

LOGISTICS BEHAVIOR IN LAST-MILE DISTRIBUTION OF FOOD PRODUCTS IN VILLAVICENCIO, COLOMBIA

 WILSON ADARME JAIMES
MARTÍN DARÍO ARANGO SERNA
IVÁN DARÍO CÁRDENAS

ABSTRACT

Urban logistics are a major issue given that urban centers tend to grow and consolidate economic and industrial activities with social and human activities. The vast majority of studies related to this field follow the traditional transport approach, which aims to explain variables related to the supply of transportation instead of analyzing the actual demand. There is a lack of understanding regarding customers' behavior, and this concern is evident in previous studies related to city logistics. In this paper, we aim to provide an analysis of the main trends and behaviors of household purchases, specifically food products, through the use of primary information sources and statistical tools. The results obtained in a rapidly growing urban center in Colombia provide a framework to understand the behavior of household purchases based on three main variables: (i) products, (ii) vehicles, and (iii) purchase frequency related to the type of food procurement facility (store).

KEYWORDS: City logistics; Urban goods distribution; Food; Last-mile distribution; Household purchases.

COMPORTAMIENTOS LOGÍSTICOS EN LA DISTRIBUCIÓN DE ÚLTIMA MILLA DE PRODUCTOS ALIMENTICIOS EN VILLAVICENCIO, COLOMBIA

RESUMEN

La logística de la ciudad es uno de los asuntos principales en logística debido que los centros urbanos tienden a crecer y consolidar las actividades económicas e industriales con aquellas sociales y humanas. La gran mayoría de los estudios se centran en el enfoque tradicional de transporte, que tiene como objetivo explicar las variables relacionadas con la oferta de transporte, en lugar de analizar la demanda real. Existe una falta de comprensión sobre el comportamiento de los clientes, lo que es explícito en estudios previos relacionados con la logística de la ciudad. Este trabajo tiene como objetivo ofrecer un análisis de las principales tendencias y el comportamiento de las compras en el hogar, específicamente en la compra de alimentos, mediante el uso de fuentes primarias de información y herramientas de

¹ Industrial Engineer, Doctor in Engineering – Industry and Organizations. Professor in the Engineering Faculty, Universidad Nacional de Colombia, Bogotá.

² Industrial Engineer, Doctor in Industrial Engineer, Associate Professor in the Organization Engineering School, Minas Faculty. Universidad Nacional de Colombia, Medellín.

³ Industrial Engineer, M.Sc. in Engineering. Professor in the Engineering Faculty, Universidad Nacional de Colombia, Bogotá.

 Correspondence author: Jaimes, W.A. (Wilson Adarme): Carrera 45 N. 26-85 - Edificio Antonio Nariño, Oficina 115, Universidad Nacional de Colombia, sede Bogotá, Bogotá (Colombia). Tel: (57 1) 316 50 00
Email: wiadarme@unal.edu.co

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estadísticas. Los resultados obtenidos en un centro urbano de rápido crecimiento en Colombia, ofrecen un marco para comprender el comportamiento de las compras en los hogares, con base en tres variables principales: a) Los productos, b) Vehículos y c) La frecuencia de compra en relación con las instalaciones para la adquisición de alimentos (tiendas).

PALABRAS CLAVE: Logística de ciudad, Distribución urbana, Alimentos, distribución de última milla, compras para el hogar.

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RESUMO

A logística da cidade é um dos assuntos principais em logística devido que os centros urbanos geralmente crescem e consolidam as atividades econômicas e industriais com as atividades sociais e humanas. A maioria dos estudos concentram-se no enfoque tradicional de transporte, que tem como objetivo explicar as variáveis relacionadas com a oferta de transporte, em vez de analisar a demanda real. Existe uma carência de compreensão sobre o comportamento dos clientes, o que é explícito nos estudos prévios relacionados com a logística da cidade. Este trabalho tem o objetivo de oferecer um análise das principais tendências e do comportamento das compras no lar, especificamente na compra de alimentos, mediante o uso das fontes primárias de informação e ferramentas de estatísticas. Os resultados obtidos num centro urbano de rápido crescimento em Colômbia oferecem um quadro para compreender o comportamento das compras nos lares, com base em três variáveis principais: a) os produtos, b) veículos e c) a frequência de compra em relação com as instalações para a aquisição de alimentos (lojas).

PALAVRAS-CHAVE: Logística de cidade; Distribuição urbana; Alimentos; Distribuição de última milha; Compras para o lar.

1. INTRODUCTION

The logistical activities that take place both between cities and within them are of vital importance to the economic and social development of communities. They guarantee continual operation of different economic and industrial activities, providing sources of employment and wellbeing for citizens and ensuring access to goods and services necessary for satisfying their needs.

Aside from the importance of logistical activities, it is essential to consider some negative externalities that are derived from them (Russo & Comi, 2011). These impacts are manifested in traffic congestion, reductions in road capacity due to loading and unloading operations, visual, sound, and environmental impacts, and an increased risk of accidents due to the presence of heavy transport vehicles. For example, nitrogen oxide emissions in urban areas are attributed to cargo

shipping in the following ratios: 28% in London, 50% in Prague, and 77% in Tokyo. Meanwhile, countries are experiencing rapid growth in urban population, which is expected to reach 85% of the world's population in 2020 (OECD, 2003).

The activities inherent to logistical processes at the urban level contribute to this problem in a context in which conflicts arise over public interests and the use of limited resources: public space and others, such as air, the sound environment, and safety (Danielis, Ritaris y Marcucci, 2010). Taniguchi (2001) defines urban logistics as "*the process of totally optimizing private transportation and logistics activities in urban areas considering traffic, congestion, and energy consumption within the structure of a market economy.*"

The considerations discussed above imply that urban logistical planning must be treated as an aggregate process, not seen from the local level, but with a holistic approach that considers the system's overall

performance. This task has traditionally fallen among the responsibilities of public administration through policies surrounding urban logistics in an attempt to promote and implement sustainable and coordinated strategies in order to control and monitor externalities that may be caused. At the same time, this allows for the development of economic activities that take place in the city (Russo & Comi, 2011).

The complexity and relevance that urban planning entails make it an issue of interest both for the scientific community and in practice. For the same reason, different approaches have been studied from various standpoints in order to contribute to the understanding and resolution of the externalities caused by urban merchandise distribution. One of these approaches is known as last-mile distribution.

28% of the total transportation costs for a product are attributed to the final stretch of the supply network (Goodman, 2005). The attention to the "last mile problem" tends toward improved assignment of resources so that the level of services is maximized and the costs are minimized in the final segment of transportation (Balcik, Beamon & Smilowitz, 2008).

Although the last mile situation has received a great deal of attention in recent years, each network experiences different problems associated with this type of distribution, especially for food products. In this type of distribution, multiple individuals visit supply centers, both large and small, to obtain the products necessary for their sustenance, creating routes from multiple origins to multiple destinations. According to estimations made by the World Health Organization (World Health Organization, 2012), an average of 1.24kg of food are consumer per day per capita. For a city with a population like that of Villavicencio (the object of this study) with its 400,000 inhabitants, this figure means that approximately 500 tons of only food products must be transported daily between different nodes in the network.

This article proposes a methodology for contributing to the understanding of logistical behaviors at the micro level in food product supply by analyzing the shopping trips of family units. The evaluation is based on a Multiple Correspondence Analysis (MCA) (Le Roux & Rouanet, 2004). This study also suggests establishing how the specific characteristics of different

types of food products are related to the operation of urban logistics. Finally, the results allow for identification of important trends that must be considered in last-mile transportation planning.

2. LITERATURE REVIEW

In the literature review, two bodies of literature can be identified for this study; (i) the analysis of methodologies used, both for gathering and analyzing the information that allows for decision-making regarding urban cargo transportation, and (ii) the identified need for future studies. Below, the main contributions made in each of these aspects will be reviewed. An endless number of existing alternatives must be studied, and it is necessary to bear in mind that the particular features of the urban environment can mean that successful policies may fail in other contexts (Danielis, Ritaris & Marcucci, 2010).

2.1 Methodologies for Data Collection and Analysis.

A good part of the methodologies applied to cargo transportation optimization are robust methodological approaches from the world of passenger transportation. However, the particular characteristics of cargo transportation make it impossible to fully adapt them (Holguin-Veras & Thorson, 2000), (Benjelloun & Crainic, 2008). Therefore, various authors agree that there are opportunities for research regarding the methodological aspects of urban logistics since they are currently in an experimental stage (Crainic, Ricciardi & Storchi, 2009), (Ambrosini & Routhier, 2004). Another essential component is the need to include coordination among different actors in the network (Adarme, Arango & Otero, 2011), as well as possible underlying strategies (Arango, Zapata & Adarme, 2011).

In a study by Ambrosini & Routhier (2004), methodologies implemented for information collection and analysis in different cities around the world are reviewed. The authors found that methodological development is related to the needs of urban logistics in different countries. For example, in countries with established infrastructures and broad geographical areas, such as the United States, Australia, or Canada,

the studies focus on the analysis of commercial vehicles. Meanwhile, in countries with densely populated urban areas like European countries or Japan, the studies consider a greater number of elements, such as the logistical dynamics of residents or even garbage collection.

According to Holguín-Veras & Thorson (2000), adapting passenger transportation models to cargo transportation is not a valid option. We can consider, for example, a complex population like that of New York, in which passenger transportation is one-dimensional in terms of demand since the passenger is the model's fundamental unit. However, in cargo transport, other dimensions (volume, weight, trips, value of merchandise) appear and must be considered as measures of demand. Another relevant aspect, according to the authors, is decision-making. While in passenger transportation the user is the decision-maker, in cargo transportation different companies with different goals and information make decisions, increasing the system's complexity and emphasizing the importance of human behavior in decision-making.

With this perspective, Routhier, Patier & Aubert (1996) propose a methodology in which matrices of origin/destination are not reproduced, but rather in which the information gathered has the following goals: (i) estimating vehicle flows according to the commercial or industrial activity with which they are associated, (ii) understanding the organizational schemes for transportation in urban areas (hired or personal), and (iii) identifying loading/unloading conditions in businesses. The gathering of information was done with surveys in businesses and with shippers focused on loading/unloading activities. The information allowed the researchers to create and evaluate a model of the system using a simulation. The alternatives include: (i) logistics (platforms, modes of transportation and operation, means of transportation, packaging, and handling), (ii) legal aspects (restrictions on time and location for logistical activities), and (iii) urban planning (transportation infrastructure). A similar focus is found in Allen, Anderson & Jones (2000), including participative techniques instead of surveys.

Other analysis approaches propose including new techniques for working with information, such as simulation and discrete decision modeling to charac-

terize the decision-making processes of different agents present in the logistics operation (Taniguchi & Heijden, 2000), (Danielis, Ritaris & Marcucci, 2010), (Holguín-Veras, Silas, Polimeni & Cruz, 2007), (Holguín-Veras, Polimeni & Cruz, 2008).

In conclusion, the techniques used for research in urban logistics have moved from a traditional approach influenced by passenger transport toward an approach that contributes to understanding the flows of goods and services, urban transportation, and policies that provide sustainability (Allen, Anderson & Jones, 2000). This approach is centered on industrial and commercial dynamics while emphasizing relational elements between the different agents and decision-making processes that are decisive in the logistical system's function.

2.2 Identified Necessity of Research

Although the academic contributions to the literature review in the urban logistics sphere are considerable, there are still gaps in current knowledge that create a need for further research. Generally, the contributions tend to consider a larger number of variables that aid in understanding, modeling, analyzing, evaluating, and deciding upon the aspects related to urban merchandise distribution. Below, the proposed perspectives are considered based on previous research results.

Some trends that are still awaiting detailed study have been identified, such as the development of subterranean structures for transportation of merchandise (Ambrosini & Routhier, 2004). The latest technological advances and urban dynamics make it necessary to consider these alternatives in the future. Other relevant trends are related to the evolution of logistics systems, philosophies like lean logistics, and electronic commerce, which have caused changes in network behavior (Ambrosini & Routhier, 2004). The use of intelligent packaging, in harmony with the development of sophisticated information and communication systems, feed the expectation for advances in logistics.

One urgent approach that is present in various studies focuses on the need for coordination between agents involved in the logistics process. In this sense,

two spheres of possible scenarios that require coordination arise: on the one hand, an intra-city scenario in which the interactions to be coordinated are carried out between participating urban agents that act as generators and petitioners of cargo, shippers and providers of cargo services, such as consolidation centers, storage warehouses, and service providers dedicated to different activities, such as packaging, loading/unloading, agencies, and others.

Ambrosini & Routhier (2004) highlight the work done in Germany with the "City Logistics" program, which allows agents involved in merchandise transportation to establish modes of cooperation according to merchandise characteristics, such as type, quantity, or location. The authors emphasize the importance of identifying different participating agents and the roles and interactions present within the system. In this sense, Danielis, Ritaris, & Marcucci (2010) recommend using discrete choice models such as those used by various authors (Holguín-Veras, Silas, Polimeni, & Cruz, 2007), (Marcucci & Danielis, 2008). These authors also work with inter-city coordination, in which different cities, due to their location or economic activities, maintain interactions that must be coordinated. Pertinent studies highlight the need for harmonization among the urban logistics policies between different cities, both domestically and internationally, though international coordination does not yet seem to exist (Ambrosini & Routhier, 2004). The goal of this harmonization is to reduce logistical costs that may be associated with a lack of coordination among these policies (Quak & Koster, 2007).

Another approach present in the literature is that of considering a wider spectrum of elements and variables that, despite their presence in urban logistics systems, have been left aside in various studies. Ambrosini & Routhier (2004) show the necessity of considering variables such as family purchases or garbage collection trips. Similarly, there is a trend toward the movement of merchandise that enters or exits the city, incorrectly removing the focus from movements with origins and destinations within the city itself (Crainic, Ricciardi, & Storchi, 2009).

Urban logistics systems are mainly based on consolidation. These activities take place in urban Distribution Centers (DC) where long-distance

transportation vehicles arrive and unload merchandise. Once there, the merchandise is organized and consolidated into vehicles with a smaller capacity (Crainic, Ricciardi, & Storchi, 2009). However, current initiatives related to DCs are generally considered to be unsuccessful, mostly in terms of their financial viability, with a strong trend toward the necessity of municipal financial subsidies (Ambrosini & Routhier, 2004). In regards to this issue, Crainic, Ricciardi, & Storchi (2009) compare experiences in Germany and Switzerland to those in Monaco and Holland, thereby illustrating the importance of the role played by local and central governments in the success and sustainability of urban DCs. DCs located in airports are among the successful cases given that the conditions of these DCs ensure the successful operation of the platform. Since a modal exchange already exists, consolidation in the DC is obligatory (Ambrosini & Routhier, 2004).

Some studies indicate that use of a DC is related to the type of merchandise (Ambrosini & Routhier, 2004), (Comune di Venezia, 2004) and to the structure of the supply network to which the DC belongs. These two aspects determine the modes and means used in the logistics operation (Dufour & Patier, 1999). Therefore, the policies adopted will affect each network in some way (Danielis, Ritaris, & Marcucci, 2010). A detailed understanding of the particular function of networks (Ambrosini & Routhier, 2004) is necessary in order to establish how they will be affected by the proposed interventions.

Among the findings of various research projects, the need to delve more deeply into the individual behavior of agents stands out (Regan & Garrido, 2000). The proposals made regarding this aspect include the use of qualitative information collection methods, including discussion groups that may provide better results. One behavior that has been overlooked in urban merchandise transportation studies but deserves special consideration is that of family units in their purchases (Ambrosini & Routhier, 2004). In this sense, contributions such as the modeling tools proposed by "Freturb" in France have been an effort in considering the "buying trips" made by families within the city using surveys completed in homes and with individuals. These surveys are an approach to understanding the behaviors of these trips for obtaining supplies, which

is useful in planning for retailers (Routhier, Segalou, & Durand, 2001).

3. METHODOLOGY

The methodological approach followed in this study is divided into four phases: (i) planning, (ii) field work, (iii) data consolidation, and (iv) analysis and results. These phases were systematically executed in the context of creating a mobility plan for the city of Villavicencio.

The planning phase included activities of secondary information collection, recognizing the city's logistics system, estimating the sample, and designing and creating instruments for primary information collection. These instruments included multiple choice questions with a single answer that summarize the characteristics of food purchases which are essentially explained through variables that must be considered for different groups of products: groceries, meat and eggs, grains, plantains, and tubers, vegetables and grains, fruits, and milk and dairy. The features to be observed are: place where the product was bought, frequency with which the purchase was made, and the means of transport used for the acquisition of each product. The values for the instrument's variables were established according to a review of the secondary information, considering the main purchasing centers in the city, the means of transport (by foot, bicycle, bus, taxi, motorcycle, personal car, truck), and the frequency of purchase (daily, weekly, bi-weekly, monthly).

A total of 705 surveys was estimated using a simple random sample. The target population was made up of 101,717 homes in the city that were of social interest according to the Villavicencio-Meta Sector Context, completed by the Center for Construction and Urban and Regional Development Studies (2013). The approximate error is of 3% according to the estimation of the simple population.

$$n = \frac{N \cdot p \cdot q \cdot z_{\alpha}^2}{i^2 (N-1) + z_{\alpha}^2 p \cdot (1-p)} \text{ In which:}$$

- n: Sample size
- N: Target population size
- z: Quartile value according to normal distribution with error α .
- p: Prevalence of the parameter to be estimated
- i: Expected error

Once the instrument had been reviewed and evaluated through pilot tests, the field work stage was executed. In this stage, information was collected by means of the survey applied (i) in homes, and (ii) in strategic points in the city in which citizens were approached to collect the target information.

For the information consolidation phase, the data was tabulated on an electronic spreadsheet. The statistics software SPAD, a data analysis, data mining, and text mining program, was used to analyze the information, providing a descriptive and exploratory approach.

The analysis proposed consists of the application of the multiple correspondence analysis model to establish relationships between variables included on a multiple contingency table. This method is able to analyze relationships among the rows and columns of said table through dimensionality reduction of the matrix that contains the information using Chi-squared distribution. In this study, the analysis facilitates the construction of different individual behaviors by comparing all the characteristics observed through the modalities that they present and drawing conclusions about the relationships among the variables of study and, in turn, among the modalities they present (Greenacre, 2008). The development of the proposed method included the elaboration of a plan in which the variables' modalities are projected, thereby visualizing the relationships graphically in the matrix obtained with a size of 705 x 32.

In order to establish the relationships between the place of purchase, the means of transportation used, and the frequency with which the purchase trips are made by the family units, Cartesian planes are formed by the related variables on **Table 1**. This allows for the identification of individual food product purchasing behaviors and trends that are useful in last-mile transportation planning.

4. CASE STUDY

The city of Villavicencio has some 400,000 inhabitants, according to available information sources. However, this figure may be more than 600,000 due to the economic and social dynamics present in the city, given that it is the main point of access to the Eastern

Plains from the center of the country (**Figure 1**). This geographical situation has important consequences from a logistical point of view. First, different industrial products enter the city from the center of the country in order to supply the entire Eastern Plains region. Second, this region contains approximately 70% of the country's oil production, and, due to the insufficient capacity of duct infrastructure, it must rely on highway transportation to move the oil from the deposits to refineries and exportation points.

This situation forces the city to attend to logistical activities not only based on its internal dynamics, but also to support the economic activities of the eastern region of the country. In regards to this second aspect, various studies have been completed to collect information on the products that are moved along the region's highways that connect Villavicencio with Bogotá and the oil deposits.

5. RESULTS

The study identified eight (8) main food distribution centers (**Figure 2**) in which 75% of the city's food purchases are concentrated. One of these centers is Llanoabastos, a distribution center built in the outskirts of the city for gathering agricultural products. This center has a participation level of 15% for all the products selected, except dairy products.

The analysis of the instruments showed the vocation of each of the distribution centers identified in the city. The food products selected were compared with the places in which they were bought, generating the following results. The large-area vendors, centralized markets of a large size, showed groceries as their main vocation; markets, decentralized conglomerates with individual vendors, have a vocation focused on selling vegetables, grains, and similar products; fruits are found both in these markets and in stores, individual and isolated sales establishments whose vocation is the provision of dairy products and eggs, as shown in **Figure 3**.

Once the analysis had been completed, two factorial planes were created with the information obtained, taking the different (individual) points in accordance with the responses given and describing behavior within food product provision (**Table 2**). The

Table 1. Specification of variables related to each Cartesian plane obtained.

	First Related Variable	Second Related Variable
First Factorial Plane	Place of purchase	Means of transportation used
Second Factorial Plane	Place of purchase	Frequency of purchase

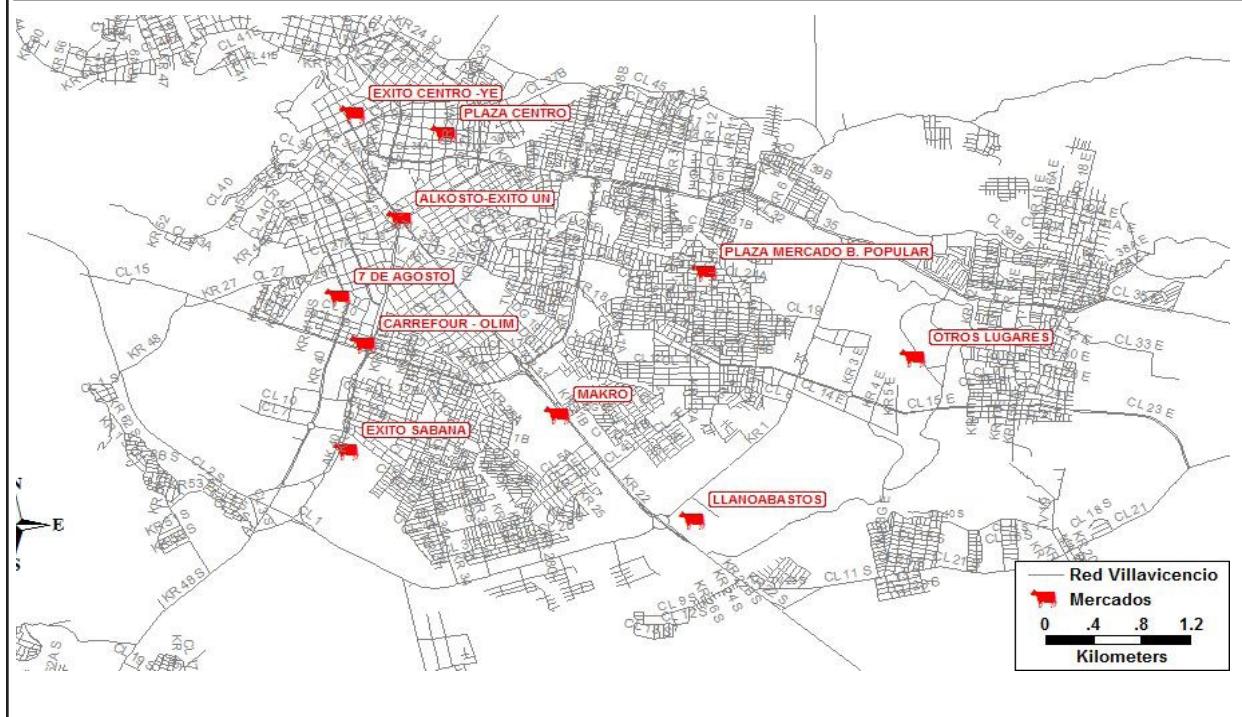
Figure 1. Location of the city of Villavicencio



closeness between them was evaluated as a sample of mobility trends in Villavicencio.

By means of a simple correspondence analysis, the contributions to each of these axes were evaluated for each article of interest: Groceries (1), Meat and eggs (2), Cereals, plantains, and tubers (3), Vegetables and grains (4), Fruits (5), Milk and dairy (6) in terms of the place of purchase and the means of transportation used in order to determine the plane on which to interpret the projections.

The results of the analysis provided information on the means of transportation used for reaching the purchase locations for food products as shown in **Table 3**. It was found that means like motorcycles, bicycles, and trips on foot are related to purchase locations in the city center, mainly explained by traffic and reduced parking in these areas.

Figure 2. Main food product distribution centers in the city**Table 2.** Description of the relationships offered by the factorial planes obtained.

Relationships Established	
First Factorial Plane	Distribution of the means of transportation according to the place of purchase
Second Factorial Plane	Distribution of the frequency of purchase according to the place of distribution.

Private transportation was related to purchases made in large-area vendors with large parking bays and locations in the outskirts of the city. Besides the parking capacity, the generation of trips to these vendors in personal transportation is also related to the purchasing power of the consumers. Finally, public taxis are associated with markets and supply centers with traffic-free points of access but limited parking. These centers are also not frequented by buyers with high purchasing power. For stores, the main means of transportation are public buses and by foot.

The final analysis was completed considering variables related to the frequency of purchase for products, as can be seen in **Table 4**. The results also showed that trips with greater frequency (weekly,

daily) are mainly related to purchases made in stores and, therefore, to means of transportation like the bus and trips on foot. Purchases associated with markets and supermarkets located in the city center show bi-weekly frequencies that can be associated with the type of vehicle used for movement (motorcycle, by foot). Large-area vendors are associated with monthly purchases, explained not only by the vehicles used, but also by the savings opportunities of buying in bulk.

Table 5 compiles the main results associated with the three types of establishments identified in the food supply system along with the main logistical behaviors related to them.

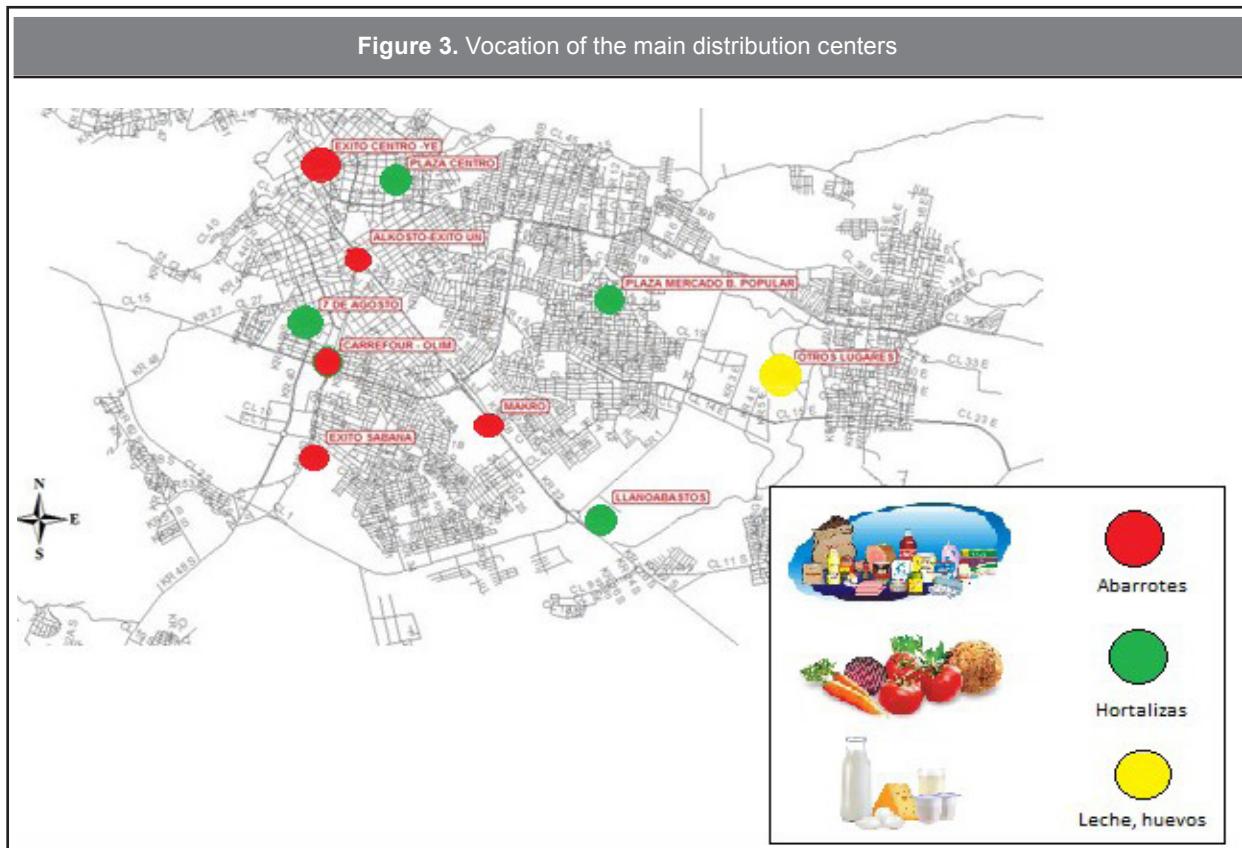


Table 3. Contributions of products to the first four axes for the place of purchase and the means of transportation used.

	Place				Transportation			
	Axis 1	Axis 2	Axis 3	Axis 4	Axis 1	Axis 2	Axis 3	Axis 4
1	6,4	3,8	1,7	3,9	9,0	9,7	13,2	10,9
2	6,1	5,4	3,7	3,9	10,1	10,5	13,5	11,5
3	7,5	7,6	4,1	5,1	10,3	11,3	13,6	13,0
4	7,1	7,4	3,4	5,9	10,1	11,1	12,9	13,0
5	6,6	6,9	3,8	5,0	9,8	10,3	13,2	12,5
6	7,3	6,1	3,6	4,1	9,8	10,0	13,2	11,1

6. CONCLUSIONS

This study included quantitative-qualitative research in order to find the main purchasing trends of family units in their food product acquisition. The study's results identify trends related to the place of purchase in terms of the type of products bought,

the vehicle used to complete the purchase, and its frequency.

The results obtained represent important information for public decision-making regarding urban logistics on the strategic level in order to project installations such as logistical platforms and urban consolidation centers, as well as tactics/operations such

Table 4. Contributions of the products to the four main axes for the place of purchase and the frequency of purchase.

	Place				Frequency			
	Axis 1	Axis 2	Axis 3	Axis 4	Axis 1	Axis 2	Axis 3	Axis 4
1	7,2	6,3	6,3	12,0	8,1	7,2	6,9	3,0
2	8,9	7,1	8,7	13,3	8,4	9,1	7,6	3,8
3	8,3	8,2	9,1	14,6	8,4	10,1	8,8	3,7
4	8,4	8,1	9,1	13,6	8,1	10,2	9,3	3,8
5	8,6	7,7	8,6	13,1	8,5	10,1	8,0	3,9
6	8,5	7,5	8,9	12,0	8,7	8,4	8,7	3,2

Table 5. Results obtained

Establishment	Type of Food Products	Means of Transportation	Frequency
Markets	Fruits and Vegetables	By foot, Motorcycle, Taxi	Bi-weekly
Large-area Vendors	Groceries	Personal Car	Monthly
Stores	Dairy	Bus, By foot	Weekly, Daily

as vehicular and parking restrictions and coordination mechanisms. The study also aims to contribute to the status of understanding by providing analyses on the individual behavior of consumers that has been widely ignored in previous studies.

The multiple correspondence analysis methodology used for this study must be evaluated in other contexts in order to check its precision and usefulness in considering urban centers of greater or lesser size. Another possible line of research should be focused on providing better tools for analysis of information like those that focus on the behavior of individual actors and that have been used in other studies (agent communities and discrete selection models, among others).

It is also necessary to take into account a wider spectrum of logistical variables to evaluate the price of purchases, volume and weight, windows of time in which purchases are made, and seasonal behavior. These analyses should also be implemented for purchases of other types of products and for other types of buyers. Various studies emphasize the relevance of the construction sector's supply network in terms of its impact on urban logistics.

It is necessary to construct decision-making models that receive and consider these results to provide logistical solutions on strategic and tactical horizons, not only for public decision-making, but also to provide mechanisms for coordination among different private agents involved in supply networks. In this sense, the literature proposes exploring cooperation and coalition opportunities such as joint offers, shared parking sites, and other similar possibilities.

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