UNIVERSIDAD
NACIONAL
DE COLOMBIA

Quantitative analysis of freight trip attraction due to the groceries sector in urban areas of developing countries

Jhan Kevin Gil Marin, C.E.

Universidad Nacional de Colombia

Facultad de Minas, Departamento de Ingeniería Civil

Medellín, Colombia

2023

Quantitative analysis of freight trip attraction due to the groceries sector in urban areas of developing countries

Jhan Kevin Gil Marin, C.E.

Tesis o trabajo de investigación presentada(o) como requisito parcial para optar al título de:

Magister en Ingeniería - Infraestructura y Sistemas de Transporte

Director (a):

Carlos Alberto González Calderón, Ph.D.

Codirector (a):

John Jairo Posada Henao, Ph.D.

Línea de Investigación:

Transporte de carga

Grupo de Investigación:

Grupo de Investigación en Vías y Transporte

Universidad Nacional de Colombia

Facultad de Minas, Departamento de Ingeniería

Medellín, Colombia

2023

Declaración de obra original

Yo declaro lo siguiente:

He leído el Acuerdo 035 de 2003 del Consejo Académico de la Universidad Nacional. «Reglamento sobre propiedad intelectual» y la Normatividad Nacional relacionada al respeto de los derechos de autor. Esta disertación representa mi trabajo original, excepto donde he reconocido las ideas, las palabras, o materiales de otros autores.

Cuando se han presentado ideas o palabras de otros autores en esta disertación, he realizado su respectivo reconocimiento aplicando correctamente los esquemas de citas y referencias bibliográficas en el estilo requerido.

He obtenido el permiso del autor o editor para incluir cualquier material con derechos de autor (por ejemplo, tablas, figuras, instrumentos de encuesta o grandes porciones de texto).

Por último, he sometido esta disertación a la herramienta de integridad académica, definida por la universidad.

Jhan Kevin Gil Marin

Nombre

31/01/2023

Fecha

Resumen

Análisis cuantitativo de la atracción de viajes de carga debido al sector de comestibles en zonas urbanas de países en desarrollo

Esta investigación se enfoca en encontrar las variables más influyentes en la atracción de viajes de carga de establecimientos comerciales que venden alimentos y se encuentran en áreas urbanas de países en desarrollo, donde el mercado minorista de alimentos es comúnmente dominado por pequeñas tiendas familiares ubicadas en los barrios, en lugar de supermercados. Este análisis se realizó con datos del Área Metropolitana de Medellín (Colombia) obtenidos de las dos encuestas de carga realizadas en la ciudad (2012 y 2018). Los datos se utilizaron para estimar modelos utilizando la técnica de mínimos cuadrados ordinarios y transformación logarítmica de los datos para obtener un mejor ajuste. El área total del establecimiento y el número equivalente de empleados de tiempo completo fueron las variables más influyentes. Los practicantes se beneficiarán de estos modelos porque podrán incluir la generación de viajes de carga en barrios residenciales y zonas comerciales para planificar mejor el transporte en la ciudad.

Palabras clave: modelación de carga, generación de viajes de carga, atracción de viajes de carga, supermercados, nano-stores, Medellín.

Abstract

This research focuses on identifying the variables with a significant impact on the freight trip attraction of supermarkets and nano-stores in urban areas of developing countries. Both supermarkets and nano-stores are commercial establishments that sell groceries. However, in developing countries, the grocery retail market is by nano-stores rather than supermarkets, which dominated the grocery retail market in developed countries. Nano-stores are family-owned stores typically located in neighborhoods. This analysis used data from the Medellin Metropolitan Area in Colombia obtained from the two freight surveys conducted in the city (2012 and 2018). Data were used to estimate models using the ordinary least squares technique and logarithmic transformation of the data to obtain a better fit. The total area of the establishment and the equivalent number of full-time employees were the most influential variables. Practitioners will benefit from these models because they could include freight trip attraction in residential neighborhoods and commercial zones to better plan transportation in the city.

Keywords: freight modeling, freight trip generation, freight trip attraction, supermarkets, nano-stores, developing countries, Medellin.

Contents

List of figures

Pág.

List of tables

Pág.

1. Introduction

The transport dynamics of a city change as the city grows. This change occurs for the transport of passenger but also for freight movement. Some reasons that affect the dynamics in the transportation system are the construction of new residential homes, commercial establishments, parking sites, road infrastructure, and so forth. As Holguin-Veras et al. (2019) claimed, the city's growth and urbanization create challenges regarding freight transportation since there is more demand for the movement of goods in and out of the city centers, changes that produce numerous externalities. In this sense, it is essential for the city administration to control the changes in the transport dynamics, or at least channel these changes to specific city sectors, according to the city's objectives. Thus, to establish a course of action that is expected to contribute to achieving the predefined set of objectives (by the city administration), planning is necessary for fostering urban growth and reducing negative externalities.

Transport planning is a component of city planning. As Ortúzar & Willumsen (2011) claims, transport planning aims to cater to the demand for the movement of goods and persons given a transport system with a specific operating capacity. It means that the primary goal of transport planning is to provide the best conditions for the people traveling and for the freight movement (transportation of goods). To do so, conducting a technical analysis that allows knowing the actual situation and forecasting the future necessities, issues, travel patterns, and so forth to evaluate possible solutions is necessary. This technical analysis uses transport modeling to support transport planning. The transport modeling is presented by Ortúzar & Willumsen (2011) with the classic transport model composed of four steps or sub-models: trip generation, trip distribution, modal split, and traffic assignment.

Various authors have recognized the importance of freight movement for the city. For example, Holguin-Veras et al. in 2014 stated that *"The freight transport system is a key contributor to the vibrancy of local and regional economies,"* Gonzalez-Calderon et al. in 2018 noted that *"The movement of goods is an essential factor in the economy of cities, regions, and countries."* Later, Holguin-Veras et al. in 2019 claimed that *"Understanding urban economics and how these relate* *to urban freight and service activity is imperative to addressing the key challenges faced in city logistics."* So, given the significance of freight transportation in the economy of the cities, it is crucial to understand freight movement. This will be especially helpful in developing economies, such as numerous cities in Latin America, since it is an essential factor for improving the economy. Oliveira et al. (2017) also support this and state that there is a need to enhance the relationship between urban planning and transportation planning from a logistic standpoint to promote quality of life, economic sustainability, and environmental sustainability. Also, the author suggests investigating the attractiveness of urban activities that attract the movement of people and goods and other components of urban space.

Some shopping centers in Latin-American cities are not large stores, but they are a set of small stores, which together generate a significant amount of cargo and freight trips every day. The term for this type of economy is nano-store, according to Blanco & Fransoo (2013). These set of nano-stores present a complex operating model for the logistic chain, making deliveries of goods supplied with vehicles circulating in densely populated areas, generating inefficient freight transportation because of the low percentage of the capacity of cargo vehicles, making it very expensive, as noted by Kin et al. in 2018. According to Wilmsmeier et al. (2015), the nano-stores can receive about 30 deliveries per week, making this a complicated puzzle for logistic operations. This feature encourages a large volume of vehicles that generate externalities. For example, a large amount of vehicles doing deliveries can produce insufficient parking spaces forcing other vehicles to park in areas where they may interrupt the regular traffic, generating congestion; it also creates pollution because of the number of circulating vehicles affecting the air quality.

Based on this, the interest of this research is to analyze freight trip attraction (FTA), one part of the freight trip generation. This is one step of transport modeling (applied to the movement of goods), which according to Holguin-Veras et al. (2014), reveals fundamental information about the understanding of freight mobility in urban areas. Then, that information can be used by planners and decision-makers to propose effective solutions in urban areas about several areas such as pollution, congestion, and safety, among others.

This research focuses on supermarkets and nano-stores. In developing economies such as Medellin, Colombia, these freight generators are of particular interest because of new trends of opening small supermarkets in neighborhoods where, traditionally, only existed nano-stores. Some examples of these small supermarkets are D1, Justo & Bueno, La Vaquita Express, and Merkapaisa. The opening of these establishments attract more cargo and truck trips in residential zones where the infrastructure was not planned for it. In addition, as shown by McKinnon (2006), road freight is usually an unwelcome sign for residents living in the city as they perceive trucks to be road hazards and main congestion and pollution contributor; trucks are also potentially straining the local roads, causing more maintenance.

In cities where neighborhoods commonly have a considerable number of nano-stores for the inhabitants to buy groceries, the suppliers are usually vans or small vehicles. Though, the number of trucks circulating and the externalities increase with the construction of small supermarkets in the neighborhoods. However, there is a lack of studies that characterize freight patterns because of this phenomenon.

1.1 Objectives

1.1.1 General Objective

To develop econometric models to forecast the freight trip attraction (FTA) patterns in the groceries sector in urban areas of developing countries.

1.1.2 Specific Objectives

- To identify the most influential variables to forecast the FTA of the groceries sector in urban areas of developing countries.
- To estimate the FTA of the groceries sectors using the developed models.

2. Background

It is worth noting the FTG is defined as the number of freight-vehicle trips generated by a commercial establishment, and it is composed of the summation of freight trip attraction (FTA) and freight trip production (FTP) (Gonzalez-Feliu & Sanchez-Diaz, 2019; Holguin-Veras et al., 2014; Holguin-Veras, Ramirez-Rios, & Pérez-Guzmán, 2021; Ortúzar & Willumsen, 2011). Also, it is essential to understand that this research focuses on the FTA, which is the number of freight trips where the destination is the commercial establishment. Then the FTA differs from the FTP, the number of freight trips where the origin is the commercial establishment.

The FTG in urban areas and its importance have been studied and recognized by various authors such as Gonzalez-Calderon et al. (2018) and Holguin-Veras et al. (2014, 2019). They agree that FTG is an essential factor for economic development, but it also is a challenge that the city logistics must face, even more, when the concentration of people in dense areas generates more cargo and freight trips. However, these studies focus on the FTG of all sectors. But for the specific sector of groceries, there are few studies. This is surprising since the freight movement of this sector of the economy can affect different levels of the road network in a city; as McCormack et al. (2010) found, the FTG due to grocery stores may affect the whole road network from local roads to highways. This is because the location of the grocery stores can vary from the Central Businesses District to the residential zones in the neighborhoods.

Freight transportation activity rises important implications for land-use planning and policymaking, which is the reason that the Freight-Efficient Land Uses, explained by Holguin-Veras, Ramirez-Rios, Ng, et al., in 2021, aims to minimize the social cost of the supply chains and economic activities of the consumption and production of goods. Inside the freight activity, the wholesale and retail trade, where the commercial activity of supermarkets and nano-stores belong, are considered as freight intensive sectors with a significant contribution to the freight trip generation (FTG) in urban areas, as stated by Gonzalez-Calderon et al. in 2022. Meaning that the economic activity of the supermarkets and nano-stores may significantly impact the transportation network of the urban areas, since freight activity is an essential factor for the economy.

The freight trips enclosed by FTA are commonly performed by trucks. As Holguin-Veras, Ramirez-Rios, Ng, et al. (2021) founded, for companies it is more beneficial to use large trucks for their deliveries than a set of small vans to minimize operational costs. However, Holguin-Veras, Ramirez-Rios, Ng, et al. (2021) also found that the traffic produced by freight activity, especially with large trucks, implies such negative externalities as congestion, pollution, noise, security, accidents, and aesthetic degradation. McCormack et al. (2010) explain that large trucks are not welcome specifically in residential zones, where the nano-stores are located. Therefore, the transportation planning and traffic analysis includes the modeling of the FTA.

2.1 Freight Trip Attraction Modeling

The FTA modeling is part of the FTG modeling since, as noted before, the FTA is part of the FTG. Therefore, the three key principles for developing FTG models explained by Holguín-Veras et al. (2016) apply for the FTA modeling. Two of the three principles apply directly to this research. First, distinguish between the FTG, which refers to the vehicle trips, and the freight generation (FG), which refers to the cargo transported by the vehicles. Second, the accuracy of the FTG will depend on the classification system, the measure of business sizes, the statistical technique, and the aggregation level of the data.

Different methodologies have been applied to model the FTG, and as mentioned before FTG is composed by FTA and FTP, so the methodologies for FTG apply for both: FTA and FTP. Holguin-Veras et al. (2014) summarize different types of models used to model the FTG: time series, trip rates, input-output, ordinary least squares regression, spatial regression, cross classification method, and neural networks. However, Holguin-Veras et al. (2014) states that most of the publications about the FTG uses constant trip rates and ordinary least square regression. Following that, the NCFRP Research Report 37: Using Commodity Flow Survey Microdata and Other Establishment Data to Estimate the Generation of Freight, Freight Trips, and Service Trips (Holguín-Veras et al., 2016) uses ordinary least squares regression with establishment-level data and economic-based variables, like the employment, in its models.

According to the literature, the area (as a measure of the physical size of the establishment) and the number of employees has shown evidence to be significant in predicting the FTA for the food sector. However, other variables such as storage space may also be significant, as found in the studies by Iding et al. in 2002, Kawamura et al. in 2005, Asuncion et al. in 2012, Sanchez-Diaz et al. in 2016, Oliveira et al. in 2017, Sanchez-Diaz in 2020, and Cheah et al. in 2021. Thus, to explore the previous work related to this research, the remaining content of this section will discuss the freight trip attraction in nano-stores; and freight trip attraction in supermarkets, where summary and key findings are presented.

2.2 Freight Trip Attraction in Nano-Stores

A particular case of grocery stores located in residential zones is the nano-stores. Because of its small size, compared to a supermarket, it is not seen as a great contributor to urban freight traffic. However, considering that nano-stores and small offices are similar in that both have small sizes but many establishments in the cities, it is reasonable to think that their FTG impacts are similar. Sanchez-Diaz (2020) found that individual offices' impact on FTG is non-significant, but aggregating all trips generated by offices became significant. This may also be the case for nano-stores. However, to the author's best knowledge, there is no similar study for nano-stores.

However, other nano-store studies focused on the operation and characteristics rather than the FTA. For example, Fransoo & Blanco (2017) studied retail distribution in emerging megacities, finding that in most Latin-American countries, nano-stores dominate about 95% of the total retail channels, which plays a vital role in the subsistence of families. Also, factors like an increase in population density and high-income inequality indicate that nano-store will remain dominant in the market share (Fransoo & Blanco, 2017). There is also a study by Mejía-Argueta, Agudelo, et al. (2017) analyzing how the Colombian company Colombina sells and delivers its products to nano-stores in Bogota but, again, it describes the operation and the supply chain, rather than modeling the freight trips. The study by Mejía-Argueta, Blanco, et al. (2017) compares different operation models used in Latin America to serve the nano-stores. Finally, Blanco & Fransoo (2017) analyze the supply chain for nano-stores finding that the delivery routes commonly serve 100 nano-stores per day in dense urban areas. In general, some studies characterize nano-stores' operation and supply chain but do not model their impact on traffic.

2.3 Freight Trip Attraction in Supermarkets

Most existing studies about the grocery sector have tried to explain its FTG with variables related to the number of employees and the size of the store (retail and storage space). Asuncion et al. (2012) found that size of the store and number of employees strongly correlated with the number of attracted freight trips when they analyzed the FTA rates of supermarkets, convenience stores, farmer's markets, and bulk-food stores in New Zealand. In contrast, McCormack et al. (2010), with their study of the grocery sector FTA in Puget Sound, Washington state, found that the number of employees and the store's size are not good predictors of the FTA. An additional study by Kawamura et al. (2005) in midwestern states analyzed the freight trip attraction for specific types of business. However, they discarded the business related to groceries from the research since they could not collect data because of the highly decentralized supply chain.

Additionally, Asuncion et al. (2012) suggest that the FTG and stores and supermarkets' characteristics vary significantly with their geographic location. Supporting that, Sanchez-Diaz et al. (2016), in their study of the effects of spatial variables in the FTA of different industry sectors, found that these variables have a significant impact that needs to be studied. Sanchez-Diaz et al. (2016) found that variables related to the location of the establishment, such as the width of the front street and the value of land, also significantly impact the FTG of the food sector, among other sectors.

To the author's best knowledge, no studies have been conducted on FTA in supermarkets and nano-stores in developing economies. However, there are few studies on this topic in developed economies. Some of these studies were performed by McCormack et al. (2010) in Washington, Asuncion et al. (2012) in New Zealand, and Heldt et al. (2017) in Berlin. Thus, this study intends to shed light on analyzing FTA in supermarkets and nano-stores in developing economies.

3. Case Study: Medellin Metropolitan Area

The research focuses on the developing economy of Colombia, specifically in the Metropolitan Area of Medellin. This section presents the characteristics of the urban area where the methodology is applied as well as the collection, revision, and classification process of the data.

3.1 Description

The Medellin Metropolitan Area, in Colombia, comprises ten municipalities, as illustrated in Figure 1. By 2018, the Metropolitan Area of Medellin had approximately 4.2 million inhabitants and around 160,000 commercial establishments documented by the chambers of commerce in the related municipalities (Universidad Nacional de Colombia & Area Metropolitana del Valle de Aburrá, 2019). Among those ten municipalities, the best known is the city of Medellin, which is the second-largest city in Colombia, after Bogota, the capital of the country. Also, the Medellin Metropolitan Area has an international airport that plays an important role in the import and export of goods (Gonzalez-Calderon et al., 2018) and contributes, approximately, 11% to the national GDP (Universidad Nacional de Colombia & Area Metropolitana del Valle de Aburrá, 2019).

Medellin is the urban core of the Medellin Metropolitan Area and plays a major role in terms of commercial activity, suffering the largest freight-related traffic impacts. As Gonzalez-Calderon et al. (2018) found, approximately 85% of the MMA commercial establishments are in Medellin, along with 70% of the population. Also, 4% of the establishments are in the Northern municipalities, compared to the Southern municipalities with 10% of the establishments, but each of them has 15% of the population. According to Gonzalez-Calderon et al. (2018) a potential reason for this is the lower income of the Northern, compared to the Southern, municipalities.

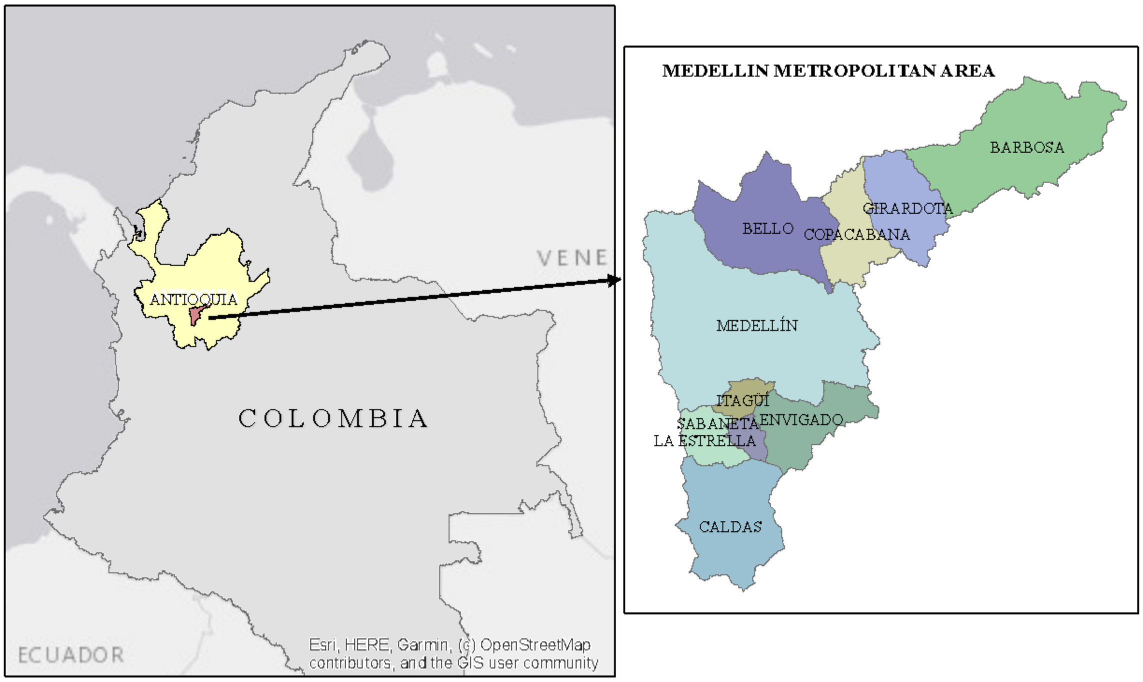

Figure 1: Geographical location of the Medellin Metropolitan Area and its 10 municipalities.

3.2 Data collection

The data for this research come from the two freight studies performed in the Medellin Metropolitan Area, conducted in 2012 and 2018.

Both freight studies, 2012 and 2018, grouped the commercial establishments by groups following the classification used in the chambers of commerce of the Medellin Metropolitan Area municipalities. They classify the commercial establishments based on their economic activity using the International Standard Industrial Classification of All Economic Activities (ISIC). The ISIC system group the economic activities using a hierarchical structure, starting with the category called Section represented by a letter, then the Division represented by two numeric digits, and finally the Group with three numeric digits (United Nations - Department of Economic and Social Affairs - Statistics Division, 2008).

The 2012 freight study of surveyed 2,947 commercial establishments. Subsequently, the 2018 study was conducted to supplement the 2012 study aiming to achieve an statistical error of 25% in each zone of analysis with a 10% of significance (Universidad Nacional de Colombia & Area Metropolitana del Valle de Aburrá, 2019). Together, the data collected with the 2012 and

2018 study amounting to a total sample of 4,382 commercial establishments. The data of those 4,382 commercial establishments surveyed in the freight studies of 2012 and 2018 was used for this research.

It is worth mentioning that in 2012 the commercial establishments were classified under the revision 3.1 of the ISIC system, presented in (United Nations - Department of Economic and Social Affairs - Statistics Division, 2002). However, in 2018, the chambers of commerce reclassified the commercial establishments using the revision 4 of the ISIC system presented in (United Nations - Department of Economic and Social Affairs - Statistics Division, 2008). To have a unified classification of the commercial establishments, the 2018 freight study updated the classification of the commercial establishments surveyed in 2012 using revision 4 of the ISIC system.

With the unified data of the two freight studies, Table 1 shows a summary the freight movement in the Medellin Metropolitan Area. It is important to note that the Group G—where supermarkets and nano-stores belong—is the group that produces/attracts the most cargo in the case study. Based on this, this research use data of this ISIC group to analyze FTA patterns in supermarkets and nano-stores in urban areas.

So, to analyze the FTA of supermarkets and nano-stores the author focused on the groups 471 -retail sale in non-specialized stores (where supermarkets belong) and 472-retail sale of food, beverages, and tobacco in specialized stores (where nano-stores belong) of section G. However, a revision of the data revealed that for both groups there were included establishments whose commercial activity does not imply the commerce of groceries. This leads to reclassifying some of the establishments.

Table 2 shows the initial and final number of commercial establishments in the sections of interest. This corresponds to the changes seeking the best dataset for modeling through a cleaning process. In doing so, it was reviewed if each establishment corresponded to the type of interest (which are supermarkets and nano-stores). When it was necessary, original surveys were reviewed or checked looking for type outs, outliers, or any other possible errors. Also, some doubt establishments were located through Google Maps (Google LLC, 2022) to verify they belong to the mentioned categories.

Table 1. Description of the number of freight trips and amount of cargo transported in the Medellin Metropolitan Area grouped by establishment's economic activity.

ISIC Type	Percentage of the Total Trips per Day	Percentage of the Total tons of Freight per Day
A-Agriculture, forestry, and fishing	0.7 %	2.1 %
B-Mining and quarrying	0.2 %	0.1 %
C-Manufacturing	15.8 %	13.4 %
D-Electricity, gas, steam, and air conditioning supply	0.0 %	0.0 %
E-Water supply; sewerage, waste management and remediation	0.5 %	1.1 %
F-Construction	5.5 %	11 %
G-Wholesale and retail trade; repair of motor vehicles and motorcycles	44.9 %	62.6 %
H-Transportation and storage I Accommodation and food service activities	2.9 %	1.4 %
I-Accommodation and food service activities	12.1 %	2.9 %
J-Information and communication	1.6 %	0.2 %
K-Financial and insurance	1.3 %	0.1 %
L-Real estate activities	1.8V	0.3 %
M-Professional, scientific, and technical activities	5.6 %	1.9 %
N-Administrative and support service activities	1.9 %	1.8 %
O-Public administration and defense	0.0 %	0.0 %
P-Education	0.3 %	0.1 %
Q-Human health and social work activities	0.8 %	0.2 %
R-Arts, entertainment, and recreation	0.9 %	0.2 %
S-Other service activities	3.3 %	0.6 %
T-Activities of households as employers; undifferentiated goods- and services- producing activities of households for own use	0.0 %	0 %

Table 2. Number of establishments per ISIC code groups used to study supermarkets and nano-stores.

Section	Division	Group	Description	Number of establishments	
				Before Revision	After Revision
G	47	471	Retail sale in non-specialized stores (where supermarkets belong).	175	112
		472	Retail sale of food, beverages, and tobacco in specialized stores (where nano-stores belong).	255	157

3.3 Characterization of Supermarkets and Nano-Stores

For both supermarkets and nano-stores, their main economic activity is to provide groceries at retail. Its classification considered the study by (Blanco & Fransoo, 2013); for traditional retailer's business usually family-operated, where establishments with 15-40 m^2 of surface area is called mini-stores, and establishments with less than 15 m^2 are called nano-store. Also, the proposed by (Mejía, 2022) where a nano-store has between 0 and 5 employees, where 0 employees mean that only the owner operates the establishment. So, for this research, authors consider as nano-stores establishments with less than 40 m^2 of surface and less than 8 employees, and supermarkets establishments with more than 40 m^2 of surface. This classification was adapted according to the combinations of establishment area and employees found in the literature and collected data. This will allow to know the FTA patterns in places where they are located, and for this research in neighborhoods specifically.

Table 3 presents the summary of the data for both supermarkets and nano-stores. It is interesting how the mean, median and mode of the attracted trips per week are similar in both cases. However, the amount of cargo attracted per week is significantly larger for supermarkets. It makes sense since nano-stores do not have a lot of storage space, so it needs numerous trips per week with few cargoes, and supermarkets have more demand of products and large storage space so they can have a similar number of trips but with much more cargo to store.

Also, Figure 2 shows that supermarkets' attracted trips have a wider range of values and dispersion than the nano-stores. However, Figure 3 shows the behavior for the attracted trips is similar in both cases.

Table 3. Sample descriptive statistics. Summary of model variables.

Statistic	Hours Open	Employees	Area (m²)	Warehouse Area (m²)	Unloading Time (min)	Trips per Week	Kg per Week
Supermarkets							
Mean	13.2	5.2	118.8	63.7	16.7	10.3	2407.2
Standard Error	0.3	0.5	12.3	11.1	1.2	0.8	386.3
Median	13.0	4.0	80.0	32.0	12.4	7.8	770.8
Mode	13.0	2.0	60.0	0.0	10.0	3.0	133.8
Standard Deviation	2.8	5.7	130.4	117.0	13.0	8.5	4088.6
Minimum	4.0	1.0	42.0	0.0	5.0	1.0	13.2
Maximum	24.0	40.0	900.0	900.0	72.0	42.0	21125.0
Count	112.0	112.0	112.0	112.0	112.0	112.0	112.0
Nano-stores							
Mean	12.9	2.0	23.4	18.6	13.8	9.0	704.4
Standard Error	0.3	0.1	0.8	7.6	1.3	0.6	97.5
Median	13.0	2.0	24.0	4.0	10.0	6.5	255.5
Mode	12.0	2.0	30.0	0.0	10.0	3.0	187.5
Standard Deviation	3.5	5.7	9.9	95.8	16.5	7.8	1221.1
Minimum	5.0	1.0	2.0	0.0	1.0	1.0	7.8
Maximum	24.0	8.0	40.0	1200.0	180.0	40.0	7689.5
Count	157.0	157.0	157.0	157.0	157.0	157.0	157.0

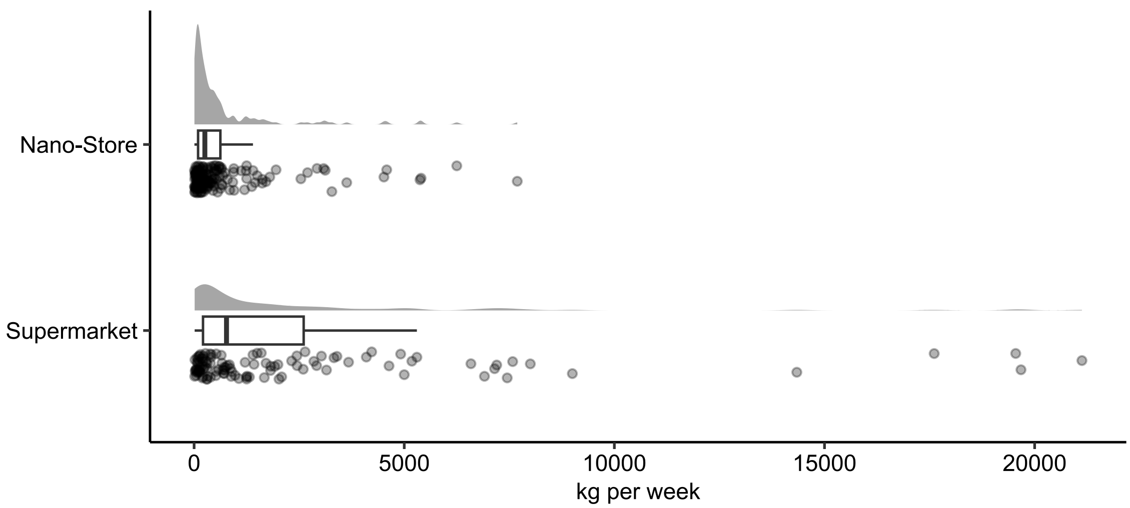

Figure 2. Attracted cargo per week of supermarkets and nano-stores.

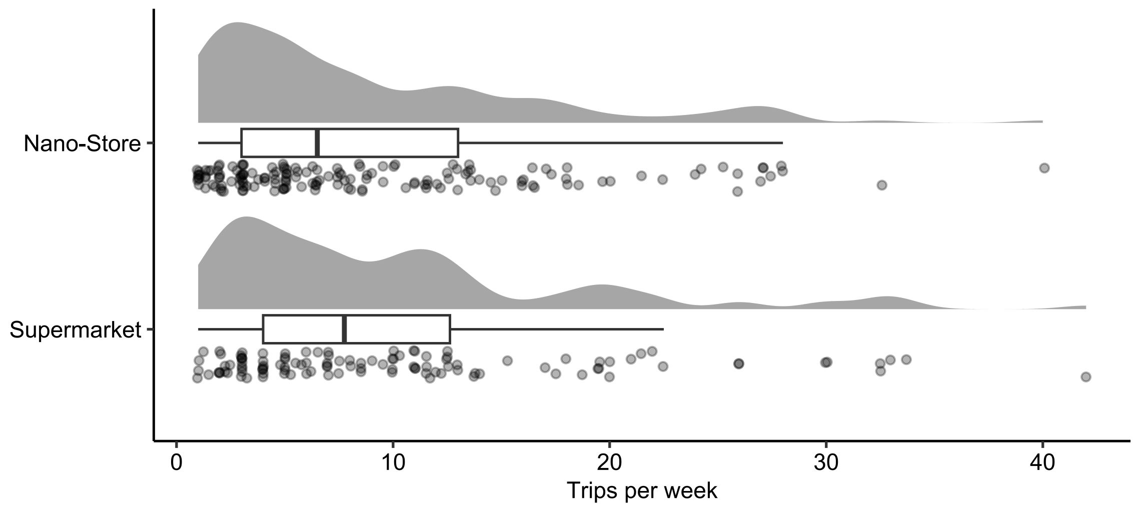

Figure 3. Attracted freight trips of supermarkets and nano-stores.

It can be observed from Figure 2 and Figure 3 than supermarkets and nano-stores have a similar amount of attracted trips per week, but the amount of cargo per week has a considerable difference, with the supermarkets attracting more cargo. It means that with the same number of trips different amount of cargo is transported to these establishments. These implies that most likely different types of vehicles are used to supply the establishment. Since supermarkets attract more cargo, the vehicles should have a major capacity than the vehicles used for nano-stores. Also, Figure 2 shows that the supermarkets have a greater outlier than the nano-stores. Probably it is because in the ISIC classification supermarkets and departments stores are in the same group, and the freight study (Universidad Nacional de Colombia & Area Metropolitana del Valle de Aburrá, 2019) collected the total cargo, but it was not split by department in the case of department stores.

The next section presents the modeling of the FTG for supermarkets and nano-stores, as well as the recommended models for each type of establishment.

4. Freight Trip Attraction Modeling

The data used for the present study, were collected from the two freight studies conducted in MMA. The objective with the models is to identify content information about the physical, operational, and socioeconomic characteristics of the establishments. The information available from the survey is listed in Table 4. It was found that the most influential variables affecting the weekly freight trips for both supermarkets and nano-stores are the total area (including service and storage space, in m^2) and the number of employees (converted to full-time employees). However, a Pearson correlation test was computed and the area and employees variables were correlated. So, they were not considered together in the models.

Table 4. Summary of variables used during the modeling process.

Variable	Description
Response variable	
FTA	Number of freight trip attracted per week
Explanatory variables	
Business size	
Area	Total are of the establishment (in m^2), including retail and storage spaces
Employees	Equivalent number of full-time employees. The owner is considered as an employee.
Parking	Dummy variable showing if the establishment 1: has parking spaces and 0 otherwise.
Storage	Dummy variable showing if the establishment 1: has storage space and 0 otherwise.
Business operation	
Hours open	Number of hours open to customers per day
Unloading time	Time, in minutes, to unload/load the cargo

The other variables in Table 4 that represent some characteristic of the operation of the establishment (i.e., were the presence or no of parking and storage spaces, and the time for loading/unloading the freight) were also tested but in all cases, they resulted non-significant for the models.

An important consideration is that this study only estimated freight trip attraction models. But as noted in a previous section, the freight trip generation is composed by freight trip attraction and freight trip production. For the grocery sector, the freight trip production has the particularity that freight trips can become passenger trips that carries some freight, and it is normally do it in passenger cars, not trucks. However, the attracted freight trips of the establishment accounts for the trips from the suppliers to the establishments.

The following two sub-sections present the estimated models for the weekly freight trip attraction for supermarkets, and nano-stores. Different functional forms for the models were tested, as shown in Table 5. For all of them, the method to estimate the models was the ordinary least square regression.

Table 5. Functional forms tested in the modeling process.

Response variable	**Explanatory variables**	
	x_i	$ln(x_i)$
y	Linear-Linear (Lin-Lin) $y = C + \beta_i x_i$ (1)	Linear-Logarithmic (Lin-Log) $y = C + \beta_i ln(x_i)$ (2)
$ln\ (y)$	Logarithmic-Linear (Log-Lin) $ln\ (y) = C + \beta_i x_i$ (3)	Logarithmic-Logarithmic (Log-Log) $ln\ (y) = C + \beta_i ln\ (x_i)$ (4)

For the equations in Table 5:

y: number of weekly freight trips attracted iEn the urban area.

C: constant of the model.

β_i: coefficient of the variable x_i.

x_i: explanatory variables.

In the cases where the independent variable is log-transformed a new factor should be added to correct the bias caused by the transformation (Miller, 1984; Newman, 1993). This new term called bias correction, is defined as show in equation (5) (Holguín-Veras et al., 2016; Miller, 1984; Newman, 1993). Thus, by adding the bias correction term, equations (3) and (4) change to (6) and (7) respectively.

$$\alpha = 0.5s^2 \quad (5)$$

$$ln(y) = C + \beta_i x_i + \alpha \quad (6)$$

$$ln\ (y) = C + \beta_i ln\ (x_i) + \alpha \quad (7)$$

However, the interest of the model is to obtain the number of trips attracted to the establishments, not the logarithm of the trips (i.e., the interest is y, not $ln(y)$). So, the models must be transformed again as shown in Table 6.

Table 6. Transformed functional forms.

Response variable	**Explanatory variables**	
	x_i	$ln(x_i)$
y	Linear-Linear (Lin-Lin) $y = C + \beta_i x_i$ (1)	Linear-Logarithmic (Lin-Log) $y = C + \beta_i ln(x_i)$ (2)
$ln\ (y)$	Logarithmic-Linear (Log-Lin) $y = C^* \cdot e^{\beta_i x_i} \cdot \alpha^*$ (8)	Logarithmic-Logarithmic (Log-Log) $y = C^* \cdot x_i^{\beta_i} \cdot \alpha^*$ (9)

For the equations in Table 6:

y: number of weekly freight trips attracted in the urban area.

$C^* = e^C$: constant of the model.

β_i: coefficient of the variable x_i.

x_i: explanatory variables.

$\alpha^* = e^{\alpha}$: bias correction.

4.1 Estimated FTA Models for Supermarkets

The estimated models considered linear and non-linear modeling with the functional forms presented in Table 7 correspond to the supermarkets. The models presented were estimated with the functional forms of Table 5. Thus, for non-linear models it estimates the natural logarithm of the weekly freight trip attraction. To obtain the actual weekly freight trip attraction it is necessary to apply the exponential function to the results or use the formulas in Table 6.

Table 7. Estimates - Weekly supermarkets freight trips attracted.

Model Type	Variable	Estimate (SE)	t-value	Adjusted R^2	F-value	RMSE	Bias
Lin-Lin	Area	0.043*** (0.006)	7.21	0.31	51.915***	10.98	na
Lin-Lin	Employees	0.968*** (0.134)	7.21	0.31	52.017***	10.98	na
Lin-Log	ln(Area)	2.268*** (0.175)	12.94	0.60	167.514***	8.40	na
Lin-Log	ln(Employees)	6.057*** (0.596)	10.17	0.48	103.429***	9.57	na
Log-Log	ln(Area)	0.436*** (0.018)	23.89	0.84	570.747***	0.95	0.39
Log-Log	ln(Employees)	1.157*** (0.079)	14.73	0.66	217.057***	1.19	0.69
Log-Lin	Area	0.008*** (0.001)	8.76	0.40	76.661***	1.31	0.84
Log-Lin	Employees	0.182*** (0.020)	9.02	0.42	81.421***	1.30	0.83

**p<0.1; **p<0.05; ***p<0.01*
Sample size for each model: 112 establishments.

4.2 Estimated FTA Models for Nano-Stores

Table 8 presents the estimated models considering linear and non-linear modeling functional forms for nano stores. The models presented were estimated with the functional forms of Table 5. So, for non-linear models it estimates the natural logarithm of the weekly freight trip attraction. As in the previous sub-section, to obtain the actual weekly freight trip attraction it is necessary to apply the exponential function to the results or use the formulas in Table 6.

The models presented in Table 7 and Table 8 were selected based on conceptual validity and statistical significance. All the models depend on the total area of the establishment or the equivalent number of full-time employees. Thus, for conceptual validity, the models do not have a constant term. Establishments with no area or no employees cannot perform any activity, so they cannot attract freight trips. It is worth noting that for this study if the owner of the establishment works on it, was considered as an employee. Also, the variables are easy to obtain, and the models are no complex depending on only one explanatory variable. This is good since for practitioners, simple is better.

Since the area and number of employees were correlated, they were not included together in any models. However, the other variables (i.e., presence of parking spaces, presence of storage space, and time for loading/unloading) were tested together with the area and employment. None of them were significant for the models. Also, this procedure was performed with two databases: before and after the reclassification of the establishments, and in both cases the results were similar. The only significant variables in the models were the total area and number of employees.

Table 8. Estimated models for nano-stores.

Model Type	Variable	Estimated (SE)	t-value	Adjusted R^2	F-value	RMSE	Bias
Lin-Lin	Area	0.319*** (0.027)	11.68	0.463	136.451***	8.66	-
Lin-Lin	Employees	3.227*** (0.312)	10.35	0.403	107.163***	9.12	-
Lin-Log	ln(Area)	2.855*** (0.206)	13.83	0.548	191.175***	7.94	-
Lin-Log	ln(Employees)	8.367*** (1.063)	7.87	0.28	61.996***	10.03	-
Log-Log	ln(Area)	0.577*** (0.026)	22.48	0.763	505.287***	1.07	0.49
Log-Log	ln(Employees)	1.718*** (0.166)	10.36	0.404	107.267***	1.33	0.89
Log-Lin	Area	0.065*** (0.004)	17.48	0.66	305.430***	1.21	0.66
Log-Lin	Employees	0.651*** (0.046)	14.18	0.56	201.020***	1.28	0.78

**p<0.1; **p<0.05; ***p<0.01*
Sample size for each model: 157 establishments

For supermarkets and nano-stores the non-linear models have a better performance. Particularly, the log-log transformed form with area as explanatory variable present a better fit for the data, having the better performance on the three metrics: F-value, adjusted R^2, and RMSE. Thus, this type of model is recommended to be applied for practitioners. However, for supermarkets the log-log model depending on number of employees also is a good option, having the second better F-value and RMSE. However, for nano-stores the model depending on number employees with better performance is the log-lin with the third best F-value, adjusted R^2, and RMSE. These two recommended models for both cases: supermarkets and nano-stores. It gives the better performance with the two variables: area and employment depending on the witch one is available for the practitioners. A summary of the recommend models is presented in Table 9.

Table 9. Recommended practitioner-ready models to predict the weekly number of freight trips attracted by supermarkets and nano-stores.

Supermarkets		Nano-Stores	
Total area of the establishment in square meters as explanatory variable			
$FTA = 1.48 \cdot Area^{0.436}$	(10)	$FTA = 1.63 \cdot Area^{0.577}$	(11)
Equivalent number of full-time employees as explanatory variable			
$FTA = 1.99 \cdot Employees^{1.157}$	(12)	$FTA = 2.18 \cdot e^{0.651 \cdot Employees}$	(13)

Thus, the recommended models for supermarkets and nano-stores: log-log transformed depended on the total area of the establishments. Equations (10) and (11) estimate the FTA presented in Figure 4, which also compares the models' predictions with the collected data.

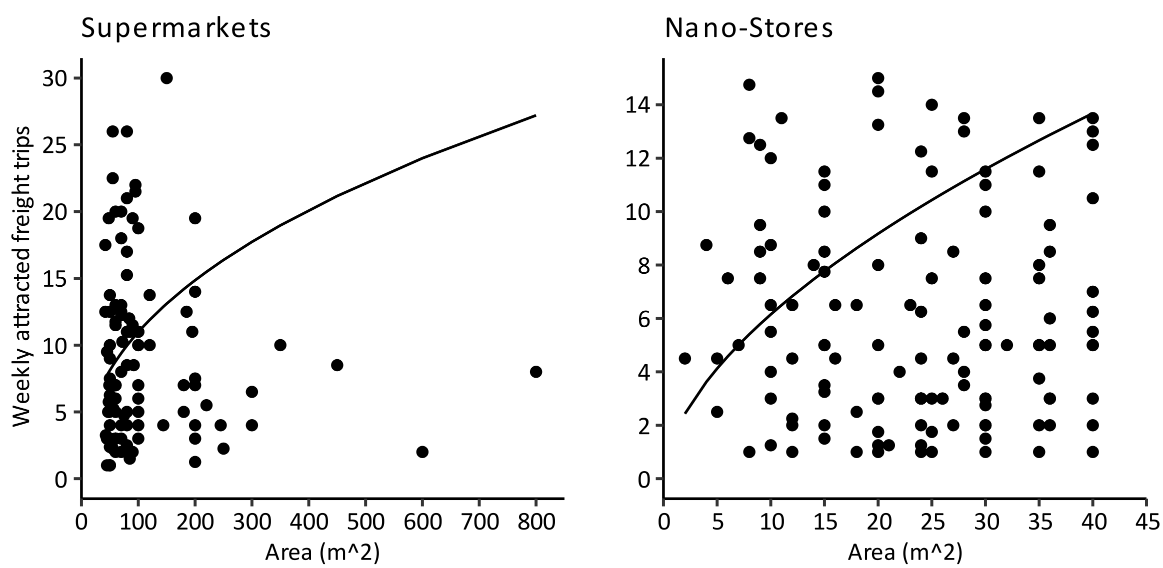

Figure 4. Weekly FTA for supermarkets and nano-stores based on total area of the establishment.

Supermarkets and nano-stores have the same relationship between the total area of the establishment and the weekly attracted freight trips, as shown in Figure 4. Also, even when the difference the area between supermarkets and nano-stores is notorious, having greater values of area for supermarkets, the weekly trips do not have a such notorious difference. In fact, the weekly trips have the same magnitude order for both supermarkets and nano-stores, but the area has one magnitude order of difference.

5. Conclusions and Recommendations

5.1 Conclusions

- The freight trip attraction of supermarkets and nano-stores depend, mainly, on the area of the establishments, and the number of employees. However, the area is a better predictor than the number of employees.
- When the total area of the establishment is known models from equations (10) and (11) are recommended. Alternatively, when the equivalent number of full-time employees is known, models from equations (12) and (13) are recommended, for supermarkets and nano-stores, respectively. The models (10) and (11) are preferred over (12) and (13).
- The significant variables found in this study correspond with the results of studies in other cities, for the whole grocery sector.

5.2 Recommendations

- To include in the study the type of vehicle used for delivering the cargo in each type of establishment. This will allow to know better understanding about the necessity of the infrastructure and the affectations in the traffic. Also, it is of interest since supermarkets and nano-store have similar number of attracted freight trips per week, but a different amount of cargo per week.
- To disaggregate the study by residential zones and commercial zones. The density of nano-stores and supermarkets probably will be different for each zone, leading to different number of attracted freight trips. Also, the type of road, available space, and traffic will differ. All this can include different FTA patterns, requirement in infrastructure, and externalities.

6. References

Asuncion, J., Page, S., Murray, R., & Krumdieck, S. (2012). Analysis of the Truck Trip Generation Characteristics of Supermarkets and Convenience Stores. In U. of Canterbury. (Ed.), *IPENZ Transportation Group Conference*. University of Canterbury. Mathematics and Statistics. http://hdl.handle.net/10092/7792

Blanco, E. E., & Fransoo, J. C. (2013). Reaching 50 million nanostores: retail distribution in emerging megacities. *BETA Publicatie : Working Papers*, *404*(January), 1–19. https://research.tue.nl/en/publications/reaching-50-million-nanostores-retail-distribution-in-emerging-me

Blanco, E. E., & Fransoo, J. C. (2017). Supplying nanostores. In J. C. Fransoo, E. E. Blanco, & C. Mejía-Argueta (Eds.), *Reaching 50 Million Nanostores: Retail Distribution in Emerging Megacities* (pp. 23–38). CreateSpace Independent Publishing Platform. https://research.tilburguniversity.edu/en/publications/reaching-50-million-nanostores-retail-distribution-in-emerging-me-2

Cheah, L., Mepparambath, R. M., & Ricart Surribas, G. M. (2021). Freight trips generated at retail malls in dense urban areas. *Transportation Research Part A: Policy and Practice*, *145*(November 2020), 118–131. https://doi.org/10.1016/j.tra.2021.01.015

Fransoo, J. C., & Blanco, E. E. (2017). 50 Million Nanostores. In J. C. Fransoo, E. E. Blanco, & C. Mejía-Argueta (Eds.), *Reaching 50 Million Nanostores: Retail Distribution in Emerging Megacities* (pp. 10–21). CreateSpace Independent Publishing Platform. https://research.tilburguniversity.edu/en/publications/reaching-50-million-nanostores-retail-distribution-in-emerging-me-2

Gonzalez-Calderon, C. A., Moreno-Palacio, D. P., Posada-Henao, J. J., Quintero-Giraldo, R., & Múnera, C. C. (2022). Service trip generation modeling in urban areas. *Transportation Research Part E: Logistics and Transportation Review*, *160*, 102649. https://doi.org/10.1016/j.tre.2022.102649

Gonzalez-Calderon, C. A., Sanchez-Diaz, I., Sarmiento-Ordosgoitia, I., & Holguin-Veras, J. (2018). Characterization and analysis of metropolitan freight patterns in Medellin, Colombia. *European Transport Research Review*, *10*(2), 23. https://doi.org/10.1186/s12544-018-0290-z

Gonzalez-Feliu, J., & Sanchez-Diaz, I. (2019). The influence of aggregation level and category construction on estimation quality for freight trip generation models. *Transportation Research Part E: Logistics and Transportation Review*, *121*, 134–148. https://doi.org/10.1016/j.tre.2018.07.007

Google LLC. (2022). *Google Maps*. https://www.google.com/maps/

Heldt, B., Matteis, T., Frenzel, I., & Blechschmidt, J. (2017). *Grocery Stores and Urban Transport-Theoretical and Empirical Approaches to Explain Store Location*.

Holguin-Veras, J., Jaller, M., Sanchez-Diaz, I., Campbell, S., & Lawson, C. (2014). Freight Generation and Freight Trip Generation Models. In *Modelling Freight Transport* (pp. 43–63). Elsevier Inc. https://doi.org/10.1016/B978-0-12-410400-6.00003-3

Holguín-Veras, J., Lawson, C., Wang, C., Jaller, M., González-Calderón, C., Campbell, S., Kalahashti, L., Wojtowicz, J., & Ramirez, D. (2016). *Using Commodity Flow Survey Microdata and Other Establishment Data to Estimate the Generation of Freight, Freight Trips, and Service Trips: Guidebook*. Transportation Research Board. https://doi.org/10.17226/24602

Holguin-Veras, J., Ramirez-Rios, D., Encarnacion, T., Gonzalez-Feliu, J., Caspersen, E., Rivera-Gonzalez, C., Gonzalez-Calderon, C. A., & Da Silva Lima, R. (2019). Metropolitan Economies and the Generation of Freight and Service Activity: An International Perspective. In M. Browne, S. Behrends, J. Woxenius, G. Giuliano, & J. Holguin-Veras (Eds.), *Urban Logistics: Management, Policy and Innovation in a Rapidly Changing Environment* (pp. 19–51). https://halshs.archives-ouvertes.fr/halshs-03114392

Holguin-Veras, J., Ramirez-Rios, D., Ng, J., Wojtowicz, J., Haake, D., Lawson, C., Calderón, O., Caron, B., & Wang, C. (2021). Freight-Efficient Land Uses: Methodology, Strategies, and Tools. *Sustainability*, *13*(6), 3059. https://doi.org/10.3390/su13063059

Holguin-Veras, J., Ramirez-Rios, D., & Pérez-Guzmán, S. (2021). Time-dependent Patterns in Freight Trip Generation. *Transportation Research Part A: Policy and Practice*, *148*(April), 423–444. https://doi.org/10.1016/j.tra.2021.03.029

Iding, Mirjam., Meester, W. J., & Tavasszy, L. A. (2002). Freight Trip Generation by Firms. *42nd European Congress of the Regional Science Association*, 14. http://www.raumplanung.tu-dortmund.de/rwp/ersa2002/cd-rom/papers/453.pdf

Kawamura, K., Shin, H., Mcneil, S., & Ogard, L. (2005). *Business and Site Specific Trip Generation Methodology for Truck Trips*. https://minds.wisconsin.edu/handle/1793/6958

Kin, B., Ambra, T., Verlinde, S., & Macharis, C. (2018). Tackling Fragmented Last Mile Deliveries to Nanostores by Utilizing Spare Transportation Capacity—A Simulation Study. *Sustainability*, *10*(3), 653. https://doi.org/10.3390/su10030653

McCormack, E., Ta, C., Bassok, A., & Fishkin, E. (2010). *Truck Trip Generation by Grocery Stores*.

McKinnon, A. (2006). Life Without Trucks: The Tmpact of a Temporary Disruption of Road Freight Transport on a National Economy. *Journal of Business Logistics*, *27*(2), 227–250. https://doi.org/10.1002/j.2158-1592.2006.tb00224.x

Mejía, C. (2022). *Christopher Argueta - The Impact of Nano Stores on Underserved Communities - 2 of 5*. MIT Corporate Relations. https://www.youtube.com/watch?v=SPBRaJXxSDU

Mejía-Argueta, C., Agudelo, I., Hidalgo-Carvajal, D. A., & Soto, M. A. (2017). Colombina: Shifting from on-board to presales in Bogota. In J. C. Fransoo, E. E. Blanco, & C. Mejía-Argueta (Eds.), *Reaching 50 Million Nanostores: Retail Distribution in Emerging Megacities* (pp. 181–196). CreateSpace Independent Publishing Platform. https://research.tilburguniversity.edu/en/publications/reaching-50-million-nanostores-retail-distribution-in-emerging-me-2

Mejía-Argueta, C., Blanco, E. E., Agudelo, I., & Torres, L. A. (2017). Benchmarking of Latin American last-mile operations in the consumer packaged goods industry. In J. C. Fransoo, E. E. Blanco, & C. Mejía-Argueta (Eds.), *Reaching 50 Million Nanostores: Retail Distribution in Emerging Megacities* (pp. 250–277). CreateSpace Independent Publishing Platform. https://research.tilburguniversity.edu/en/publications/reaching-50-million-nanostores-retail-distribution-in-emerging-me-2

Miller, D. M. (1984). Reducing Transformation Bias in Curve Fitting. *The American Statistician*, *38*(2), 124–126. https://doi.org/10.2307/2683247

Newman, M. C. (1993). Regression analysis of log-transformed data: Statistical bias and its correction. *Environmental Toxicology and Chemistry*, *12*(6), 1129–1133. https://doi.org/10.1002/etc.5620120618

Oliveira, L. K. de, Nóbrega, R. A. de A., Ebias, D. G., & Corrêa, B. G. e S. (2017). Analysis of Freight Trip Generation Model for Food and Beverage in Belo Horizonte (Brazil). *REGION*, *4*(1), 17. https://doi.org/10.18335/region.v4i1.102

Ortúzar, J. de D., & Willumsen, L. G. (2011). *Modelling Transport* (4th ed.). Wiley. https://doi.org/10.1002/9781119993308

Sanchez-Diaz, I. (2020). Assessing the magnitude of freight traffic generated by office deliveries. *Transportation Research Part A: Policy and Practice*, *142*(November 2020), 279–289. https://doi.org/10.1016/j.tra.2020.11.003

Sanchez-Diaz, I., Holguin-Veras, J., & Wang, X. (2016). An Exploratory Analysis of Spatial Effects on Freight Trip Attraction. *Transportation*, *43*(1), 177–196. https://doi.org/10.1007/s11116-014-9570-1

United Nations - Department of Economic and Social Affairs - Statistics Division. (2002). International Standard Industrial Classification of All Economic Activities (ISIC) Revision 3.1. In *Statistical Papers*. United Nations. https://unstats.un.org/unsd/classifications/Econ/ISIC.cshtml

United Nations - Department of Economic and Social Affairs - Statistics Division. (2008). *International Standard Industrial Classification of All Economic Activities (ISIC) Revision 4*. United Nations. https://unstats.un.org/unsd/classifications/Econ/ISIC.cshtml

Universidad Nacional de Colombia, & Area Metropolitana del Valle de Aburrá. (2019). *Estudio de transporte de carga en el Area Metropolitana del Valle de Aburra*. https://www.metropol.gov.co/movilidad/Documents/Estudio-de-transporte-de-carga-en-el-Area-Metropolitana-del-Valle-de-Aburra.pdf

Wilmsmeier, G., Johansson, L., & Jallow, D. (2015). *The Complex Urban Freight Puzzle* (Issue 340). ECLAC. https://repositorio.cepal.org/handle/11362/38960