Research Article

TRR
JOURNAL OF THE TRANSPORTATION RESEARCH BOARD

Transportation Research Record
1–17

DOI: 10.1177/03611981221127282
journals.sagepub.com/home/trr
SAGE

Impact of Goods Distribution in the Last Mile: An Investigation in the City of São Paulo

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Abstract

The number of goods deliveries made in the city of São Paulo has been rising every year. This growth is caused by new consumption habits, as people increasingly opt for online shopping, having goods delivered to their homes or neighborhood markets. However, these deliveries have become increasingly complex because of several issues found in the last-mile distribution of goods. This research sheds light on the interactions among issues related to truck circulation restrictions, receiver characteristics, accessibility and delivery planning, urban road infrastructure, driver behavior, and safety and risk problems that hamper last-mile delivery distribution. Data were collected (via a questionnaire) from drivers who work in the urban distribution of non-durable consumer goods in the city of São Paulo. From the data, structural equation modeling is proposed to evaluate these interactions. Empirical results demonstrate that "lack of accessibility and delivery planning" and "poor urban road infrastructure" are the elements that have the most impact on the "safety and risk problems in urban freight distribution" from the driver's point of view. These results also contribute to mapping the main problems encountered in the last-mile delivery distribution in the city of São Paulo.

Keywords

driver perception, freight systems, human factors of infrastructure design and operations, last mile, Structural Equation Modeling (SEM), urban freight transportation

In recent years, several factors have significantly contributed to the increase in logistics distribution costs and complexity in the last mile for retailers: globalization, economic development, population growth, urbanization, densification, and e-commerce intensification (*1–6*). The rapid growth of e-commerce, leading to fierce competition among retailers, has accustomed consumers to receiving their online purchases at their homes in increasingly short delivery times (*7*). This way of operating has generated an overload on logistic service providers and carriers, who have had to adapt their fleets and deal with the problems inherent in the logistics aimed at the final consumers. Furthermore, urban freight distribution issues, such as truck circulation restrictions (*8*, *9*), receiver characteristics (e.g., based on local constraints, lack of equipment to move goods, lack of receiver support on deliveries) (*10*, *11*), lack of accessibility and delivery planning (e.g., difficulty in reaching the delivery location, lack of delivery planning, and traffic congestion) (*11*), deficient urban road infrastructure (e.g., lack of loading/unloading areas, inappropriate sidewalks and signage) (*10*, *12*), driver behavior (*13*), and safety and risk problems (*8*, *9*), have increased over the two decades since the early 2000s and now challenge truck operators in the freight distribution system.

Urban distribution regulations are established by local authorities (*14*) that determine the availability of parking areas and control traffic, vehicle access, and land use in

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strategic regions in large cities (*15*, *16*). However, local authorities may have few initiatives to solve the problems for all the actors involved in the distribution problems in an egalitarian way (*10*). Urban logistical operations often play a secondary role in city planning priorities (*15*) and the authorities do not consider this problem as a whole (*17*). Truck circulation restrictions, for instance, zone circulation areas (residential or structural path) and license-plate-based truck access (*11*), are applied in limited downtown areas to control vehicle flow, such as heavy trucks (*18*). These restrictions lead to a need for more, smaller trucks to be hired to meet demand, thus increasing congestion (*12*). Furthermore, when there is no adequate structure for urban distribution, such as adequate parking lots, drivers stop on double lines (where parking is prohibited) and also commit other infractions that worsen congestion problems (*17*). These aspects also contribute to accentuating issues of accessibility and delivery planning and difficulties for drivers as they attempt to reach the delivery location (*15*). Moreover, occasional inconveniences occur, such as the noise generated by the operation in residential areas, more significant risks of cargo theft, and an increase in labor costs, both for carriers and receivers (*11*, *19*). Receivers of goods are also part of this context. They can help to establish alternative policies that can mitigate distribution problems, such as flexibility to receive the goods in off-hours (*20*) and provide better support during deliveries (*10*).

This research sheds light on the interactions among these issues, especially constructs related to truck circulation restrictions, receiver characteristics, accessibility and delivery planning, urban road infrastructure, driver behavior, and safety and risk problems, from the perspective of drivers directly involved at the end of the logistics chain, by testing hypotheses on last-mile distribution in urban areas of São Paulo.

Most of these issues are present generally in megacities (*11*) and may affect the logistical performance of companies in the last mile of distribution. This is the case in the city of São Paulo, where these issues have contributed to increased inefficiency in urban freight distribution (*11*, *12*). The authors found that regulations are one of the Achilles' heels of freight distributors, with the potential to negatively affect companies' logistical performance, especially the large ones (*12*). Moreover, traffic congestion and lack of security for deliveries in unsafe areas are two of the most significant issues affecting deliveries (*11*). However, the previous studies are related to a broad view of the issues in the urban distribution system, from the perspective of shippers, logistics service providers, and carriers. This research focuses on the operations of last-mile logistics from the perspective of drivers, who are one of the main groups of actors that operate locally (or in an end-haul segment) and focus on transportation of goods.

The results may help authorities and companies to understand better the problems of last-mile distribution in São Paulo city and could serve as a basis for establishing policies that can reduce or solve such problems. In Brazil, research on urban logistics in large cities is still incipient, and the logistical challenges have been increasing with the complexity of cargo distribution in these locations (*12*). Considering this, it is also possible to adopt the premise that the problems and results identified in this work can be extrapolated to other cities in the country that adopt the same solutions (*21*). This study may also serve as an inspiration for last-mile operation improvements in other megacities. Therefore, our research contributes to providing a complete model that measures the relationships among the main distribution issues in last-mile operations.

This paper is organized as follows: the literature review section is based on the factors that affect cargo transport in large cities and creates hypotheses that will serve as a base for construction of the theoretical model. The subsequent sections show the methodology, present the results and empirical analysis, discuss the results, and draw the conclusions and contributions of this research. The final section points out the limitations of the research and proposes directions for future research.

Literature Review

Companies operating in last-mile distribution in urban areas face many problems in achieving efficient freight movements (*22*). Based on a review of the literature, we identified several issues related to regulations, logistics, and risk that most affected these operations (*11*). We classified them into six groups according to their characteristics: truck circulation restriction, receiver characteristics, accessibility and delivery planning, urban road infrastructure, driver's behavior, and safety and risk in urban freight distribution. We investigated the effects of these issues in urban distribution and here broaden the scope of the theory by understanding these effects from the point of view of the drivers who effectively perform the deliveries.

Previous studies that demonstrated the benefits and impacts of regulations on urban distributions (*12*) report that restrictions on truck circulation and delivery timetables are initiatives implemented by municipalities to regulate traffic congestion and seem to be the most efficient (*22*). Although several cities have successfully mitigated traffic congestion by implementing truck restrictions, negative externalities have emerged from this controversial policy. Woxenius (*23*) argues that regulations that create restriction zones can cause "detours" in delivery routes. "Detours" can be explained as the driver not choosing the shortest route because of regulatory or physical restrictions, causing increased operational risks, liability to fines, delayed deliveries, and cargo damage or theft. Moreover, vehicle access restrictions worsen congestion level accessibility because of the need for a more significant number of small vehicles to circulate through the city to meet the demand (*24*, *25*).

Logistical restrictions also occur in last-mile distribution. Inadequate road infrastructure forces drivers to use alternate routes because of physical constraints, such as narrow roads, causing a direct impact on increased travel distances and vehicle kilometers traveled, and difficulties in reaching the delivery location (*24*). Furthermore, the lack of public spaces for parking or inadequate space planning forces drivers to park in a distant location, increasing the risk of cargo theft while the vehicle is unattended (*15*).

At the receiver's end, the issues reported in the literature are related to a lack of specific infrastructure for "load/unload interfaces" (such as private parking and loading/unloading bays) (*15*). Furthermore, the literature reports that issues of long queues for unloading (*22*) cause delays, disrupt route planning, and result in more time spent on delivery (*15*).

Proposed Hypotheses and Model Structure

A research model was developed to test a set of hypotheses related to issues that may affect the last-mile distribution in urban areas from the driver's perception of last-mile distribution of goods to small retailers. In addition to these hypotheses, the model-building process allows for setting up a series of complementary relationships between the variable groups, leveraging on the existing data to provide additional insights into the relationships between the variables. The complete set of variable group relationships that were included in the model is shown in Figure 1.

Effects of Truck Circulation Restriction on Accessibility and Delivery Planning. In urban freight transport, accessibility can be defined as the ease of reaching destinations. Operators face several problems in establishing efficient movement in urban areas, mainly in limited traffic zones (*22*, *26*). For example, congested traffic along with the other variables of the construct (long times for trucks to find a slot, difficulties in reaching the delivery location, and need for delivery planning from receivers) has become a problem in most large cities.

Government agencies establish traffic regulations in cities to organize the flow of people and vehicles in urban centers (*27*). Considering this, regulations such as time-window access restrictions, restrictions of access to structural roads, and restrictions on truck circulation are aimed at reorganizing the flows of delivery vehicles in congested areas of the city (*15*, *16*). The São Paulo government determined an area where trucks are restricted from circulating during specific periods of the day and called it the "Maximum Circulation Restriction Zone." This area comprises a region with a high concentration of stores and service activities in the São Paulo municipality. Commercial trucks are not allowed to circulate between Monday and Friday from 5:00 a.m. to 9:00 p.m. and on Saturdays from 10:00 a.m. to 2:00 p.m. The only exception is if they have special authorization from the municipal authorities (e.g., permit for "Urban Cargo Vehicle – Small Vehicle") (*18*). Inefficiency is typical in this type of delivery, as freight vehicles are used for deliveries to small retailers, and generally have a lower vehicle loading factor (*28*). Restrictions in size and

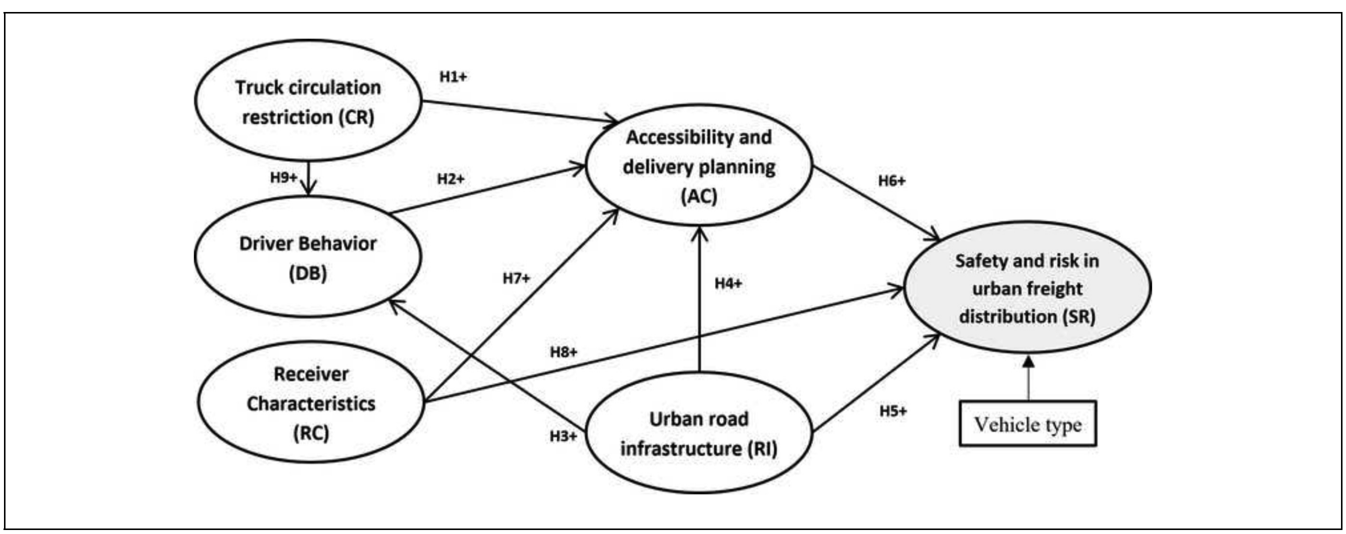

Figure 1. Structural model of the research.

weight are also imposed for commercial vehicles. Most authorities have a policy that the transport of cargo by trucks is something to be prohibited or severely restricted (*29*).

Restrictions imposed on the flow of goods become a clearer obstacle in urban logistics, especially considering the increasing demand for deliveries caused by the expansion of the e-commerce market (*30*). As a result of this expansion, there is a higher frequency level of deliveries in cities and fragmentation of demand and cargo flows (*30*). The regulations created to restrict the circulation of cargo vehicles cause more small vehicles to circulate through the city to meet the demand (*19*, *21*), worsening the congestion levels and overall accessibility and delivery planning issues. These restrictions also make delivery difficult in malls, condominiums, and stores located in central regions.

Therefore, we aim to test the following hypothesis:

> **H1:** "Truck circulation restriction" is positively related to "lack of accessibility and delivery planning."

Effects of Driver Behavior on Accessibility and Delivery Planning. Driver behavior is the description of intentional and unintentional characteristics and actions a driver performs while operating a motor vehicle (*31*). Using double parking for loading/unloading, occupying parking spaces at restricted times, and use of irregular space during loading/unloading are examples of misbehaviors that drivers may exhibit (*32–34*).

Research indicates that these driver misbehaviors can affect congestion indices (*17*) and may show a lack of delivery planning. Route detours are used to access difficult-to-access places, requiring more delivery planning from companies (*12*). Commercial vehicle drivers are also often forced to enter congested areas during peak hours, thus worsening traffic and resulting in more delivery delays or taking a long time to find a slot, blocking traffic, and leading to greater difficulty in reaching delivery destinations, reducing urban distribution accessibility.

Therefore, we aim to test the following hypothesis:

> **H2:** "Driver misbehavior" is positively related to "lack of accessibility and delivery planning."

Impact of the Lack of Urban Road Infrastructure on Driver Behavior, Accessibility and Delivery Planning, and Safety and Risk Problems in Urban Freight Distribution. Intense economic activity, common in every big city, leads to demands for the circulation of traded goods and service providers. For this to happen sustainably, there needs to be an urban road infrastructure that supports urban logistics, which is generally absent or deficient in most cities. Areas for parking and unloading trucks are the most accessible solutions to implement and maintain a sustainable urban logistics policy (*35*) and are more efficient than other measures (*36*). When the number of such spaces available for commercial vehicles is insufficient or when there are narrow streets, the delivery operation becomes inefficient (*11*) and the need for delivery planning increases. These factors lead couriers to stop far from delivery locations or to park irregularly (e.g., double parking) (*32*, *33*), causing the risk of cargo theft (*11*, *12*). According to Dablanc (*13*), the lack of places for loading and unloading in cities accentuates the congestion problem as these operations start to occur in the lanes destined for the circulation of vehicles (or on sidewalks inappropriate for unloading), reducing the urban distribution accessibility, and increasing the risk of delay in delivery and breakdowns (*12*).

In turn, driver behavior can also be affected by the lack of urban infrastructure. For example, parking in irregular areas or on double lines may occur because of the lack of public structures or regulated areas for loading and unloading (*13*). Chiara et al. (*37*) reported that, in response to the lack of available parking, drivers behaved in one of the following ways: (a) unauthorized parking: drivers park in alternative locations that include unauthorized curb parking, travel lanes, alleys, and other off-street parking; (b) cruising: drivers search for available parking; (c) queueing: drivers park and wait in the vehicle until the desired parking spot becomes available; and (d) re-routing: drivers change their delivery destination route, postponing the parking choice to serve a given location at a later time.

Therefore, we aim to test the following hypothesis:

> **H3:** "Lack of urban road infrastructure" is positively related to "driver misbehavior."
> **H4:** "Lack of urban road infrastructure" is positively related to "lack of accessibility and delivery planning."
> **H5:** "Lack of urban road infrastructure" is positively related to "safety and risk problems in urban freight distribution."

Effects of Accessibility and Delivery Planning on Safety and Risk Problems in Urban Freight Distribution. Vehicle congestion has been one of the biggest problems in every large metropolis for a long time. Allied to noise and pollutant emission, these are characteristics that reduce the accessibility and attractiveness of urban areas. Approximately 25% of road traffic in the city is from cargo movement, representing up to 30% of vehicles per kilometer (*29*), reducing the region accessibility and causing delays in deliveries (*11*, *12*). Greater difficulty accessing multiple locations (e.g., in unsafe areas), a long time to find a parking space, and lack of delivery planning can all increase the risk of cargo theft (*11*, *23*). Furthermore, freight trips are concentrated in brief time frames, leading to overcrowding in urban areas (*38*); in turn, the risk of being fined may increase. In addition to affecting companies' operating costs, higher congestion rates expose logistics to the risk of delay, damage, and theft during deliveries (*11*, *23*).

Therefore, we aim to test the following hypothesis:

> **H6:** "Lack of accessibility and delivery planning" is positively related to "safety and risk problems in urban freight distribution."

Impact of the Receiver's Characteristics on Accessibility and on Safety and Risk Problems in Urban Freight Distribution. One of the most common problems in the interaction between shippers, transporters, and receivers of goods is the time spent on deliveries, whether because the customer is not prepared to receive the goods when the truck arrives because of a lack of structure or equipment to receive and move the goods or because of the number of trucks that arrive at the same time, creating an imbalance between demand and receiving capacity. Small retailers usually receive goods without advance scheduling (*16*), which may show a lack of delivery planning. One of the reasons for retailers not to schedule goods being received is the low level of planning, where orders are generated as inventories are consumed (*10*). Moreover, intrinsic factors of delivery-specific characteristics such as weight, volume, the number of delivery workers, and the number of businesses served may affect the delivery time (*39*). These characteristics of the receiver affect accessibility, which can lead to long lines (*22*) and drivers spending a long time finding a parking space (*15*). These factors also hamper the operators in reaching the delivery location and cause traffic congestion in the region. Researchers often view delivery activities as a major contributor to congestion and traffic problems in urban areas (*16*). In addition, inconveniences occur, such as the noise generated by operating in residential areas, more significant risks of cargo theft, and increased labor costs, both for carriers and receivers (*11*, *19*).

Therefore, we aim to test the following hypothesis:

> **H7:** "Receiver characteristics" is positively related to "lack of accessibility and delivery planning."
> **H8:** "Receiver characteristics" is positively related to "safety and risk problems in urban freight distribution."

Impact of Truck Circulation Restrictions and Driver Behavior. The regulations related to time-windows allowed for trucks and areas with restricted access affect drivers' behavior by forcing them to replan the sequence of deliveries they will make during the day and use alternate routes to avoid restricted areas (*12*). Regulations also force driver misbehavior by using inadequate parking areas and parking on double lines (*17*). These alternate routes are known as detours (*23*, *40*), increasing the traffic and the operational risks of incurring a fine, and causing delay to delivery, as well as cargo damage or theft (*23*).

Therefore, we aim to test the following hypothesis:

> **H9:** "Truck circulation restriction" is positively related to "driver's misbehavior."

Control Variable. We included the variable "Vehicle type" in the structural model as a control variable affecting the main construct "safety and risk problems in urban freight distribution" to evaluate if vehicle type has an influence on the construct. We expect that small vehicles that are allowed to operate in restricted zones and time-windows will experience more safety and risk issues from high traffic volumes.

These hypotheses are summarized in Table 1, supported by the literature previously mentioned.

Table 1. Hypotheses and Supporting Literature

Hypothesis	References
H1: "Truck circulation restriction" is positively related to "lack of accessibility and delivery planning"	(*15*, *16*, *18*, *19*, *21*, *22*, *27–30*, *41*)
H2: "Driver misbehavior" is positively related to "lack of accessibility and delivery planning"	(*12*, *17*, *31–34*, *42*, *43*)
H3: "Lack of urban road infrastructure" is positively related to "driver misbehavior"	(*12*, *13*, *32*, *33*, *35–37*)
H4: "Lack of urban road infrastructure" is positively related to "lack of accessibility and delivery planning"	(*12*, *13*, *32*, *33*, *35–37*)
H5: "Lack of urban road infrastructure" is positively related to "safety/risk"	(*11–13*, *32*, *33*, *35–37*)
H6: "Lack of accessibility and delivery planning" is positively related to "safety and risk"	(*11*, *12*, *23*, *29*, *38*)
H7: "Receiver characteristics" is positively related to "lack of accessibility and delivery planning"	(*10*, *11*, *15*, *16*, *19*, *22*, *39*)
H8: "Receiver characteristics" is positively related to the "safety and risk"	(*10*, *11*, *15*, *16*, *19*, *22*, *39*)
H9: "Truck circulation restriction" is positively related to "driver's misbehavior"	(*12*, *23*, *40*)

Table 2. Constructs, Respective Items, and Scale Measurement

#	Construct		Item	Scale measurement
1	Location		Address (street name)	Text
2	Delivery		Vehicle	Category (4 options)
			Average deliveries in the street	Category (2 options)
			Delivery frequency in the street	Category (3 options)
			Time of delivery	Category (3 options)
3	Truck circulation restriction (CR)			
		CR1	Restricted delivery time window	Scale (0–10)
		CR2	Restricted Structural Roads (VER)	
		CR3	Restricted truck circulation (ZMRC)	
4	Receiver characteristics (RC)			
		RC1	Lack of structure for receiving cargo	Scale (0–10)
		RC2	Long truck lines during delivery	
		RC3	Lack of equipment to move the goods	
		RC4	Excessive time for loading and unloading	
		RC5	Long waiting time to be attended	
		RC6	Lack of receiver support on delivery	
		RC7	Receiver flexibility to receive in another period	
5	Accessibility and delivery planning (AC)			
		AC1	Traffic congestion	Scale (0–10)
		AC2	Lack of delivery planning	
		AC3	Difficulty in reaching the delivery location	
		AC4	Long time to find a slot	
6	Urban road infrastructure (RI)			
		RI1	Lack of loading and unloading area	Scale (0–10)
		RI2	Constraints such as "narrow track"	
		RI3	Inappropriate sidewalks for unloading	
		RI4	Inappropriate local signage	
7	Driver's behavior (DB)			
		DB1	Frequent use of double parking for loading/unloading	Scale (0–10)
		DB2	Use of vacancies at restricted times	
		DB3	Frequent use of irregular space during loading/unloading	
		DB4	Often exceeds track speed	
8	Safety and risk in urban freight distribution (SR)			
		SR1	Risk of delivery delay	Scale (0–10)
		SR2	Risk of getting fine	
		SR3	Lack of safety in the loading/unload bays	
		SR4	Risk of cargo theft	
		SR5	Risk of cargo damage	

Methodology

Based on the literature review presented in the previous sections, the preliminary model was defined to design the questionnaire and collect data from the drivers (representatives of the carriers), which will be presented in the following sections. The proposed model was evaluated through an exploratory approach using the analysis of structural equation modeling (SEM) to obtain the most appropriate model for reliability and validity.

Questionnaire Development

The questionnaire was developed following the guide proposed by Forza (*44*), encompassing three types of individuals in this freight urban transport study: (i) research colleagues who participated in the study and who evaluated the alignment of the survey with the study's objectives; (ii) experts from the transport sector to validate the questions; and (iii) organizations that showed the contingencies that may affect data collection. These phases were conducted during 14 meetings using the Google Meet platform between August and December 2020. These meetings comprised the following representatives: two shippers, two logistics service providers, four start-ups from the logistics sector, two experts from the São Paulo Institute of Cargo Transport (IPTC in Portuguese) and the Regional Association of Cargo Carriers (SETCESP in Portuguese), the manager of the Traffic Engineering Company (CET in Portuguese) in São Paulo city, and four academic researchers. Finally, the questionnaire was distributed to various drivers using the SurveyMonkey electronic platform to evaluate the issues related to the urban last-mile distribution.

Table 2 shows the division of the questionnaire blocks and the details of each construct. In the first block of the questionnaire, information was collected on the location to be analyzed through the street name. In the second block, we sought to understand better the logistical context of service in these locations by collecting information on the frequency of visits to the site, the average number of deliveries, the profile of the most used vehicles, and the most frequent reception time. The other blocks of the questionnaire (blocks 3 to 8) are intended to map the main problems and challenges to deliveries in the region in question. To do this, 27 attributes common to urban distribution logistics were listed so that drivers could indicate their perception on a Likert ordinal scale from 0 to 10 if the attribute was present in that location (where 0 = totally disagree and 10 = totally agree). We assumed an 11-point scale as recommended by Leung (*45*) and Wu and Leung (*46*) to make the data closer to continuous scales and normality so that it can be treated as a continuous measure, and arithmetic operations can be performed. Moreover, it was observed that interviewers in Brazil preferred the 0 to 10 scale because it is easy to understand (*47*).

Method of Analysis

SEM is a group of multivariate statistical techniques that enable simultaneous examination of a set of theoretical relationships between one or more independent variables and one or more dependent variables (*48*). Combining aspects of factor analysis (for the stage of measurement) with multiple regression (in the structural modeling), SEM enables the researcher to examine, simultaneously, multiple relationships of dependence and independence between latent variables through observed variables, and is one of the most recent multivariate techniques used in operations management (*49*).

Therefore, a SEM consists of two elements. There is a structural model, also called the inner model, in which the relationships (paths) are displayed between the constructs. The second element, the measurement model, also known as the external model (outer model), shows the relationships between constructs and indicators. Empirical measures enable us to compare structural models with theoretically established reality, making it possible to determine how well the theory fits the data (*50*, *51*). Our inner model (Figure 1) comprises six latent constructs ("truck circulation restriction," "receiver characteristics," "accessibility and delivery planning," "urban road infrastructure," "driver's behavior," "safety and risk in urban freight distribution") and the outer model by each respective indicator (Table 2). The model was developed to confirm a set of primary hypotheses (Table 1) as to the influence/interaction between the constructs.

We chose to use the PLS method because the sample size is relatively small (*52*), and some of the measured variables showed unequally high distributions. It is noteworthy that the PLS method has an advantage over other covariance-based approaches for SEM. The PLS method does not assume any form of distribution as a premise for the measured variables, adapting itself to the proposed study model (*53*). In addition, PLS requires only 10 cases per predictor in regression with a larger number of parameters, which can be more easily applied when a relatively small dataset is available (*53*).

It is important to highlight, in SEM, the measurement of the phenomenon. As a rule, it is not directly observable (latent construct) and occurs through indicators that serve as representative variables of the latent variable of interest. Thus, combining several items that make up a scale makes it possible to measure, indirectly, the abstract concept of interest (*54*). Latent variables can be exogenous, as those constructs that explain other constructs in the model ("truck circulation restriction," "driver behavior," "receiver characteristics," "accessibility and delivery planning," and "urban road infrastructure") and endogenous, as those constructs that are explained in the model ("safety and risk in urban freight distribution," "accessibility and delivery planning," and "driver behavior").

Having implemented the model, it must be validated to guarantee its quality and predictive ability. The evaluation of measurement and structural models in SEM are based on non-parametric evaluation criteria, using procedures such as bootstrapping and blindfolding (*50*). In this aspect, the evaluation of measurement models (relationships between indicators and constructs) and the structural model (relationships between the constructs) are submitted to specific tests. Confirmatory factor analysis is used to validate the measurements of the variables. The measurement model is analyzed based on the reliability of consistency, evaluated by Cronbach's α and composite reliability indicators, accepting, for exploratory research, values between 0.60 and 0.70. Convergent validity is assessed by the average variance extracted (AVE) indicator, accepting values above 0.5, and factorial load (external load) accepting values above 0.70. Discriminant validity is assessed by the Fornell and Larcker criterion (*55*, *56*). This method states that the construct shares more variance with its indicators than any other construct. It compares the square root of the AVE values with the latent variable correlations. Specifically, the square root of each construct's AVE should be greater than its highest correlation with any other construct (*57*).

The prediction of the structural model is evaluated by the coefficient of determination (R^2), predictive relevance (Stone-Geisser, Q^2), size and significance of path coefficients, effect sizes (f^2), and (q^2) (*50*). The coefficient R^2 explains the variance of the endogenous or dependent constructs given by the exogenous or independent constructs and represents the measure of the predictive power within the sample. Values of 0.67 are considered significant, while values of 0.33 and 0.19 are considered moderate and weak, respectively (*53*). The blindfolding procedure estimates the predictive relevance (Q^2) and represents a measure of the predictive relevance of the path model for a dependent construct. Chin and Newsted (*52*) suggests that a good model demonstrates relevance when Q^2 is greater than zero. The path coefficients represent the hypothesized relationships linking the constructs. Path coefficient values are standardized from 1 to -1 with coefficients closer to $+1$ representing strong positive relationships and coefficients closer to -1 indicating strong negative relationships. Although values close to $+1$ or -1 are almost always statistically significant, a standard error must be obtained using bootstrapping to test for significance (*55*, *58*). We used the goodness of fit (GOF) measure to evaluate the model's overall fit (*59*).

The effect size is calculated by noting the change in R^2 when a specific construct is eliminated from the model. To calculate the f^2, the researcher must estimate two PLS path models. The first path model should be the full model as specified by the hypotheses, yielding the R^2 of the full model (i.e., R^2 included). The second model should be identical although a selected exogenous construct is eliminated from the model, yielding the R^2 of the reduced model (i.e., R^2 excluded). Based on the f^2 value, the effect size of the omitted construct for a particular endogenous construct can be determined such that 0.02, 0.15, and 0.35 represent small, medium, and large effects, respectively (*60*, *61*). The q^2 effect size is calculated with the same procedure but reflects the effects of the predictive relevance Q^2.

The PLS model follows the systematic procedure for applying PLS-SEM proposed by Leguina (*57*) and is implemented using the software package SmartPLS2.0 (*62*).

It is also worth mentioning that we evaluated whether it was necessary to control the model bias. A common method bias can occur when the dependent variable and the independent variables are obtained from the same source (e.g., an interviewee), resulting in undervaluing or overvaluing the correlation between latent variables (*63*). As the scales used in this research were between 0 and 10, there was a balance between the number of items evaluated with the frequencies "not important" and "very important," "not affected," and "the most affected" and "bad" and "great." Therefore, we discarded the possibility that modeling bias could have occurred.

Study Area, Population, and Sampling

The study area covers the sub-prefecture of the city of São Paulo. According to Brazilian Institute of Geography and Statistics data (*64*), the population of the city of São Paulo is approximately 12.3 million inhabitants, and the population density exceeds 7,000 inhabitants per km^2, making it the largest and most densely populated city in Brazil. In economic activity, São Paulo is the city that makes the most significant contribution to Brazil's production of goods and services, with a gross domestic product of R$ 699 billion. Logistics chains become increasingly complex because of operational limitations set by regulatory authorities in cities and growing consumer demand. The locations mentioned in the answers belong to the various regions of the city: east, west, center, north, south, and other cities belonging to the greater São Paulo area. Each region has a distinct geographic size, population, Human Development Index (HDI), and infrastructure characteristics.

The research was conducted with carriers that deliver consumers purchases from large companies; as this service is mainly dedicated, there is a high degree of loyalty, and delivery feedback is often required. The profile of customers served is primarily small retailers; supermarket chains are not part of this study. These retailers are engaged in selling recurrent consumer products, such as food and hygiene and cleaning products. It is also important to note that the urban freight transport for such recurrent consumer products may differ from deliveries of other products, such as cosmetics, or goods for bazaar and stationery stores.

The sample comprised 143 drivers. The answers were analyzed to check their validity and that the streets were located in the region of interest (São Paulo metropolitan area). All the 143 answers were validated, which is above that needed by the test's sample size, executed by the G*Power software (*65*, *66*) of 129 answers. The participating drivers from the research work in the State of São Paulo and the city represent about 35% of the Brazilian Gross Domestic Product (GDP).

Table 3 presents the results of the survey on geographic location, frequency, and quantity of deliveries on the streets surveyed, the most frequent delivery times, and the profiles of vehicles used. As expected for urban logistics, small vehicles, urban cargo vehicles (Veículo Urbano de Carga [VUC]), and light freight vehicles predominate, and they deliver almost exclusively during business hours. All regions of the city are represented in that they were mentioned by the survey respondents. In most of the streets analyzed, there are daily deliveries. At most times, the number of deliveries is less than three deliveries per street. This low rate can be explained by the drivers surveyed being engaged in the service of markets (business-to-business, B2B), where the number of deliveries per street is usually lower than for end-consumer service (business-to-consumer, B2C).

Data Collection and Analysis

The data were collected between November 2020 and October 2021. Furthermore, the data obtained were analyzed using descriptive statistics that allowed a geographic mapping of the main last-mile logistics problems and quantified their intensity. To investigate the relationships between urban distribution constructs based on the perception of agents involved in the activity, we propose a SEM to explain the interaction among them and urban logistics problems in the city of São Paulo.

The collected data were statistically tested to guarantee validity (Table 4). Three measurement variables were excluded from the model because of the statistical significance (p-value > 0.05) of a low answer.

Table 3. Research Sample

Item	Detail	Frequency	Percent	Cumulative percent
Location (city of São Paulo)	North zone	7	5	5
	South zone	25	17	22
	East zone	21	15	37
	West zone	25	17	55
	Center	33	23	78
	Greater São Paulo	32	22	100
Average deliveries per day on the street	Up to 3 deliveries	116	81	81
	3 or more deliveries	27	19	100
Frequency of deliveries	Daily	58	41	41
	1× per week	45	31	72
	3× per week	40	28	100
Delivery time	Morning	100	70	70
	Afternoon	41	29	99
	Night/dawn	2	1	100
Vehicle type	Light freight vehicle	29	20	20
	VUC 1.6 t	76	53	73
	VUC 3.5 t	33	23	97
	Truck	5	3	100

Note: VUC = urban cargo vehicle (Veículo Urbano de Carga).

Results and Empirical Analysis

Validity of the Measurement Model

The confirmatory factor analysis was conducted to examine the reliability and validity of the measurement items. Table 5 shows the calculation results of the factor loadings (FL), reliabilities (Cronbach's α and composite reliability), and AVE of each construct. FLs were calculated and were above 0.6, ranging from 0.51 to 0.94 to all measurement items, excepting item DB3 (0.51). Generally, indicators with FLs between 0.40 and 0.70 should be considered for removal from the scale, but they were retained on the basis of their contribution to content validity (*57*). The Cronbach's and composite reliability measures were calculated for all six latent variables and were above 0.6, ranging from 0.63 to 0.94. In general, these results indicated strong composite reliability. Convergent validity was checked using AVE for the six latent variables and it was found that for all the variables, the AVE was above 0.5, ranging from 0.58 to 0.84, indicating strong convergent validity.

In addition, Table 6 presents the model discriminant validity. The square root of each construct's AVE (diagonal) is greater than its highest correlation with any other construct. The constructs share more variance with their associated indicators than with any other construct. The highest correlation among constructs was obtained with the construct "Truck circulation restriction" of 0.91.

The measurement model was found to have adequate fit, reliability, convergent validity, and discriminant validity. All the tests were successful, and the measurement model is valid and reliable.

Validity of the Structural Model

Table 7 shows that all the constructs present a valid predictive relevance for the model ($Q^2 > 0$) and performed suitably for this research. The results of communalities (AVE of each construct) are valid (>0.5) as the results of R^2. The construct's accessibility and delivery planning, and safety and risk problems in distribution, are considered to have a significant level of predictive power ($R^2 > 0.67$). At the same time, driver behavior was considered to have a moderate level of predictive power ($R^2 > 0.33$). The results of R^2 are also necessary to calculate the GOF value. The global GOF value is 0.69, which exceeds the cut-off value of 0.36 for large effect sizes of R^2 (*67*). The GOF result validates the overall model fit.

We measured the structural model properties using beta coefficients, standard deviation error, and t-values computed using 1,000 bootstrapping runs. Figure 2 shows all the path analyses, and the results partially support the hypothesized effects of the constructs. The hypothesized effects results are reported in Table 8.

We highlight the large effect of the receiver characteristics on accessibility and delivery planning (H7 = 0.43). The lack of structure or equipment for receiving and moving the cargo during the delivery may cause excessive dwell time and truck lines during the delivery or waiting time to be attended, worsening the accessibility issues in the retail area and the city.

The statistical analysis did not support hypothesis H1. This may be because drivers only access the city with small vehicles that are authorized (by the municipal authorities) and may not perceive that it could interfere

Table 4. Statistical Validity

Factor	Measurement	Descriptive statistics Mean	Descriptive statistics SD	Confirmatory analysis p-values
Truck circulation restriction (CR)				
CR1	Restricted delivery time window	6.75	2.91	0.01
CR2	Restricted structural roads (VER)	6.73	2.86	0.01
CR3	Restricted truck circulation (ZMRC)	6.66	3.09	0.02
Receiver characteristics (RC)				
RC1	Lack of structure for receiving cargo	6.74	2.76	0.01
RC2	Long truck lines during delivery	7.07	2.74	0.00
RC3	Lack of equipment to move the goods	6.78	2.96	0.01
RC4	Excessive time for loading and unloading	7.12	2.82	0.01
RC5	Long waiting time to be attended	7.07	2.74	0.00
RC6	Lack of receiver support on delivery*	3.73	3.18	0.12
RC7	Receiver flexibility to receive in another period*	2.89	2.87	0.16
Accessibility and delivery planning (AC)				
AC1	Traffic congestion	7.43	2.58	0.00
AC2	Lack of delivery planning	7.32	2.80	0.00
AC3	Difficulty in reaching the delivery location	6.59	3.00	0.01
AC4	Long time to find a slot	7.47	2.64	0.00
Urban road infrastructure (RI)				
RI1	Lack of loading and unloading area	7.16	2.79	0.01
RI2	Constraint such as "narrow track"	6.99	2.83	0.01
RI3	Inappropriate sidewalks for unloading	7.23	2.90	0.01
RI4	Inappropriate local signage	6.66	2.80	0.01
Driver's behavior (DB)				
DB1	Frequent use of double parking for loading/unloading	6.61	2.84	0.01
DB2	Use of vacancies at restriction times	6.92	2.94	0.01
DB3	Frequent use of irregular space during loading/unloading	5.66	3.73	0.05
DB4	Often exceeds track speed*	5.35	3.27	0.06
Safety and risk in urban freight distribution (SR)				
SR1	Risk of delivery delay	6.80	2.84	0.01
SR2	Risk of get fine	7.96	2.63	0.00
SR3	Lack of safety in the loading/unload bays	7.03	3.06	0.01
SR4	Risk of cargo theft	7.38	2.85	0.00
SR5	Risk of cargo damage	7.04	2.70	0.00

Note: SD = standard deviation. *Measurements excluded from the model.

with accessibility and may suggest better delivery planning. All the other hypotheses were supported.

Discussion of the Results

To investigate which construct has the most impact on the model objective, we analyzed the explained variance for each one (Table 9). We also calculated each construct's effect size (f^2). The results of (f^2) are classified according to the results considering that the value of (f^2) is 0.02 (small), 0.15 (medium), and 0.35 (large) (*61*).

We found that the constructs accessibility and delivery planning, urban road infrastructure, receiver characteristics, and vehicle type explained 67.60% of the variance in safety and risk in urban freight distribution. However, the accessibility and delivery planning construct was responsible for 44.78% (f^2 = 0.08) of the total variance. In other words, our results show that safety and risk in urban freight distribution issues are mainly caused by the lack of accessibility to the delivery locations (e.g., traffic congestion, a long time for trucks to find a slot, difficulties in reaching the delivery location) and may also be the inefficient delivery planning. In addition, urban road infrastructure is also a relevant construct contributing with 37.46% (f^2 = 0.10), the receiver characteristics construct with 25.86% (f^2 = 0.02) and the vehicle type with −8.10% of the total variance.

The individual constructs of accessibility and delivery planning, and urban road infrastructure have the strongest effects on safety and risk in urban freight distribution.

Accessibility and delivery planning is the first construct that has the most impact on safety and risk in urban freight distribution (44.78%). Vehicle congestion is one of the biggest problems in every large metropolis and reduces the accessibility of urban areas. Approximately 25% of this road traffic is caused by

Table 5. Confirmatory Factor Analysis and Scale Reliability

Scale items	Factorial loadings	Cronbach's alpha	Composite reliability	Average variance Eextracted
Truck circulation restriction (CR)				
ZC1	0.91	0.90	0.94	0.84
ZC2	0.94			
ZC3	0.89			
Receiver characteristics (RC)				
RC1	0.79	0.87	0.90	0.65
RC2	0.81			
RC3	0.76			
RC4	0.85			
RC5	0.83			
Accessibility and delivery planning (AC)				
AC1	0.88	0.86	0.91	0.71
AC2	0.88			
AC3	0.76			
AC4	0.85			
Urban road infrastructure (RI)				
RS1	0.84	0.87	0.91	0.71
RS2	0.91			
RS3	0.84			
RS4	0.79			
Driver behavior (DB)				
DB1	0.86	0.63	0.80	0.58
DB2	0.86			
DB3	0.51			
Safety and risk in urban freight distribution (SR)				
SR1	0.85	0.83	0.88	0.60
SR2	0.76			
SR3	0.75			
SR4	0.78			
SR5	0.73			

Table 6. Discriminant Validity

Items	AC	RC	DB	RS	SR	CR
Accessibility and delivery planning (AC)	**0.84**	—	—	—	—	—
Receiver characteristics (RC)	0.83	**0.81**	—	—	—	—
Driver behavior (DB)	0.76	0.74	**0.76**	—	—	—
Urban road infrastructure (RS)	0.81	0.81	0.67	**0.85**	—	—
Safety and risk in urban freight distribution (SR)	0.78	0.76	0.70	0.76	**0.77**	—
Truck circulation restriction (CR)	0.74	0.73	0.66	0.78	0.72	**0.91**

Note: Numbers shown in bold on the diagonal denote the square root of the average variance extracted; the other numbers represent correlations between the latent variables.

cargo movement (*29*). The accessibility and delivery planning construct in our model is most affected (43.57%) by the receiver characteristics and urban road structure. Small retailers do not usually schedule or work with receiving schedules because of a lack of operational organization, and therefore they deal with the unbalance of demand in their operations (*16*) or experience a concentrated demand during the peak hours. Accessibility and the need for a better delivery planning is also a challenge for the freight operators in developing markets (*11*, *68*) that face several problems establishing efficient movement in urban areas with heavy traffic congestion. The rapid, organic, and widely unplanned growth of these cities means that their infrastructure is often insufficiently equipped to deal with the increasing private, public, and commercial vehicular traffic, leading to more or less permanent congestion (*12*, *69*). Growing fragmentation of freight flow, increased frequency, smaller

Table 7. Model Measures

Latent variables	R^2	Communalities	Goodness of fit	Q^2 - Predictive relevance
Accessibility and delivery planning	0.80	0.71	—	0.36
Safety and risk	0.68	0.60	—	0.37
Driver behavior	0.50	0.58	—	0.37
Receiver characteristics	—	0.65	—	0.37
Urban road infrastructure	—	0.71	—	0.37
Truck circulation restriction	—	0.84	—	0.37
Vehicle type	—	1.00	—	0.38
Average	0.66	0.73	0.69	0.37

Table 8. Hypothesis Testing

Hypothesized directions	Impact	Results	T statistics
H1. Truck circulation restriction	Accessibility	Not supported	1.92 NS
H2. Driver behavior	Accessibility	Supported	4.81***
H3. Road infrastructure	Driver behavior	Supported	4.67***
H4. Road infrastructure	Accessibility	Supported	3.70***
H5. Road infrastructure	Safety and risk	Supported	3.85***
H6. Accessibility	Safety and risk	Supported	4.68***
H7. Receiver characteristics	Accessibility	Supported	7.62***
H8. Receiver characteristics	Safety and risk	Supported	2.84***
H9. Truck circulation restriction	Driver behavior	Supported	4.66***

Note: NS = Not significant, *** $p < 0.01$.

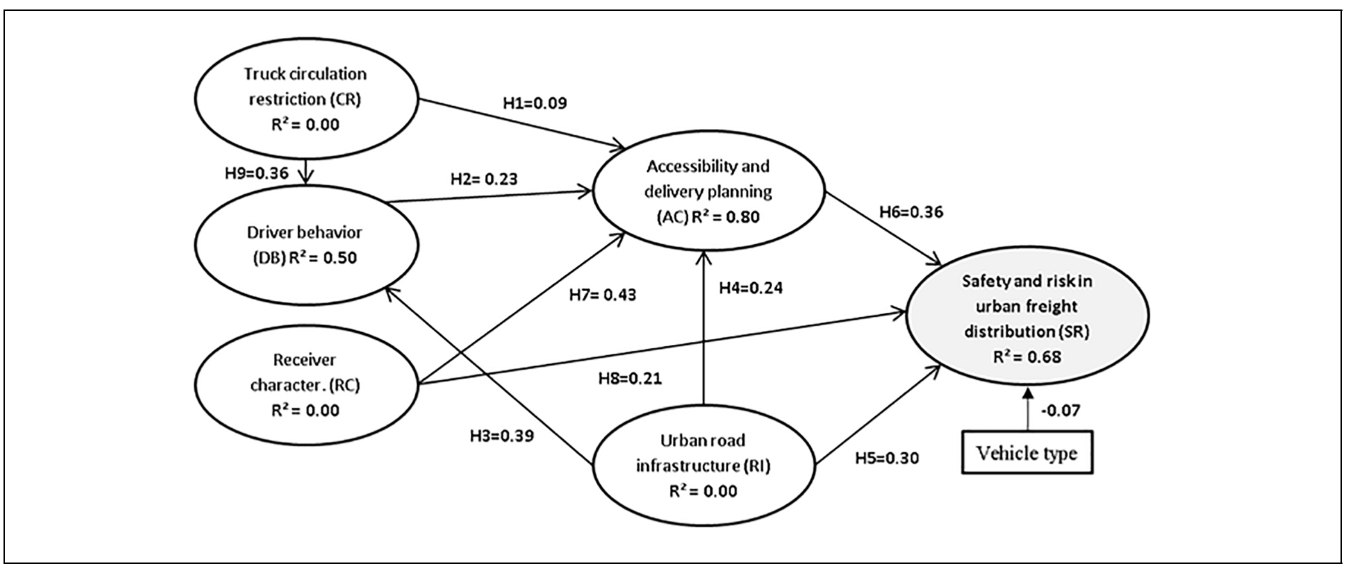

Figure 2. Path analysis.

volumes, and just-in-time deliveries leads to lower vehicle load factors and the unnecessary presence of freight vehicles (*29*, *30*).

Urban road infrastructures is the second construct that most affects safety and risk in urban freight distribution (37.46%). The strong demand for goods in a highly dense and congested city where spaces are scarce may incur poor parking practices (e.g., illegal and double parking, traveling for parking, and other practices). These practices can result from an inefficient infrastructure, worsening the congestion levels even more (*8*, *9*, *33*). These results also corroborate with the research of

Table 9. Explained Variance for Each Construct of the Structural Model

Relationships (hypothesized directions)	% VAR	% Total VAR	Effect size (f^2)*
Urban road infrastructure ➔ Safety and risk (H5)	25.33	37.46	0.10
Accessibility and delivery planning ➔ Safety and risk (H6)	30.27	44.78	0.08
Receiver characteristics ➔ Safety and risk (H8)	17.48	25.86	0.02
Vehicle type ➔ Safety and risk (Control variable)	−5.47	−8.10	0.02
Total construct Safety and risk	**67.60**	**100.00**	—
Receiver characteristics ➔ Accessibility and del. planning (H7)	34.77	43.57	0.25
Driver behavior ➔ Accessibility and delivery planning (H2)	18.61	23.32	0.11
Urban road infrastructure ➔ Accessibility and del. planning (H4)	19.35	24.24	0.07
Truck circulation ➔ Accessibility and delivery planning (H1)	7.08	8.87	0.01
Total construct Accessibility and delivery planning	**79.80**	**100.00**	—
Urban road infrastructure ➔ Driver behavior (H3)	25.65	51.53	0.12
Truck circulation restriction ➔ Driver behavior (H9)	24.13	48.47	0.10
Total construct Driver behavior	**49.78**	**100.00**	—

Note: VAR = Variance *Effect size (f^2): f^2 values are classified according to the results for (f^2) as 0.02 (small), 0.15 (medium), and 0.35 (large) (*60*). Total construct variance in bold.

Dablanc (*13*), reporting that freight needs dedicated urban spaces, such as loading and unloading areas (public or private, on-street or off-street) and that insufficient delivery spaces will transfer delivery operations onto traffic lanes, and will lead to congestion. Several cities or countries have created policies to achieve this objective (Paris, London, Argentina, Tokyo, Spain, South Korea), but these discussions are still incipient in São Paulo (*21*). Moreover, vehicle types with higher transport capacity produce a negative impact on safety and risk in urban freight distribution ($\beta = -0.07$; t-value = 2,24; p-value = 0.03; $f^2 = 0.02$), reducing the issues found in the operations. In other words, vehicle types with higher transport capacity have less problems than those with lower transport capacity.

Conclusion

Our study innovates by providing a theoretical understanding of the complex urban freight distribution system. Rather than focusing on "accessibility and delivery planning," and "urban road infrastructure" as separate freight distribution antecedents, our model provides insights into how "safety and risk in urban freight distribution" are affected by the lack of "accessibility and delivery planning" and poor "urban road infrastructure." Therefore, the findings provide a theoretical understanding of how last-mile operations affect safety and risk in urban freight distribution.

Contributions of the Study

This research contributes to the literature by developing and presenting a novel model that measures the perceptions of drivers operating in the last mile of urban distribution. The model jointly analyses several relevant constructs and indicators on regulatory and logistics issues and truck size that affect the operation's safety and risk. According to the existing literature and the best of our knowledge, this is the first study that provides an integrated approach to investigating last-mile issues in urban freight distribution.

Contributions for Practitioners and Policymakers

For practitioners, this study offers a range of attributes (e.g., restrictions, planning, driver behavior, risks) that must be evaluated to optimize their distribution networks. The distribution planning can be improved by analyzing the regional specificities such as the demand level, type of products, truck size, truck occupation, or risk of theft, which may require greater interaction/collaboration among shippers, transporters, and receivers. In addition, an integrated intelligent transport system could monitor the parking time and the availability of load/unloading areas, providing real-time information for parking schedules. It could optimize the available time-windows for delivery to retailers and the time to find a parking space, reducing the delivery frequency level.

Improvements in training and incentives for drivers with better behavior would also significantly reduce double parking and congestion within urban areas. These initiatives may mitigate the risks of delay, damage, and theft during deliveries. According to the literature, those initiatives are present in developed countries but are not fully tested or implemented in a megacity, for instance, in São Paulo. Therefore, if the model is implemented, it may provide significant gains for everyone in the urban freight distribution.

This research also contributes to public policymakers with a theoretical background to develop an efficient urban freight mobility plan for Brazilian cities. These managers consider urban distribution a problem, but few actions have been taken to change this scenario, especially those related to the restrictions (*21*). In this line, this research may support specific policies, such as:

(a) Implementing off-hour deliveries and regulating freight parking and loading zones: these are the most representative and potent initiatives that could improve the "accessibility and delivery planning" issues (e.g., traffic congestion, difficulty in reaching the delivery location, and a long time to find a slot). Public policies promoting access to urban locations according to weight, volume, and vehicle type (*15*) should also reduce the number of vehicles transiting and the risk of accidents or theft.
(b) "Urban road infrastructure" issues (e.g., lack of loading and unloading area, narrow track, inappropriate sidewalks, and signage) can be addressed with adequate public policies. The considered policies include revitalizing sidewalks, implementing adequate signage for cargo trucks, creating and regulating freight parking and loading zones, and improving the supply infrastructure to support cargo vehicles (*8*, *9*). These policies may provide an adequate number of optimally located loading and unloading locations, ensuring availability and reducing the illegal parking of cargo and non-cargo vehicles (*70*). Creating regulated and safe parking and unloading areas for trucks is one of the simplest solutions to implement and maintain a sustainable urban logistics policy (*35*).
(c) Revise the standard truck regulations, adapting them to each district's characteristics, considering the region's demand level, the types of products most delivered, and the existing infrastructure.

Limitations and Future Studies

This research was carried out with a sample of the population of drivers who work primarily in urban operations serving small retailers. The sample is relatively small and restricted to retailers in São Paulo, although it could be helpful in analyzing similar operations in other megacities. Other retailers' operations vary depending on the products, customers, fleet profiles, and location, which may have different results. With regard to vehicle type of fleet, the results showed a weak effect (0.02) on safety and risk problems, although this relationship was at 1% statistical significance. However, a larger sample may be more appropriate to confirm this result.

We found opportunities for future studies to enrich knowledge on the subject:

- Expand the search horizon for other types of products and end-consumer operations (B2C).
- Carry out a more in-depth study within the same chain researched in the current work, expanding the analyses to other agents of the logistics chain, such as freight receivers and logistical service providers, to verify if there is convergence in the results.
- Evaluate operations in other megacities and perform a cross-country analysis comparing developed and emergent economies.
- Evaluate sustainable aspects of urban distribution.
- Evaluate the impacts on the vehicle load factor from different policies of truck circulation restrictions.
- Evaluate practitioners' perceptions of nighttime deliveries to propose alternative operational policies for urban distribution.

Author Contributions

The authors confirm contribution to the paper as follows: study conception and design: J. Vieira, L.Guarino; data collection: F.Barros; analysis and interpretation of results: L.Guarino, F.Barros; draft manuscript preparation: L.Guarino. All authors reviewed the results and approved the final version of the manuscript.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This research was funded by the National Council for Scientific and Technological Development (CNPq), grant number 3099172019-0.

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References

1. Ranieri, L., S. Digiesi, B. Silvestri, and M. Roccotelli A. Review of Last Mile Logistics Innovations in an Externalities Cost Reduction Vision. *Sustainability*, Vol. 10, No. 3, 2018, P. 782. https://doi.org/10.3390/su10030782.
2. Sheth, M., P. Butrina, A. Goodchild, and E. McCormack. Measuring Delivery Route Cost Trade-Offs Between Electric-Assist Cargo Bicycles and Delivery Trucks in Dense Urban Areas. *European Transport Research Review*, Vol. 11, No. 1, 2019, pp. 1–12. https://doi.org/10.1186/s12544-019-0349-5.

3. Nenni, M. E., A. Sforza, and C. Sterle. Sustainability-Based Review of Urban Freight Models. *Soft Computing*, Vol. 23, No. 9, 2019, pp. 2899–2909. https://doi.org/10.1007/s00500-019-03786-x.
4. Melacini, M., S. Perotti, M. Rasini, and E. Tappia. E-Fulfilment and Distribution in Omni-Channel Retailing: A Systematic Literature Review. *International Journal of Physical Distribution and Logistics Management*, Vol. 48, No. 4, 2018, pp. 391–414.
5. Cardenas, I., Y. Borbon-Galvez, T. Verlinden, E. Van de Voorde, T. Vanelslander, and W. Dewulf. City Logistics, Urban Goods Distribution and Last Mile Delivery and Collection. *Competition and Regulation in Network Industries*, Vol. 18, No. 1–2, 2017, pp. 22–43. https://doi.org/10.1177/1783591717736505.
6. Bosona, T. Urban Freight Last Mile Logistics—Challenges and Opportunities to Improve Sustainability: A Literature Review. *Sustainability (Switzerland)*, Vol. 12, No. 21, 2020, pp. 1–20. https://doi.org/10.3390/su12218769.
7. Browne, M., C. Rizet, and J. Allen. A Comparative Assessment of the Light Goods Vehicle Fleet and the Scope to Reduce its CO_2 Emissions in the UK and France. *Procedia - Social and Behavioral Sciences*, Vol. 125, 2014, pp. 334–344. https://doi.org/10.1016/J.SBSPRO.201401.1478.
8. Holguín-Veras, J., J. A. Leal, I. Sánchez-Diaz, M. Browne, and J. Wojtowicz. State of the Art and Practice of Urban Freight Management Part I: Infrastructure, Vehicle-Related, and Traffic Operations. *Transportation Research Part A: Policy and Practice*, Vol. 137, 2020, pp. 360–382. https://doi.org/10.1016/j.tra.2018.10.037.
9. Holguín-Veras, J., J. A. Leal, I. Sanchez-Diaz, M. Browne, and J. Wojtowicz. State of the Art and Practice of Urban Freight Management Part II: Financial Approaches, Logistics, and Demand Management. *Transportation Research Part A: Policy and Practice*, Vol. 137, 2020, pp. 383–410. https://doi.org/10.1016/j.tra.2018.10.036.
10. Furquim, G., R. L. M. de Oliveira, and J. G. V. Vieira. Retailers and Carriers' Viewpoint on Sorocaba's City Logistics: A Spatial Analysis. *Urbe*, p. 12. http://www.scielo.br/j/urbe/a/zbLvmjsfbKrqhCwKgtBQTYh/. Accessed May 17, 2022.
11. Vieira, J. G. V., J. C. Fransoo, and C. D. Carvalho. Freight Distribution in Megacities: Perspectives of Shippers, Logistics Service Providers and Carriers. *Journal of Transport Geography*, Vol. 46, 2015, pp. 46–54. https://doi.org/10.1016/J.JTRANGEO.2015.05.007.
12. Vieira, J. G. V., and J. C. Fransoo. How Logistics Performance of Freight Operators Is Affected by Urban Freight Distribution Issues. *Transport Policy*, Vol. 44, 2015, pp. 37–47. https://doi.org/10.1016/J.TRANPOL.2015.06.007.
13. Dablanc, L. *Freight Transport for Development Toolkit: Urban Freight*. The World Bank, Washington, D.C., 2009.
14. Buldeo Rai, H., S. Verlinde, and C. Macharis. City Logistics in an Omnichannel Environment. The Case of Brussels. *Case Studies on Transport Policy*, Vol. 7, No. 2, 2019, pp. 310–317. https://doi.org/10.1016/j.cstp.2019.02.002.
15. Muñuzuri, J., J. Larrañeta, L. Onieva, and P. Cortés. Solutions Applicable by Local Administrations for Urban Logistics Improvement. *Cities*, Vol. 22, No. 1, 2005, pp. 15–28. https://doi.org/10.1016/J.CITIES.2004.10.003.
16. Cherrett, T., J. Allen, F. McLeod, S. Maynard, A. Hickford, and M. Browne. Understanding Urban Freight Activity – Key Issues for Freight Planning. *Journal of Transport Geography*, Vol. 24, 2012, pp. 22–32. https://doi.org/10.1016/J.JTRANGEO.2012.05.008.
17. Aiura, N., and E. Taniguchi. Planning On-Street Loading-Unloading Spaces Considering the Behaviour of Pickup-Delivery Vehicles. *Journal of the Eastern Asia Society for Transportation Studies*, Vol. 6, 2005, pp. 2963–2974. https://doi.org/10.11175/EASTS.6.2963.
18. CET-SP. CET - Companhia de Engenharia de Trafego - Caminhões. http://www.cetsp.com.br/consultas/caminhoes/locais-com-restricao-ao-caminhao/zona-de-maxima-restricao-de-circulacao-zmrc.aspx.
19. Holguín-Veras, J. Necessary Conditions for Off-Hour Deliveries and the Effectiveness of Urban Freight Road Pricing and Alternative Financial Policies in Competitive Markets. *Transportation Research Part A: Policy and Practice*, Vol. 42, No. 2, 2008, pp. 392–413. https://doi.org/10.1016/J.TRA.2007.10.008.
20. Holguín-Veras, J., T. Encarnación, C. A. González-Calderón, J. Winebrake, C. Wang, S. Kyle, N. Herazo-Padilla, et al. Direct Impacts of Off-Hour Deliveries on Urban Freight Emissions. *Transportation Research Part D: Transport and Environment*, Vol. 61, 2018, pp. 84–103. https://doi.org/10.1016/j.trd.2016.10.013.
21. Dias, J. M., G. B. Sobanski, J. E. A. R. da Silva, L. K. de Oliveira, and J. G. V. Vieira. Are Brazilian Cities Ready to Develop an Efficient Urban Freight Mobility Plan? *Urbe. Revista Brasileira de Gestão Urbana*, Vol. 10, No. 3, 2018, pp. 587–599. https://doi.org/10.1590/2175-3369.010.003.ao07.
22. Stathopoulos, A., E. Valeri, and E. Marcucci. Stakeholder Reactions to Urban Freight Policy Innovation. *Journal of Transport Geography*, Vol. 22, 2012, pp. 34–45. https://doi.org/10.1016/J.JTRANGEO.2011.11.017.
23. Woxenius, J. Directness as a Key Performance Indicator for Freight Transport Chains. *Research in Transportation Economics*, Vol. 36, No. 1, 2012, pp. 63–72. https://doi.org/10.1016/J.RETREC.2012.03.007.
24. Castro, J. T., and H. Kuse. Impacts of Large Truck Restrictions in Freight Carrier Operations in Metro Manila. *Journal of the Eastern Asia Society for Transportation Studies*, Vol. 6, 2005, pp. 2947–2962.
25. de Vasconcellos, E. A. Transport Metabolism, Social Diversity and Equity: The Case of São Paulo, Brazil. *Journal of Transport Geography*, Vol. 13, No. 4, 2005, pp. 329–339. https://doi.org/10.1016/j.jtrangeo.2004.10.007.
26. Gatta, V., and E. Marcucci. Urban Freight Transport and Policy Changes: Improving Decision Makers' Awareness via an Agent-Specific Approach. *Transport Policy*, Vol. 36, 2014, pp. 248–252. https://doi.org/10.1016/J.TRANPOL.2014.09.007.
27. Yannis, G., J. Golias, and C. Antoniou. Effects of Urban Delivery Restrictions on Traffic Movements. *Transportation Planning and Technology*, Vol. 29, No. 4, 2006, pp. 295–311. https://doi.org/10.1080/03081060600905566.

28. Kin, B., T. Ambra, S. Verlinde, and C. Macharis. Tackling Fragmented Last Mile Deliveries to Nanostores by Utilizing Spare Transportation Capacity - A Simulation Study. *Sustainability (Switzerland)*, Vol. 10, No. 3, 2018, p. 653. https://doi.org/10.3390/su10030653.
29. Dablanc, L. Goods Transport in Large European Cities: Difficult to Organize, Difficult to Modernize. *Transportation Research Part A: Policy and Practice*, Vol. 41, No. 3, 2007, pp. 280–285. https://doi.org/10.1016/j.tra.2006.05.005.
30. Kin, B., S. Verlinde, and C. Macharis. Sustainable Urban Freight Transport in Megacities in Emerging Markets. *Sustainable Cities and Society*, Vol. 32, 2017, pp. 31–41. https://doi.org/10.1016/J.SCS.2017.03.011.
31. Doshi, A., and M. M. Trivedi. Tactical Driver Behavior Prediction and Intent Inference: A Review. *Proc., IEEE Conference on Intelligent Transportation Systems, ITSC*, Washington, D.C., IEEE, New York, 2011, pp. 1892–1897. https://doi.org/10.1109/ITSC.2011.6083128.
32. Kim, H., A. Goodchild, and L. N. Boyle. Empirical Analysis of Commercial Vehicle Dwell Times Around Freight-Attracting Urban Buildings in Downtown Seattle. *Transportation Research Part A: Policy and Practice*, Vol. 147, 2021, pp. 320–338. https://doi.org/10.1016/j.tra.2021.02.019.
33. de Abreu e Silva, J., and A. R. Alho. Using Structural Equations Modeling to Explore Perceived Urban Freight Deliveries Parking Issues. *Transportation Research Part A: Policy and Practice*, Vol. 102, 2017, pp. 18–32. https://doi.org/10.1016/J.TRA.2016.08.022.
34. Chiara, G. D., L. Cheah, C. L. Azevedo, M. E. Ben-Akiva, M. E. Ben, and C. L. Azevedo. A Policy-Sensitive Model of Parking Choice for Commercial Vehicles in Urban Areas. *Transportation Science*, Vol. 54, No. 3, pp. 606–630. https://doi.org/10.1287/trsc.2019.0970.
35. Iwan, S., K. Kijewska, B. G. Johansen, O. Eidhammer, K. Małecki, W. Konicki, and R. G. Thompson. Analysis of the Environmental Impacts of Unloading Bays Based on Cellular Automata Simulation. *Transportation Research Part D: Transport and Environment*, Vol. 61, 2018, pp. 104–117. https://doi.org/https://doi.org/10.1016/j.trd.2017.03.020.
36. Manzano Dos Santos, E., and I. Sánchez-Díaz. Exploring Carriers' Perceptions About City Logistics Initiatives. *Transportation Research Record: Journal of the Transportation Research Board*, 2016. 2547: 66–73.
37. Chiara, G. D., K. F. Krutein, A. Ranjbari, and A. Goodchild. Understanding Urban Commercial Vehicle Driver Behaviors and Decision Making. *Transportation Research Record: Journal of the Transportation Research Board*, 2021. 2675: 608–619.
38. Malik, L., I. Sánchez-Díaz, G. Tiwari, and J. Woxenius. Urban Freight-Parking Practices: The Cases of Gothenburg (Sweden) and Delhi (India). *Research in Transportation Business & Management*, Vol. 24, 2017, pp. 37–48. https://doi.org/https://doi.org/10.1016/j.rtbm.2017.05.002.
39. Schmid, J., X. C. Wang, and A. Conway. Commercial Vehicle Parking Duration in New York City and its Implications for Planning. *Transportation Research Part A: Policy and Practice*, Vol. 116, 2018, pp. 580–590. https://doi.org/10.1016/J.TRA.2018.06.018.
40. Castro, J. T., H. Kuse, and T. Hyodo. A Study on the Impact and Effectiveness of the Truck Ban Scheme in Metro Manila. *Journal of the Eastern Asia Society for Transportation Studies*, Vol. 5, No. 5, 2003, pp. 2177–2192.
41. Morganti, E., L. Dablanc, and F. Fortin. Final Deliveries for Online Shopping: The Deployment of Pickup Point Networks in Urban and Suburban Areas. *Research in Transportation Business & Management*, Vol. 11, 2014, pp. 23–31. https://doi.org/10.1016/J.RTBM.2014.03.002.
42. Ahmed, U., and M. J. Roorda. Modeling Freight Vehicle Type Choice Using Machine Learning and Discrete Choice Methods. *Transportation Research Record: Journal of Transportation Research Board*, 2022. 2676: 541–552. https://doi.org/10.1177/03611981211044462.
43. Furquim, T. S. G., J. G. V. Vieira, and R. M. Oliveira. Restrições de Carga Urbana e Desafios Logísticos: Percepção de Varejistas e Motoristas Em Sorocaba. *Transportes*, Vol. 26, No. 1, 2018, pp. 142–156. https://doi.org/10.14295/TRANSPORTES.V26I 1.1354.
44. Forza, C. Survey Research in Operations Management: A Process-Based Perspective. *International Journal of Operations and Production Management*, Vol. 22, No. 2, 2002, pp. 152–194. https://doi.org/10.1108/0144357021 0414310.
45. Leung, S. O. A Comparison of Psychometric Properties and Normality in 4-, 5-, 6-, and 11-Point Likert Scales. *Journal of Social Service Research*, Vol. 37, No. 4, 2011, pp. 412–421. https://doi.org/10.1080/01488376.2011.580697.
46. Wu, H., and S. O. Leung. Can Likert Scales Be Treated as Interval Scales?—A Simulation Study. *Journal of Social Service Research*, Vol. 43, No. 4, 2017, pp. 527–532. https://doi.org/10.1080/01488376.2017.1329775.
47. Aharonovitz, M. C. S., J. G. V. Vieira, and S. S. Suyama. How Logistics Performance is Affected by Supply Chain Relationships. *The International Journal of Logistics Management*, Vol. 29, No. 1, 2018, pp. 284–307. https://doi.org/10.1108/IJLM-09-2016-0204.
48. Tabachnick, B., and L. S. Fidell. *Using Multivariate Statistics*, 7th ed. Pearson, Boston, MA, 2019.
49. Peng, D. X., and F. Lai. Using Partial Least Squares in Operations Management Research: A Practical Guideline and Summary of Past Research. *Journal of Operations Management*, Vol. 30, No. 6, 2012, pp. 467–480. https://doi.org/10.1016/j.jom.2012.06.002.
50. Hair, J. F., C.M. Ringle, and M. Sarstedt. PLS-SEM: Indeed a Silver Bullet. *Journal of Marketing Theory and Practice*, Vol. 19, No. 2, 2011, pp. 139–152. https://doi.org/10.2753/MTP1069-6679190202.
51. Hair, J. F., G. T. M. Hult, C. Ringle, M. Sarstedt, N. Danks, and S. Ray. *Partial Least Squares Structural Equation Modeling (PLS-SEM) Using R: A Workbook*. Springer Nature, Berlin, Germany, 2021.
52. Chin, W. W., and P. R. Newsted. Structural Equation Modeling Analysis With Small Samples Using Partial Least Squares. In *Statistical Strategies for Small Sample Research* (R. H. Hoyle, ed.), Sage Publications, Thousand Oaks, CA, 1999, pp. 307–341.

53. Chin, W. W. The Partial Least Squares Approach for Structural Equation Modeling. *Modern Methods for Business Research*, Vol. 295, No. 2, 1998, pp. 295–336.
54. Hair, J. F. Jr., W. C. Black, B. J. Babin, and R. E. Anderson. *Multivariate Data Analysis*, 7th ed. Prentice Hall, Upper Saddle River, NJ, 2009.
55. Hair, J. F., M. Sarstedt, L. Hopkins, and V. G. Kuppelwieser. Partial Least Squares Structural Equation Modeling (PLS-SEM): An Emerging Tool in Business Research. *European Business Review*, Vol. 26, No. 2, 2014, pp. 106–121. https://doi.org/10.1108/EBR-10-2013-0128.
56. Fornell, C., and D. F Larcker. Evaluating Structural Equation Models With Unobservable Variables and Measurement Error. *Journal of Marketing Research*, Vol. 18, No. 1, 1981, p. 39. https://doi.org/10.2307/3151312.
57. Leguina, A. A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM). *International Journal of Research & Method in Education*, Vol. 38, No. 2, 2015, pp. 220–221. https://doi.org/10.1080/1743727X.2015.1005806.
58. Helm, S., A. Eggert, and I. Garnefeld. Modeling the Impact of Corporate Reputation on Customer Satisfaction and Loyalty Using Partial Least Squares. In *Handbook of Partial Least Squares* (V. E. Vinzi, W. Chin, J. Henseler, and H. Wang, eds.), Springer, Berlin, Heidelberg, 2010, pp. 515–534. https://doi.org/10.1007/978-3-540-32827-8_23.
59. Tenenhaus, M., V. E. Vinzi, Y. M. Chatelin, and C. Lauro. PLS Path Modeling. *Computational Statistics and Data Analysis*, Vol. 48, No. 1, 2005, pp. 159–205. https://doi.org/10.1016/j.csda.2004.03.005.
60. Cohen, J. *Statistical Power Analysis for the Behavioral Sciences*, 2nd ed. Routledge, New York, NY, 1988.
61. Ávila, M. M., and E. F. Moreno. Aplicación de La Técnica PLS-SEM En La Gestión Del Conocimiento: Un Enfoque Técnico Práctico / Application of the PLS-SEM Technique in Knowledge Management: A Practical Technical Approach. *RIDE Revista Iberoamericana para la Investigación y el Desarrollo Educativo*, Vol. 8, No.16, 2018, pp. 130–164. https://doi.org/10.23913/RIDE.V8I16.336.
62. Ringle, C., S. Wende, and A. Will. *SmartPLS 2.0 (M3) Beta*. University of Hamburg, Germany, 2005.
63. Podsakoff, P. M., S. B. MacKenzie, and N. P. Podsakoff. Sources of Method Bias in Social Science Research and Recommendations on How to Control It. *Annual Review of Psychology*, Vol. 63, 2012, pp. 539–569. https://doi.org/10.1146/ANNUREV-PSYCH-120710-100452.
64. São Paulo (SP). *Cidades e Estados*. IBGE. https://www.ibge.gov.br/cidades-e-estados/sp/sao-paulo.html.
65. Faul, F., E. Erdfelder, A. G. Lang, and A. Buchner. G*Power 3: A Flexible Statistical Power Analysis Program for the Social, Behavioral, and Biomedical Sciences. *Behavior Research Methods*, Vol. 39, No. 2, 2007, pp. 175–191. https://doi.org/10.3758/BF03193146.
66. Erdfelder, E., F. FAul, A. Buchner, and A. G. Lang. Statistical Power Analyses Using G*Power 3.1: Tests for Correlation and Regression Analyses. *Behavior Research Methods*, Vol. 41, No. 4, 2009, pp. 1149–1160. https://doi.org/10.3758/BRM.414.1149.
67. Wetzels, M., G. Odekerken-Schröder, and C. Van Oppen. Using PLS Path Modeling for Assessing Hierarchical Construct Models: Guidelines and Empirical Illustration. *MIS Quarterly*, Vol. 33, No. 1, 2009, p. 177. https://doi.org/10.2307/20650284.
68. Janjevic, M., and M. Winkenbach. Characterizing Urban Last-Mile Distribution Strategies in Mature and Emerging E-Commerce Markets. *Transportation Research Part A: Policy and Practice*, Vol. 133, 2020, pp. 164–196. https://doi.org/10.1016/j.tra.2020.01.003.
69. Blanco, E. E., and J. C. Fransoo. *Reaching 50 Million Nanostores*. *Retail Distribution in Emerging Megacities*. Working Paper WP 2013-01-40. Beta Research School, Eindhoven University of Technology, The Netherlands, 2013, pp. 1–19.
70. Kladeftiras, M., and C. Antoniou. Simulation-Based Assessment of Double-Parking Impacts on Traffic and Environmental Conditions. *Transportation Research Record: Journal of the Transportation Research Board*, 2013. 2390: 121–130.