

## RESEARCHES ON URBAN FREIGHT TRANSPORT IN THE MEXICAN CITY OF QUERETARO: FROM CENTRAL TO PERI-URBAN AREAS

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**Abstract:**

While in developed countries the effects of urban freight transport on congestion levels, environment and quality of life of the population have been recognized and studied, in Latin American countries a limited amount of reports have been produced on this issue, focusing only on major urban agglomerations and capital cities. The aim of this paper is to describe and discuss the results and the key analytical concepts supporting a research work carried out in the Queretaro Metropolitan Area, within the 2003–2014 period. The methodological approach considered includes a multi-year research effort for creating analytical tools and evaluation methods. As a result of this effort, urban freight related issues have been characterized in a context of urban and peri-urban interacting environments for a medium-sized city. The resulting methods and tools can now be used for studying metropolitan areas on a nation-wide basis.

**Keywords:**

Urban logistics, urban freight transport, urban planning, Mexico, Querétaro Metropolitan Area

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## INTRODUCTION

The Organization for Economic Co-operation and Development (OECD), of which Mexico is a state member, conceived in 1960 a working group focusing on urban logistics, aiming at promoting public policies designed to reach the highest levels of sustainable economic development, employment, and quality of life of the population (BESTUFS, 2005).

With the development of urban agglomerations, freight transport has become one of the main sources of congestion and pollutants and noise emissions, as well as the promoter of a variety of social concerns (Muñuzuri, 2003; González-Feliu, 2008). To mitigate such problems, goods distribution systems must evolve in order to face the new and transforming configurations of the urban and peripheral areas, understanding the close interdependency of freight mobility and city's economic and social pursuance.

Allen *et al.* (2007) reports that having goods vehicles within urban environments is perceived by the population as something that worsens congestion, increases pollution and noise, and affects road safety. Consequently, it is not surprising that, when dealing with urban logistics issues, conflict of interests emerge between representatives of commercial interest and ecology advocates. The daily urban competition for using public space, in which simultaneous contesters participate in a multi-purpose pattern, is immersed in a perspective based upon accessibility to urban roads. As a function of the player at hand (pedestrians, car drivers, freight carriers or public transport providers), there will be specific needs that each of them will try to fulfill, including the following: parking; loading and unloading commodities at stores' front door; picking up passengers or dropping them off; crossings areas for disabled people; road working; and picking up the garbage.

Since it has been shown that the flow of goods and goods vehicles (derived from cities' economic and social dynamics), affects in many ways the zonal and local transport systems (Gasparini *et al.*, 2010), the remedial actions taken through different strategic programs have shown that urban freight transport (UFT) has started to become the focus of interest of urban models, to propose innovative solutions in a context of global environments.

In Latin America, however, the UFT issue has been addressed in an embryonic manner only, in countries such as Argentina and Chile. For instance, studies reveal that the underneath intention in these countries is to have a public policy for managing the transport externalities on the basis of two different approaches (Díaz *et al.*, 2003): by quantitatively assessing different traffic congestion scenarios, and by setting standards for

controlling the risks of having hazmat passing through the cities. In relation with the intervention approaches that Latin American authorities have considered for this activity, it has been suggested in the literature that many of the implemented measures, mostly derived from economic policies at federal level, have had some negative or unexpected effects on the overall mobility of the population and on the way that the infrastructures are being used (Figueroa, 2005).

In Mexico, an early analysis of the environment problems caused by Mexico City's urban sprawl was centered on population's mobility needs (Schteingart, 1989). Recent studies, however, have included urban freight transport as an activity that contributes to urban development problems, further recognizing Mexico City as a Metropolitan Area, and proposing specific actions for improving the overall mobility in the area, including the optimization of logistic chains within specific productive sectors (Antún *et al.*, 2008; Antún *et al.*, 2003), the choice of dedicated areas for logistic activities (Lozano *et al.*, 2007); and the creation of resources for managing urban freight transport demand (Lozano *et al.*, 2006).

As the subjects of study of research efforts concerning Mexico and Latin America have involved exclusively national capitals or large urban agglomerations, the analysis of the freight transport issues in the Queretaro Metropolitan Area (QMA) acquires relevance, as this analysis might contribute to the understanding of the problem and can represent a useful reference for medium-sized Mexican and Latin American cities.

The objective of this paper is to briefly describe research works made on UFT in the Queretaro Metropolitan Area between the years 2003 and 2014, so that this paper clearly aims at disseminating the experience of its authors on this topic, in order to encourage the achievement of integral studies of similar nature in other representative medium-sized cities.

## THE URBAN FREIGHT TRANSPORT IN QUERETARO METROPOLITAN AREA

A diagnostic assessment made by Queretaro's Municipal Ministry of Public Works (Montes, 2011) indicates that around half of the State of Queretaro's population (50.69%, or 1 414 000 individuals) live in the Municipality of Queretaro, further warning on the accelerated growth of the population and on the consequent urban sprawl. Statistics from such assessment reveal that between 1970 and 2010, the City of Queretaro's population had a five-fold increase, pushing the building of urban infrastructure in response to such population dynamics. Such phenomenon just adding up to similar metropolisation trends observed in

neighbor municipalities within the State of Queretaro, such as Corregidora, El Marqués and Huimilpan, and in the municipality of Celaya, in the State of Guanajuato.

While in 1979 the population density in Queretaro Metropolitan Zone was 213 inhabitants per square hectare, in 2010 such statistic decreased to only 36. If this trend continues, by the year 2025 such numbers could decrease to 30, as the urbanized area could grow another 5406 hectares, for a total population of 1 275 136 individuals (**Table 1**).

Besides the vigorous industrial growth experienced by this metropolitan area, these statistics also illustrate in a cold way the high rate of population growth and the impressive urban sprawl. Underneath the phenomenon of population growth, however, many implied phenomena related to freight transport occur, as such urban growth involves new conditions for the demand of consumption goods, which add up to demand pressures exerted on other sectors such as housing, urban infrastructure and public services.

## DEVELOPMENT OF THE RESEARCH

The four research efforts examined in this paper (**Fig. 1**) have been conceived under the following evolving phases: (i) Integral transport planning within the Queretaro Metropolitan Area: Diagnosis and Proposal of solutions (2003–2005); (ii) Proposal of a developing plan for a sustainable urban freight transport in Queretaro (2006–2007); (iii) Logistic peri-urbanisation within the Querétaro Metropolitan Area (2008–2010); and (iv) Study of waste collection routes assisted by GPS in the Municipality of Querétaro.

Together, these research works have covered 12 stages, achieving the following objectives: (a) Learning about where we are in terms of UFT; (b) Proposing a model for having a sustainable development in the area of study; (c) Suggesting several strategies and actions for implementing this model in the short, medium and long term (Betanzo, 2006; Betanzo, 2007); (d) Determining the logistics reconfiguration of the distribution sector (Betanzo, 2013), including the assessing of the impact of the transport of goods on the population and on the arrangement of the land and the commercial activity in the peri-urban areas (Rivera & Betanzo, 2012); and (e) Assessing the performance of waste collection routes by using GPS devices. A fifth research phase (2014–2016) is currently in progress while writing this paper, dealing with a nationwide system to be created to assess the urban freight transport over the main Mexican medium-sized metropolitan areas. In this respect, **Fig. 1** illustrates the sequence of works done and projected in this period of time, which are explained throughout this paper.

**Table 1.** Population density in QMZ (Montes, 2011)

Year	Surface (ha)	Population (hab)	Gross density hab/ha
1970	1042.00	221 478	213
1980	2890.60	380 548	132
1990	6429.53	579 597	52
2000	12 899.00	816 481	45
2006	17 853.00	987 478	37
2010	30 836.81	1 079 288	36
2025	36 217.49	1 275 136	30

It should be noted that the description, discussion and results included in the following sections, have been partially published in Betanzo (2011, 2015, 2014), Betanzo *et al.* (2007, 2008, 2010, 2012, 2013a, 2013b), Betanzo & Romero (2009, 2010), Betanzo & Zavala (2008), and Betanzo & Toral (2006).

## Phase 1

**Analysis of freight vehicles flows** In order to assess potential future impacts resulting from the circulation of both heavy and commercial trucks, the starting point of the research in Phase 1 aimed at discovering two important characteristics: while the first one referred to the intensity at which the road infrastructure is used (i.e. congestion effects), the second one focused on identifying the prevalent characteristics (profile) of the freight trucks crossing the city (incidence or damage caused to roads). However, the long-haul traffic statistics for this stage were not reliable for our analysis due to implicit time-based inconsistencies or inadequacies of vehicle typologies in the official information available. In addition, the information on local or endogenous traffics was incomplete as there were not disaggregated databases on the displacements of commercial trucks in the municipalities analyzed. To address this shortcoming of basic information, a series of studies and actions to be undertaken were proposed to authorities, in order to create the needed data baseline in the short term.

Concerning the identification of vehicles' profile, the available information at the beginning of the research revealed that the most recurrent long-haul heavy vehicle circulating within QMA was the two-axle straight truck (41.6%), followed by the articulated 5-axle tractor-semitrailer vehicular combination (22.7%).

Straight trucks in the traffic, equipped with two and three axles (C2 and C3, respectively), totaled 59.9% of the vehicles in the long-haul traffic, while the articulated vehicles with 3, 4 and 5 axles, designated in Mexico as T3S1, T3S2 and T3S3, respectively, accounted for the remaining 40.1% (**Fig. 2**).

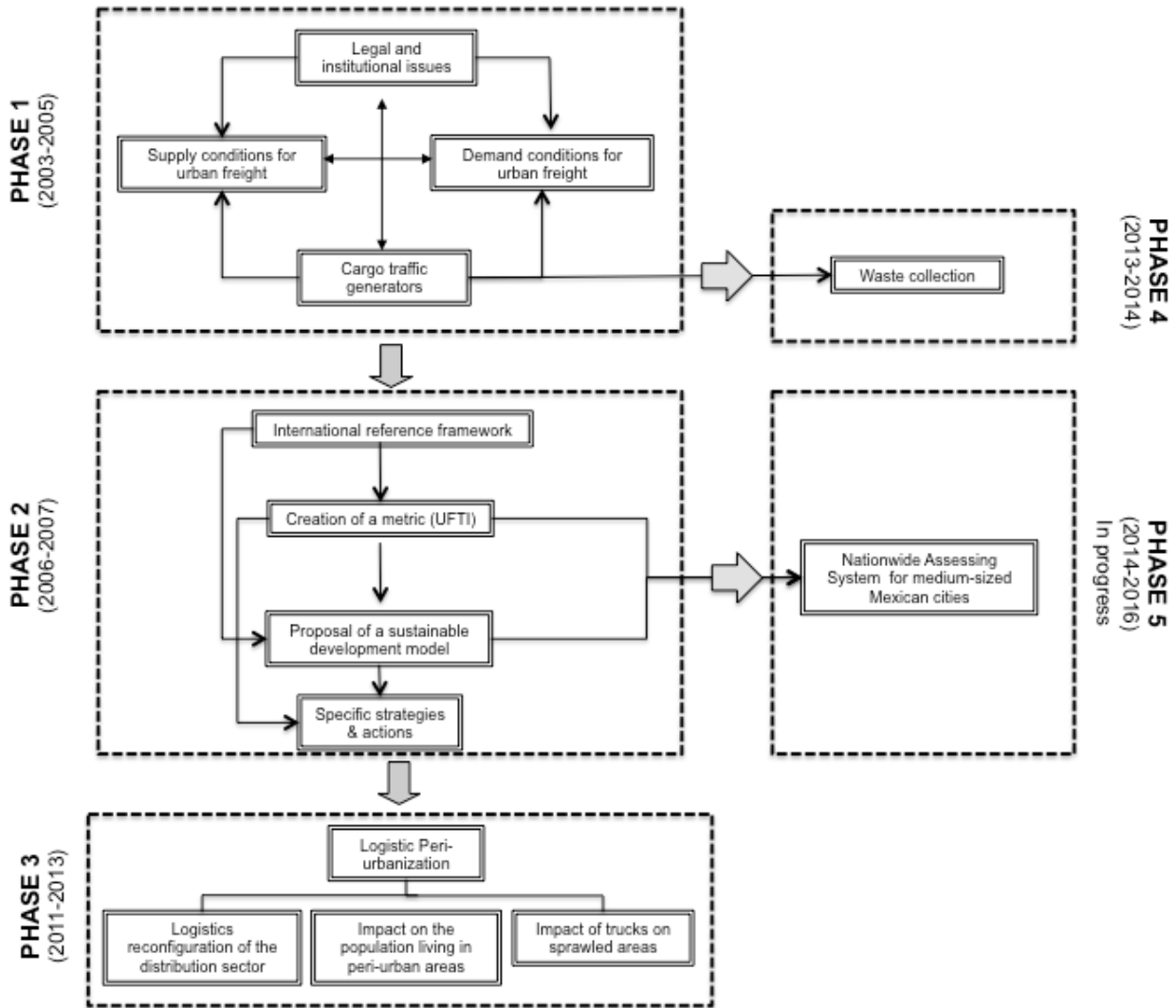


Fig. 1 Methodology for studying the effects of urban freight transport in the Queretaro Metropolitan Zone (México) and the scope for a national study (Betanzo *et al.* (2013a) with modifications).

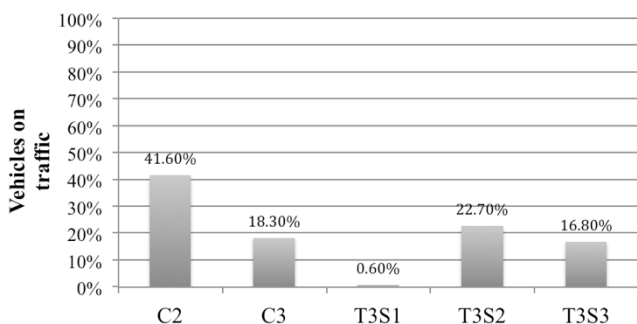


Fig. 2 Distribution of the types of long-haul vehicles circulating within QMA (summary of a 12-hour traffic count) (Betanzo, 2006).

These values are worthy to be considered because, although the available data did not include vehicles' load levels, it has been reported that the vehicles of the types C2 and C3 are prone to circulate overloaded in Mexico (Mendoza & Gutiérrez, 1994), representing a

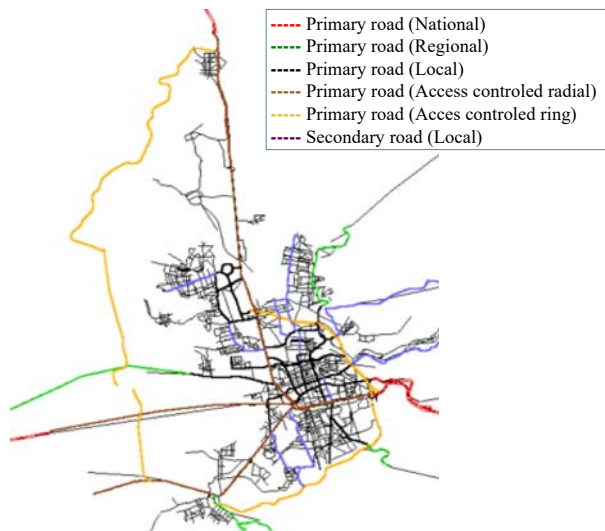
high level of aggressiveness against the main urban roads. Consequently, it is considered important to generate information on freight flows in the area of study, to realistically assess the overall impact on the area of the current freight vehicles traffic, for both local and long-haul runs, so as to improve urban road using prognostic scenarios considering road damage and traffic congestion.

**Characterization of the road network**

This part of the research was designed under the assumption that the needs for improvements in the urban road network are generated by a combination of traffic flows, whether internal-external or pure internal, and that it was convenient to define an urban road network planned with freight corridors structurally and functionally adapted for a mixed traffic composed of private cars, public buses and cargo trucks (private,

public and official) over the different areas of the city. The research work consisted in enriching the digitized inventory of urban roads and in establishing some functionality criteria, at conceptual level, for the operation of cargo trucks on primary, secondary and tertiary roads. With the help of a geographic information system (GIS), roads were characterized as national, regional and metropolitan (**Fig. 3**).

The analysis was complemented with the identification of regulation inconsistencies in the legal criteria for road and vehicular maximum weight and dimensions classifications at Federal, State and Municipal levels (Betanzo & Zavala, 2008). A review of the local methods for urban pavements maintenance was included in this study, as well as a preliminary analysis of the externalities associated with cargo transport in the city, finding that extensive work was required on the following issues: noise, road safety and pollutant gas emissions.



**Fig. 3** Characterization of Queretaro Metropolitan Zone road network (Betanzo, 2006).

### Analysis of cargo traffic generators

For this activity, a reference framework was settled to characterize a number of representative cargo traffic generators within the city (**Table 2**).

The sequence developed at this stage included a statistical study on the cargo transport vehicle fleet, both public and private, finding that the number of cargo vehicles within ZMQ almost doubled during the 1996–2006 period. The study also evidenced the correlation between the location of freight companies and the emergence of informal maneuvering or parking yards within the urban area, as well as the negative effect that some improvised facilities have on the urban development of residential areas located in the city's nucleus. The analysis also showed that commercial

**Table 2.** Cargo traffic generators within Queretaro's Metropolitan Area (Betanzo, 2006)

Cargo traffic generator	Subject of analysis	Specific analyses
Carriers	Federal Public Cargo Transportation State Concession Freight Transport	Number of registered vehicles and in use
	Private Cargo Transport	Public or private facilities
Parks or industrial zones	Location and accessibility to the road network	Access paths Access traffic counting
	Population	Concentration of the population Growth rates Purchasing power and consumption profiles
All over the city	Commercial establishments	Location and accessibility Construction mats. Bottled drinking water New cars dealers Shopping malls Convenience Stores Water in tankers Chips and Snacks Goods distribution companies
	Commercial branches	Waste collection
	Municipal services	
Critical nodes and zones	Intermodal Terminal Supplier Central Historic downtown	Access paths Effects on the surroundings

trucks were imposing greater service demands to city roads, particularly in its congested central areas.

With respect to the study about cargo traffic generators dispersed all over the urban area, a logistic approach was conceived with the purpose of rebuilding the transport chains of some activities, whose induced cargo traffic was representative or characteristically intense (Betanzo & Toral, 2006). The sectors selected were: construction materials, distribution of bottled beverages, new cars dealers, shopping centers and convenience stores, road tankers (carrying water), and snacks and bakery at industrial level. These studies set the research basis for the subsequent stages outlined in this paper

On the other hand, to quantify the potential correlation between the number of inhabitants in the area and the freight demand, an indicator was proposed: the Freight Urban Mobile Equipment (FUME) (Betanzo *et al.*, 2008). **Figure 4** illustrates the results of applying this metric in the case of QMA, revealing that the number of commercial vehicles per thousand of inhabitants rose from 42 to 79 during the 1995–2010 period.

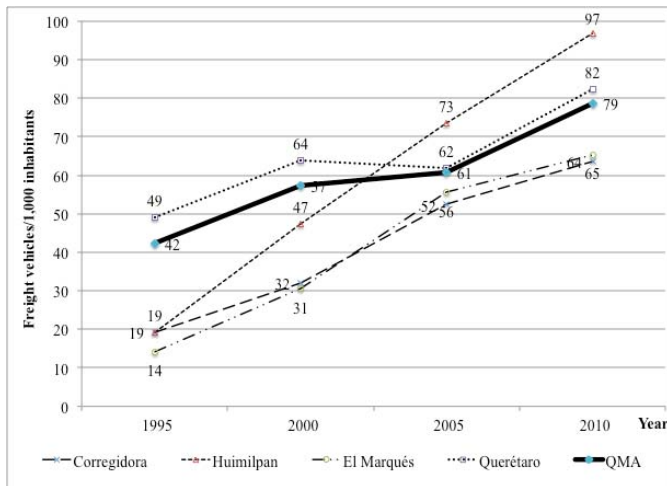


Fig. 4 FUME index for QMA (Betanzo, 2015)

Finally, within this stage, a zonal analysis was carried out regarding the accessibility to critical points (logistics nodes), characterized by a high density of freight trucks. Such nodes included the perishable foods distribution central (Supplier Central) and an intermodal terminal located within the city limits. Access paths, involving connectivity with city's main roads, were traced as well.

### Review of the legal and institutional aspects

This stage involved a review of the legal and institutional aspects of freight transportation, under the scope of Municipal, State and Federal jurisdictions. It included a review of existing rules dealing with long-haul and local traffic controls, as well as the resources allocated to technical and administrative freight related areas. Another issue was the review of the developing urban plans at the three levels of government (municipal, state and federal), as such plans contained the public policies that still lay down the actions taken at these levels. With regard to institutional aspects concurrent with the UFT, the aim was to identify the criteria for competence assignation, and the structure of the managing agencies belonging to the three levels of government. The goal was to determine whether or not there were public administration agencies intended to develop public policies on this subject, and to check if such agencies had enough power and functional capability to efficiently perform the re-arrangement of UFT.

This analysis was later complemented with the review of several State of Querétaro's General Codes, including the construction code (GEQ, 1988) and the transit code (GEQ, 2010) as well as the list of requirements for getting licenses for operating businesses (parking places for customers and suppliers), which were influential features for analyzing both the

micro-territorial influence and reconfiguration of the networks for goods distribution within the city.

## Phase 2

### Analysis of experiences at international level

The objective at this stage was to discuss UFT issues from an international perspective in order to characterize the intervention approaches in more developed economies. Through the systematization of the methodological treatments applied in other countries, a comparative assessment was made so that some representative measures or referential features were identified for countries linked to OECD (OECD, 2003; BESTUFS, 2006).

Although at this stage it was recognized that other countries' general and specific problems involved different technological solutions and particular engagements, the aim was to identify the feasibility of some successful solutions, and to learn about criteria to avoid the measures that in practice have led to conflicting results or that are still at the experimental stage. The comparative analysis also pursued the identification of the agencies involved (during both the problem statement phase and the decision-making process), the resources used to cope with specific problems, and the institutional, technological and financing determinant factors reported in those contexts (Betanzo, 2014).

### Development of a measuring tool

The idea behind the creation of an analytical metric called Urban Freight Transport Index (UFTI) was originated from the concept of standard, particularly as an international one. In this sense, the aim of this stage consisted of developing an analytical tool of practical use to set a comparative scale for assessing the progress and treatments considered to solve UFT problems. The Querétaro Metropolitan Area was evaluated under UFTI terms, obtaining a base-line rating for the deployed practices when compared with other cities (Fig. 5). This area got 115 points (14%) out of 807 points possible. Further details are described in Betanzo *et al.* (2013). This rate reveals that the recommended actions at each of the stages of intervention suggested by the standard are being addressed in a minimal way, and that there is little systematic or organized work to comprehensively undertake the problem. A modified version of the UFTI method (UFTI V2.0) will be created at the Phase 5 of this research, as explained later in this paper.

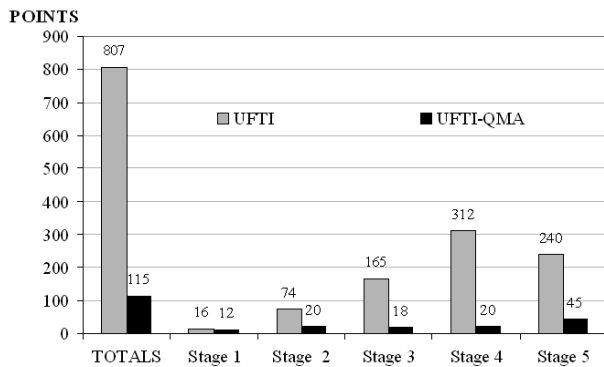


Fig. 5 Comparative summary of UFTI metric for Queretaro Metropolitan Zone (Betanzo, 2007).

### Conceptual model proposal for developing UFT

During the second phase of this research a conceptual model for a sustainable urban freight transport was proposed for the QMA. Such model was based on the need to undertake an organizational perspective, based on three contextual elements: sustainable development, national and local transport policies, and public-private collaboration.

#### Specific actions.

The second phase of the research work ended up with a proposal of strategies and actions at State and Municipal levels, including some aimed at the strengthening or building of the analytical elements for decision making. A matrix array was generated including 10 possible strategies and 15 concrete actions for urban freight transport in QMA, further suggesting potential implementation time line at short, medium and long term (Betanzo, 2011).

### Phase 3

#### Logistic reconfiguration of the consumption goods distribution networks

This stage of the investigation represents the starting point of Phase 3, aiming at characterizing the evolution of the distribution sector specifically related with non-durable consumption goods (NDCG) (Betanzo, 2013). The first set of results revealed a correlation between the location profile and the dispersion of commercial establishments, according to the urban structure for both central and peri-urban settlements. **Figure 6** describes a summary for 6 types of logistic nodes (commercial establishments) for which the urban dispersion patterns were characterized: supermarkets, municipal markets, Supplier Central, convenience stores, neighborhood stores and flea markets.

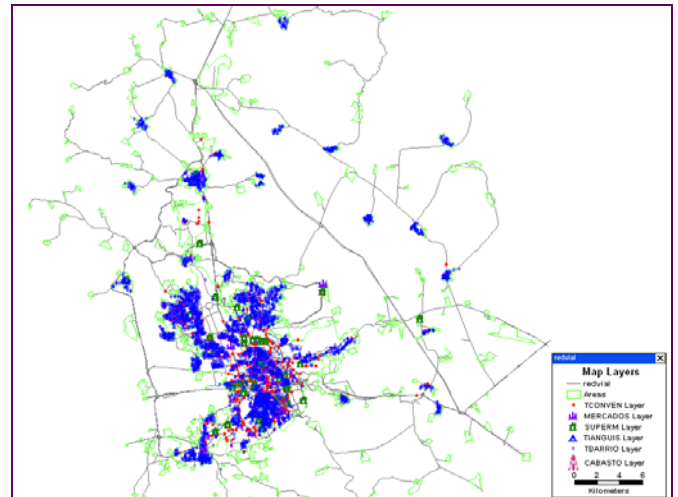


Fig. 6 The location of commercial establishments within central and peri-urban areas of QMA (Betanzo, 2015).

By undertaking an approach based upon geo-referenced databases contained in the National Directory of Economic Units (NDEU) (INEGI, 2011), several base-line scenarios for location patterns of retail establishments were created. In this context, two indicators were particularly important for studying the concentration and incidence of commercial vehicles in traffic conditions: (i) the number of retail establishments, by type, per every 1000 inhabitants, and (ii) the number of commercial establishments per square kilometer of urban area. Such indicators revealed a correlation between urban growth and the increase of commercial activity and, consequently, the potential number of commercial trucks in circulation.

#### Impact on the population in peri-urban areas

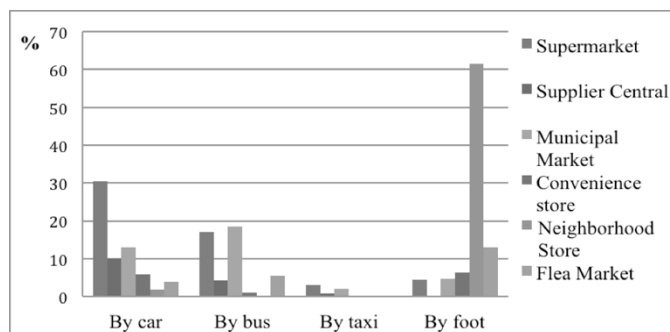
In addition to studying the phenomenon of urban sprawl and the expansion of distribution networks, a door-to-door survey containing 1023 enquiries was conducted (called ENC DOM V1.0), to investigate the mobility patterns of individuals living in the peri-urban areas, that displace to buy non-durable consumption goods (Betanzo, 2013).

It is confirmed that within the retail sector, the convenience-store chains have deeply infiltrated the retailing market distribution, which is determined by the consumption practices or profile of the peri-urban populations. According to Duhau & Giglia (2007), this phenomenon is expected to get stronger. These authors describe two facts that potentially explain the expansion of global trade: on the one hand, the “propagation of stores belonging to large commercial chains, showing a more homogeneous distribution in a socially unequal territory”; on the other hand, the development of distribution networks, in function of which the

consumption practices of individuals living in peri-urban areas are arranged.

**Figure 7** illustrates an example of the mobility parameters that were defined and studied using the ENC DOM V1.0 survey. This figure summarizes an array of displacements toward six logistics nodes: supermarkets, Supplier Central, municipal markets, convenience stores, neighborhood stores and flea markets, performed on four transport modes: car, minibus, taxi and on foot.

The database resulting from the ENC DOM V1.0 survey was conceived to be used in subsequent stages involving the use of transport modeling computer programs. This approach will make possible to model the shopping trips made by the population, and to determine the levels of commercial attraction power that the central areas have on the peri-urban areas.



**Fig. 7** Example of data on mobility patterns of the population living in peri-urban areas, in shopping-trips for consumption goods (Betanzo, 2015).

### Goods transportation, reconfiguring the territory and the commercial activity in the peri-urban areas

Together, the urban sprawl and the lack of planning for the urban freight transport complicate the distribution of goods and generate interferences with other road users. Although there are instruments for urban planning, it can be noted the absence of precise public policies and actions intended to satisfy the current and future needs of companies in both the goods transportation and commerce sectors.

The planning of new commercial areas is expected to better organize the commercial activity around new peri-urban areas; however, the land use is difficult to organize due to strong real estate strategies that press for changing the urban plans. For that reasons, it is still difficult to foresee the outcome in Mexico, as it will be the result of several interacting factors, such as the enforcement of land use restrictions, the application of building regulations and the issue of operating licenses for commercial establishments. Other restrictions include municipal transit provisions addressed to cargo trucks.

The question to answer is, could it be possible to avoid dysfunctions in peripheral areas, as those

observed in central areas, which suffer from problems associated with the uncontrolled growth of commercial activities and freight?

This last stage of Phase 3 aimed at determining the effects of cargo trucks on the urban environment of peri-urban areas, as well as its relationship with both the distribution of NDCG and the organization of the commercial activity in these areas (Rivera, 2013).

The methodology consisted of: (i) a review of the regulatory constraints governing both the activity of the commercial establishments and the circulation of cargo trucks in the municipality of Querétaro; and (ii) the design and completion of a survey at the retail premises. The field studies consisted of two steps: (i) Examination of the establishments (external and surroundings); and (ii) Application of a logistics and transport survey on 100 retail spots, located in the peri-urban areas of the QMA. **Table 3** contains repeated observed aspects.

The study revealed the need for setting changes concerning loading and unloading off-street areas, which should be properly designed in order to reduce the negative impacts of truck traffic.

### Phase 4

**Solid waste collection routes** This phase connects Phases 1 and 3: “Cargo traffic generators” (Phase 1) and “Impact of trucks on sprawled areas” (Phase 3). Management of solid waste is a complex task for public authorities due to its social, economic, technological and environmental implications. The aim of this phase

**Table 3.** Summary of recurring issues (Rivera, 2013)

Issue	Total number of locations	Total number of cases
Restrictive signs missing.	20	92
Lack of off-street parking spaces and appropriate spaces for unloading.	20	73
Conflicting competence for parking and access between freight vehicles and public buses.	13	38
Freight vehicles parked on public roads for more than one hour, performing unloading operations to one or more establishments.	9	19
Construction of commercial areas in low-value land, usually located far away from habited areas.	8	27
Narrow roads that generate congestion problems, especially in urban settlements.	7	35
Given the demand for basic daily commodities, the residents redo their homes to sell them.	7	25
A business-operating license is commonly denied, because a mall or a commercial center is already projected (to be built when a residential cluster will be managed by the municipality).	6	16
Roads in poor condition, in localities that gradually transformed from rural to urban.	5	25
Lack of control on issuing operating and construction licenses for adapting or extending homes for commercial use.	5	6



was to assess the waste collection system in the municipality of Santiago de Querétaro (Mexico) based on GPS data. A fleet of garbage trucks was monitored, covering 71 waste collection routes (Fig. 8). A methodology proposed by the Ministry of Social Development of Mexico was used to assess the main operating parameters in the process, to determine the level of efficiency of the existing routes. While the GPS information unveiled differences between planned Vs real routes, it provided the basic information to assess the efficiency of the collection routes in terms of time, speed and distances traveled during service trips and stops. A control board was also designed to help municipal planners and dispatchers to manage key cost and capacity parameters. Results encourage the use of GPS to help public authorities to cope with increasing operating costs and demand for service, diminishing environmental risks and fostering human health.

## Phase 5

### Nationwide urban freight transport assessing system

This phase is reported here as in progress. However, it is important to advance its main objective, which is to apply the principles of Phase 2 into a nationwide scope project. In this respect, at least 12 main Mexican metropolitan areas will be assessed, so as to create a monitoring baseline regarding the overall performance of urban freight systems in Mexico.

## CONCLUSION

The research progress has gradually provided some elements to analyze the different pieces of the complex puzzle that has become the urban freight transport issue (UFT). The different phases of the research have centered on the development of metrics or measuring instruments, so that such background could facilitate the conduction of other studies in Mexican or foreign cities, as depicted in Phase 5.



Fig. 8. Illustrative GPS tracking of a waste collection route in QMA

The research made possible to explore new approaches for understanding the impact of trucks on urban environments. In this sense, it is important to strength the research issues concerning the use of land, the economic trends and the characteristics of freight activity. These conceptual issues go along with the emerging technological innovations, which strongly tend to use electronic data acquisition systems, such as the GPS employed in Phase 4, rather than the development of complex transport models (Chase *et al.*, 2013).

Finally, given the need for a sustainable development of Mexican cities, like the one studied herein, it is considered as crucial, a coordinated action conducted by the Federal Government in the near future.

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## REFERENCES

- Allen, J., Thorne, G. & Browne, M. (2007). *Good practice guide on urban freight*. Best Urban Freight Solutions, Netherlands. URL:[http://www.bestufts.net/download/BESTUFS\\_II/good\\_practice/English\\_BESTUFS\\_Guide.pdf](http://www.bestufts.net/download/BESTUFS_II/good_practice/English_BESTUFS_Guide.pdf)
- Antún, J.P., Lozano, A., Hernández, R. & Alarcón, R. (2008). New trends on Physical Distribution logistics in Mexico City Metropolitan Area. In: *Innovations in City Logistics*, (ed. By E. Taniguchi & R. Thompson), 517-530. Nova Science Publishers New York.
- Antún, J.P., Casanova, R. & Lozano, A. (2003). Demand management of urban freight transport: Urban Logistics Project micro platform in the Historic Center of Mexico City for the textile garment industry. In: *Proceedings of the XII Latin American Congress on Public and Urban Transport (CLATPU)*, Bogotá, Colombia, 23-27 October.
- Best Urban Freight Solutions (BESTUFS) (2005). *BESTUFS – D 2.1 Best Practice Handbook Year 2005, Sixth Framework Program for Research and Technological Development: Integrating and Strengthening the European Research Area (2002-2006)*. Sustainable Surface Transport, Netherlands.
- Best Urban Freight Solutions (BESTUFS) (2006). *D 2.2 Best Practice Handbook Year*. Sustainable Surface Transport, Netherlands.
- Betanzo, E. (2015). Perspectives of urban growth, retail activity and transport of goods in the Queretaro Metropolitan Area in Mexico. *Ciencia ErgoSum*, **22**(1), 63-74. (In Spanish).
- Betanzo, E. (2014). Comparative analysis of international experiences on urban freight transport: proposals to address its challenges. *Acta Universitaria*, **24**(2), 41-52. (In Spanish).
- Betanzo, E. (2013). *Urban Freight Transport in Peri-urban Areas of the Querétaro Metropolitan Zone*. Vol. III, Universidad Autónoma de Querétaro, México. (In Spanish).

- Betanzo, E., Romero, J.A., Obregón, S. & Rivera, J. (2013a). Researches on urban freight transport in the Mexican city of Queretaro: From central to peri-urban areas. In: *Proc. of the First International Congress on Logistics and Supply Chain*, Querétaro, México. 24-25 October.
- Betanzo, E., Romero, J.A. & Obregón, S. (2013b). An Index to Evaluate Public Policies in Urban Freight Transport. *Gestión y Política Pública (CIDE)*, **XXII**(2), 313-354.
- Betanzo, E., Romero, J.A. & Obregón, S. (2012). An empirical approach for experimental assessments in urban freight. *Scientific Research and Essays*, **7**(20), 1917-1934.
- Betanzo, E. (2011). A methodological approach for integral studies on urban freight the case of the Queretaro Metropolitan Area in Mexico. *Revista Latinoamericana de Estudios Urbanos y Regionales-Eure*, **37**(112), 63-87. (In Spanish).
- Betanzo, E. & Romero, J.A. (2010). An urban Freight Transport Index. *Procedia - Social and Behavioral Sciences*, **2**(3), 6312-6322.
- Betanzo, E., Romero, J.A. & Obregón, S. (2010). Performance evaluation of urban freight transport systems. In: *Proc. of the XVI Latin American Congress on Public and Urban Transport (CLATPU)*, Mexico City, México, 6-8 October. (In Spanish).
- Betanzo E. & Romero J.A. (2009). Sustainable urban freight transport in Queretaro (México). In: *Proceedings of the XV Latin American Congress on Public and Urban Transport (CLATPU)*, Buenos Aires, Argentina, 1-3 March. (In Spanish).
- Betanzo, E. & Zavala, R. (2008). The maintenance of pavements in urban roads: the case of the metropolitan area of Queretaro (México). *Revista Ingeniería*, **12**(2), 67-75. (In Spanish).
- Betanzo, E., Romero, J.A. & Ojeda, L. (2008). A case study of urban freight in Mexico. In: *Innovations in City Logistics*, (ed. By E. Taniguchi & R. Thompson), 559-570. Nova Science Publishers New York.
- Betanzo, E. (2007). *Proposal of a developing plan for urban freight transport in Queretaro*. Research Report. Vol. I, Universidad Autónoma de Querétaro, México. (In Spanish).
- Betanzo, E., Romero, J.A. & Sánchez, I. (2007). Characterization of Urban Freight Transport Queretaro, México. In: *Proc. of the XIV Latin American Congress on Public and Urban Transport (CLATPU)*, Río de Janeiro, Brasil, 18-23 November. (In Spanish).
- Betanzo, E. (2006). *Integral transport planning in Queretaro's Metropolitan Zone, Stage 2A: Diagnosis, and 2B: Solutions proposal*. Research Report, Vol. II. Universidad Autónoma de Querétaro, México. (In Spanish).
- Betanzo, E. & Toral, M. (2006). Analysis of freight traffic generators in the metropolitan area of Queretaro (Mexico). In: *Proc. of VII Transportation Engineering Congress*, Ciudad Real, Spain, 14-16 June. (In Spanish).
- Chase, K., Anater, P. & Phelan, T. (2013). Freight Demand Modeling and Data Improvement. In: The Second Strategic Highway Research Program, *Transportation Research Board*, Washington, D.C.
- Díaz, C.A., Galetovic, A. & Sahuenza, R. (2003). The Freight Transport Regulation in Santiago: Characteristics, Assessment and Proposals. *Revista Latinoamericana de Economía*, **119**, 5-46. (In Spanish).
- Duhau, E. & Giglia, A. (2007). Centralities and consumption practices in Mexico City: from the micro-commerce to the hypermarket. *Revista Latinoamericana de Estudios Urbanos y Regionales-Eure*, **XXXIII**(98), 77-95. (In Spanish).
- Figueroa, O. (2005). Urban and globalization: Policies and effects in Latin America. *Revista Latinoamericana de Estudios Urbanos y Regionales-Eure*, **XXXI**(94), 41-53. (In Spanish).
- Gasparini, A., Campos, V. & D'Agosto, M. (2010). An analysis of the demand for cargo vehicles for supermarkets. In: *Proc. of the XVI PANAM*, Lisbon, Portugal, 15-18 July.
- GEQ (Queretaro Government) (1988). *Código de construcción del Estado de Querétaro (General Construction Code for the State of Querétaro)*. Gobierno del Estado de Querétaro. México. (In Spanish).
- GEQ (Queretaro Government) (2010). *Código de Tránsito del Estado de Querétaro (Transit Code for the State of Querétaro)*. Gobierno del Estado de Querétaro. México. (In Spanish).
- González-Feliu, J. (2008). *Models and methods for the City Logistics - The Two-Echelon Vehicle Routing Problem*. PhD Thesis, Politecnico di Torino, Italy.
- INEGI (National Institute of Statistics, Geography and Informatics) (2011). *Directorio Nacional de Unidades Económicas (National Directory of Economic Units - DENUE) 03/2011*, México.
- Lozano, A., Antún, J.P., Granados, F. & Santos, C. (2007). Reserve areas for logistics activities in the Metropolitan Area Zone of Mexico City. In: *Innovations in City Logistics* (ed. By E. Taniguchi & R. Thompson), 321-334. Nova Science Publishers New York.
- Lozano, A., Granados, F., Antún, J.P., Magallanes, R., Torres, V. & Romero, E. (2006). Metropolitan corridors project for cargo transportation in the metropolitan area of the Valley of Mexico. In: *Comprehensive study of metropolitan freight and environment for the Valley of Mexico*. IV, 1-348, Universidad Nacional Autónoma de México y Comisión Ambiental Metropolitana del Valle de México, Mexico.
- Mendoza, A. & Gutiérrez, J.L. (1994). Estudio de pesos y dimensiones de los vehículos que circulan sobre las carreteras nacionales: Análisis económico de los efectos del peso de los vehículos (*Study on weights and dimensions of heavy vehicles on roads: Economic Analysis of the effect of weight*). Technical Publication number 52. Instituto Mexicano del Transporte, México. (In Spanish).
- Montes, S. (2011). *Infraestructura y Desarrollo Urbano en el Municipio de Querétaro (Infrastructure and urban development in the Municipality of Querétaro)*. In: *Proc. of the XI Expo-Congress of Civil Engineering 2011*. Querétaro, México, 12-13 August. (In Spanish).
- Muñuzuri, J. (2003). *Urban Freight Logistics: Solutions, Modeling and Evaluation*. PhD Thesis. Universidad de Sevilla, Spain.
- OECD (2003). *Delivery the Goods – 21st Century Challenges to Urban Goods Transport*, OECD, Paris.
- Rivera, J. (2013). *Goods transportation in peri-urban areas: urban planning and commercial activity in Queretaro's Metropolitan Zone*. MEng. Thesis, Universidad Autónoma de Querétaro, Queretaro, México. (In Spanish).
- Rivera, J. & Betanzo, E. (2012). Is there a need for a land reserve for logistics and freight transportation in peri-urban areas of the city of Querétaro?, In: *Proc. of the eighth International Engineering Congress of the Autonomous University of Querétaro*, Querétaro, México. 23-27 April. (In Spanish).
- Schteingart, M. (1989). The environmental problems associated with urban development in Mexico City. *Environment and Urbanization*, **4**, 40-50.