported by the review of regulations to allow for dwellers to park their own trucks or to transport their own production, indicating that the decision-maker had extremely limited knowledge on the reality of the own population. This also corroborates with Quak (2008) proposition that urban freight transport policies usually emerge from the (perceived) problems, rather than from objective evaluation. The exception concerns large endeavors like Rodoanel, for which one can find detailed studies. Although the project focus is more on logistic debottlenecking, it supports the decrease of some externalities in SPMA.

We conclude that observable and measurable externalities of truck traffic in urban areas are not the main reason for governance measures restricting their circulation, but that some characteristics of the urban area are the implicit drivers that lead to restrictions when the nuisance need to be quickly addressed.

c) *UFT actions have effects in surrounding municipalities*.

SPMA cities managed UFT locally, even if some efforts existed in the Greater ABC cities to coordinate actions. This is in alignment with Dablanc statements that local authorities create rules to control impacts, although in Brazil the background for penalties to non-compliant drivers is established and the authorization to regulate their own traffic exist in the national traffic laws. We observed that the vehicles waiting in inbounding roadways to approach São Paulo are the main consequence of the restrictions adopted by the city. Taboão da Serra had to implement the same restriction to avoid truck affluent traffic, which is consistent with Quak (2008) and McLeod et al. (2019).

Moreover, we found that three types of regulations have been historically created to address UFT: off-street L/U, on-street and restrictions to traffic. As the land occupation in the urban environment intensified, administrations made the first efforts to avoid that L/U would happen in the streets, therefore requiring some types of buildings to have an area to loading and unloading. In the absence of regulation, the public space would be used in the interest of service undertakings. Thus, we consider that the lack of planning for L/U space in service facilities or to be used by a group of small commerce facilities influenced in the congestion observed in central areas. The competition for the street space becomes clear when we consider the need to manage on-street parking and loading, which focus on the central district user and leaves L/U in second plan, to mostly use the bays only when not in use by cars.

To public decision-makers, we recommend UFT management training. Also, we advise for more consideration on parking for L/U close to commerce centers to foster economic activity of small commercial facilities in a safe way, allowing the many contractor drivers to park more easily. We also advise for the search of more innovative approaches like cargo bikes.

The unavailability of city hall and administrative subdivisions ordinances or *portarias* consist in a limitation of this study, meaning that some UFT measures might not have been identified even if in place. Most cities do not provide open access to them in the world wide web, although they can be obtained in the context of the Information Access Law (LAI, in the Portuguese acronym for *Lei de Acesso à Informação)* or consulted in the official diaries. In some cases, even if publicly available, the information might have not appeared in the search due to its format. To minimize such cases, we performed the steps described in the Methodology, however it is not possible to assure that we detected all relevant information. Another limitation is that we mostly used compiled datasets for the SPMA, however specific information might be available individually in city files. As this would require extensive data collection and could involve physical gathering of information, we kept it out of the scope of this study.

We recommend that future research focus on results of UFT measures and their sustainability, as well as their impacts for third-party individual drivers: are they more affected by penalties on loading and unloading? How well are they informed on restrictions? We suspect that the characteristics of the work market of truck drivers in Brazil are unique and that more needs to be done regarding the economic impacts of this scenario.

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8. APPENDIX

Table 23 - Truck fleet per 100 people in SPMA cities.

City	2002	2010	2018
Salesópolis	2,77	4,11	5,82
Arujá	2,92	3,62	4,31
Embu-Guaçu	1,36	2,67	4,04
Ribeirão Pires	0,99	3,69	2,92
Barueri	1,31	2,81	2,87
Guararema	0,84	1,90	2,78
Cajamar	1,36	2,16	2,78
Juquitiba	0,82	2,01	2,76
Santa Isabel	1,25	2,24	2,60
São Lourenço da Serra	1,19	1,95	2,58
Mairiporã	1,27	1,86	2,53
São Bernardo do Campo	1,59	2,21	2,43
São Caetano do Sul	1,88	2,25	2,30
Vargem Grande Paulista	2,00	2,02	2,06
Guarulhos	1,12	1,82	1,99
Pirapora do Bom Jesus	0,99	1,36	1,95
Mogi das Cruzes	1,05	1,54	1,89
Itapecerica da Serra	1,04	1,61	1,83
Osasco	0,83	1,60	1,78
Santana de Parnaíba	1,39	1,62	1,75
Santo André	1,21	1,66	1,59
Biritiba Mirim	0,80	1,12	1,56
Suzano	0,96	1,06	1,49
Cotia	0,91	1,36	1,47
Diadema	0,77	1,12	1,43
São Paulo	1,19	1,31	1,36
Rio Grande da Serra	0,54	0,68	1,35
Caieiras	0,75	1,21	1,32
Embu das Artes	0,52	1,01	1,30
Jandira	0,81	1,12	1,26
Itaquaquecetuba	0,44	0,77	1,21
Ferraz de Vasconcelos	0,39	0,81	1,20
Carapicuíba	0,39	0,92	1,16
Itapevi	0,60	0,85	1,16
Taboão da Serra	0,68	1,06	1,14
Mauá	0,67	0,95	1,13
Poá	0,59	0,97	1,13
Franco da Rocha	0,35	0,51	0,68
Francisco Morato	0,23	0,33	0,38

Source: SEADE (2020).

Table 24 – Warehouses and Carriers in SPMA.

Municípios	1992	2000	2010	2017
Arujá	0	0	3	9
Barueri	8	53	126	174
Caieiras	1	1	4	8
Cajamar	0	0	10	32
Carapicuíba	0	2	7	6
Cotia	3	12	24	51
Diadema	5	12	33	43
Embu das Artes	2	10	19	45
Embu-Guaçu	0	0	1	0
Franco da Rocha	0	0	0	1
Guararema	0	0	1	2
Guarulhos	19	65	196	337
Itapecerica da Serra	0	2	6	10
Itapevi	1	5	20	44
Itaquaquecetuba	2	3	8	16
Jandira	2	4	9	27
Mairiporã	0	0	3	3
Mauá	5	8	19	35
Mogi das Cruzes	5	10	12	17
Osasco	12	36	68	102
Poá	1	3	5	6
Ribeirão Pires	0	1	2	8
Santa Isabel	1	2	2	6
Santana de Parn.	1	4	12	33
Santo André	6	23	39	43
São Bernardo do Campo	17	37	68	87
São Caetano do Sul	2	7	20	25
São Lourenço da Serra	0	1	0	0
São Paulo	123	332	666	836
Suzano	5	8	12	16
Taboão da Serra	1	11	22	30
Vargem Grande Paulista	0	0	2	9
Out of RMSP	6	15	18	5
TOTAL	228	667	1437	2066

Source: GUERIN (2019).