Analysis of Urban Freight Transport Models at District Metropolitan of Quito

Henry Acurio[#1], Byron Guaman[#2], Gonzalo Guerrón*[3]
[#]*Instituto de Investigación Geológico y Energético*
[*]*Universidad UTE*

Abstract

Urban freight transport has hardly prompted any modelling efforts when compared to passenger cars and public transport, which is mainly due to the lack of available data and the complexity of the delivery route patterns and the involved decision making. We present some models which might be available for the Metropolitan District of Quito, within this research we analysed the characteristics of the city in the context of geography, urban freight transport fleet, emissions of the trucks fleet, and at the end the recommendation of a model that can be adapted in Quito.

Keywords - *energy consumption, energy efficiency, ground transport, Ecuador.*

I. INTRODUCTION

The worldwide energy demand of the transport sector is 28.81% and the environmental impact of the sector in question is 24%. [1].

In Ecuador, according to the 2017 National Energy Balance, the transport sector is one of the main energy consumers with 50% of the total energy demanded of all sectors [2].

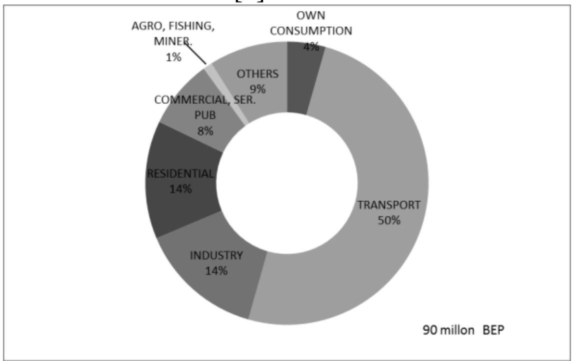

Figure 1. Energy demand by sector [2].

Besides the fact that, the transport sector is the largest emitter of greenhouse gases with more than 18 million tons of CO2 eq, which represents 50% of emissions in Ecuador, mainly due to the use of fossil fuels.

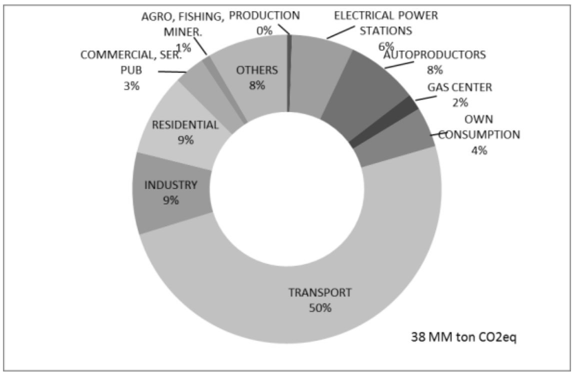

Figure 2. Emissions of Greenhouse Gases by activity [2].

Within the transport sector, light freight transport is one of the most representative in terms of energy consumption, with 21% of the total energy consumed in the sector [2].

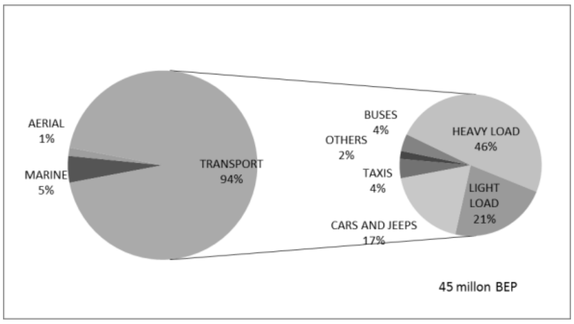

Figure 3. Consumption by type of transport [2].

On the other hand, a few decades ago, the urban centers were not as populous as they are today and there was no vehicle fleet that exists today. Therefore, congestion on public roads, air and noise pollution were also minor. Little by little, cities became congested and vehicles, little subject to environmental and safety controls, far exceeded the limits set by the Kyoto Protocol. This is how the urban distribution of goods began to be problematic [4].

The transport of goods constitutes one of the basic elements of logistics since this is the indispensable technological support of the connection between producers, merchants and consumers, throughout the process of the physical distribution of the different origins to the multiple destinations [3].

Producers, merchants and consumers are generally located in cities, since that is where industries, service centers and most consumers are located. For this reason, cities are considered as nodes within the logistics chain or points of supply for the products that are consumed and / or produced [3].

At an international and national level, the study of the behavior of urban freight transport is a low priority and there is no standard methodology for the modeling of freight transport. There are several reasons why there has not been enough research in this field, one of the main ones being the difficulty of obtaining reliable information on urban freight transport [3].

Thus, this article analyzes and recommends urban freight transport models according to the characteristics and needs of the Metropolitan District of Quito (DMQ).

II. OBJECTIVE

Analyze and recommend models of urban freight transport in its components of generation, attraction and distribution for the Metropolitan District of Quito.

III. METODOLOGY

The methodology used starts with the analysis of the DMQ and the conceptual framework of the urban distribution of goods. Afterwards, a data analysis is carried out and a model for the calculation of urban cargo transport emissions in the DMQ is developed. Finally, the existing urban freight transport models are analyzed and identified and, according to their characteristics and variables, they can be implemented through projects and studies in the DMQ.

A. Characteristics of the DMQ

The DMQ is located in the Center-North of the province of Pichincha, at an altitude of 2,850 meters above sea level (m.s.n.m). Its limits are: to the north the province of Imbabura; to the south the cantons Rumiñahui and Mejía; to the east the cantons Pedro Moncayo, Cayambe and Provincia de Napo; to the west cantons Pedro Vicente Maldonado, Los Bancos and Province of Santo Domingo de los Tsáchilas.

The DMQ occupies an area of 4,235.20 km^2 and is the territory where the political-administrative capital of the country is located. The DMQ presents, in general, an irregular relief and a particular equatorial location that defines it as a heterogeneous and diverse territory, with great potential, particularly from the productive and tourist perspective [6].

The economic importance of the DMQ in the formation of the national added value is very significant; in 2017 it generated 25.16% of the National GDP demonstrating a concentration of the productive activity in this city [7].

B. Conceptual Framework of Urban Merchandise Distribution

The urban distribution of goods is crucial for the economic movement of the city and the welfare of its inhabitants, since it directly influences congestion, pollution, energy consumption, road safety and occupation of urban space [4].

The urban transport of goods is responsible for a large part of the external harmful elements that affect urban areas at present. Urban mobility produces between 20% and 40% of global CO_2 emissions and approximately 70% of other pollutants derived from transport present in urban areas [5].

The problems of the urban distribution of merchandise require integral solutions because they affect a great diversity of actors:

- Providers of the service (transporters and logistic operators).
- Plaintiffs (load generators).
- Local authorities and users of the public road [4].

A city can count on a large network of nodes and logistics chains. For a city, logistics principles are more complex than in the treatment of a particular company, since in urban logistics, as a particular case of regional logistics, converge and overlap multiple logistics, as well as the set of industrial, commercial and service activities that operate in the territory and its relations with other regions of the country and abroad [3].

The supply chain covers several stages from the moment of supply until the finished product or product reaches its final consumer. The urban distribution of merchandise consists of the last of these links, but this does not mean that we have to detract from it. The product must arrive in optimal conditions for consumers and, in addition, efficiency and lower cost are among the most prominent and valued criteria. For this reason, the urban distribution of merchandise becomes more important; the interaction with other agents in the urban environment, such as traffic (public or private passenger transport), or the diversity of supply points in a defined perimeter with an uncertain urban typology, confer a high interest; therefore, in most cases, the causes that cause the problem in the daily routine of the urban distribution of goods must be analyzed in more depth, as in the case of the DMQ [4].

According to studies carried out by the World Bank of Development (IDB), there are three main aspects that characterize and condition the urban distribution of goods:

- The influence of infrastructure. Traffic problems, streets in a unique sense, traffic lights, among others.
- The strategy of the distribution. Number of destinations to be covered, waiting and unloading times, hours of reception of goods.
- The characteristics of the vehicles. The size of the vehicle is limited by the characteristics of the tracks (width),

unloading areas and loading must have easy access.

The urban transport of merchandise is carried out in two general ways: By means of agents that provide transport and logistics services and on their own account (private transport or private transport) [4].

In addition, the urban distribution of merchandise can be classified according to various parameters, among which are: Coordination of recipients, itineraries that can be centralized or with multiple stops, delivery characteristics, optimization of the route and load factor of the vehicle.

Urban logistics frames 3 aspects: generating and receiving nodes, activities and effects in the urban network [8]. These aspects have become more complex taking into account "the growing urbanization, the increase in the demand for frequent and just-in-time deliveries in urban areas, the growing competition for the use of limited urban infrastructures, and the growth of the complexity of the problems of cross-cutting competition that urban transport of goods generates and situations that face" [9].

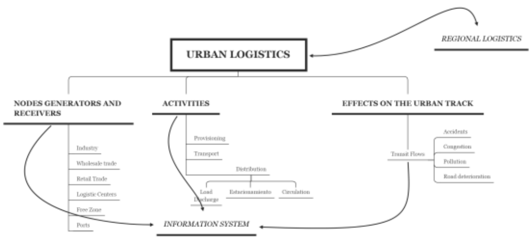

Figure 4. Scheme of the general structure of urban logistics [8].

Urban logistics is the last mile of the supply chain, which requires local administrations to provide adequate measures and infrastructure that allow the efficient flow of goods and services. With a competitive urban logistics, the economic growth of cities is achieved [10], and the economy of a country like Ecuador is directly driven, which has 62.7% of its population in urban areas [11], according to the Census data of Population and Housing of Ecuador of the year 2010, carried out by the National Institute of Statistics and Census (INEC).

The concept of the "last mile" refers to a brief stage of the supply chain: the last installment of the delivery. It is the most expensive and complex phase of this chain; it is estimated that it absorbs up to one third of the total transport cost of the supply chain [12].

Cargo transport vehicles that operate in urban areas impact on congestion considerably, however, the mobilization of cargo in the urban network also causes other negative effects such as the emission of polluting gases per kilometer traveled, especially by vehicles that They have a high age. This is due to its high fuel consumption per unit of distance traveled and the fact that most of these vehicles use diesel as fuel [3].

A good management of urban logistics can help create a more efficient and less harmful urban freight transport system for the environment, so that it plays a fundamental role in balancing the economic growth of cities that are suffering external effects negative [13].

Urban logistics varies greatly depending on the context. In many developing markets, modern distribution channels are not well developed or non-existent, while there is an excess of traditional channels. In these cases, the complex network of traditional unstructured channels, which could be described as "single-person businesses", is composed of nanocomercios that represent a large proportion of urban commercial activity [5].

Thus, it is a challenge to make the last installment of the delivery in an organized, structured and sustainable way when the urban logistics landscape is dispersed and unstructured [5].

C. Characteristics of Urban Freight Transport and Fuel Consumption in the DMQ.

In Quito, among trucks, medium trucks and big trucks classification by the NTE INEN 2656 vehicle classification, there are 11840 trucks which represent the 10% of the total number of trucks in Ecuador.

For the analysis of emissions has been considered the vehicle fleet in Quito, this data has been took from the statistics of Transit National Agency (ANT), the emissions are based in the Intergovernmental Panel on Climate Change (IPCC), which considerate annual millage, global warming potential and specific fuel consumption this information was taken from the National Energy Balance (BEN).

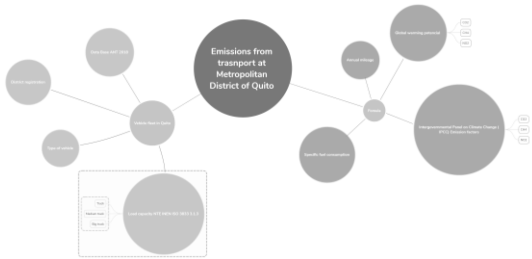

Figure 5. Methodology of urban freight transport emissions in the DMQ.

In trucks classification was considerate the following:

- Registration district (Quito)
- Type of combustible (diesel)
- Load capacity (until 12 ton)

The following chart shows the participation of the load capacity on trucks in Quito.

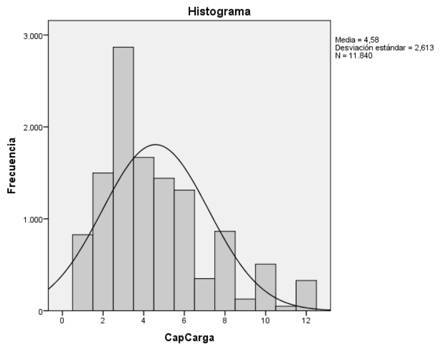

Figure 6. Chart load capacity trucks in Quito

The distribution of type of service of trucks in Quito is as the follow figure, as it shows the main purposes are particular and public use.

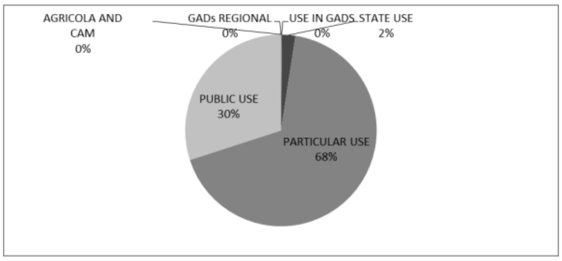

Figure 7. Type of use trucks in Quito

The freight trucks consumption in Quito is calculated by the following equation:

Equation 1. Trucks consumption

$$Trucks\ consumption\ [KBEP] = \frac{Vehicle\ fleet * Anual\ millage}{Specific\ fuel\ consumption * 42000} * 1.0015$$

At the end is multiplied by 1.0015 which is the factor for KBEP.

The emissions are calculated by the following equation:

Equation 2. Emissions of the trucks in Quito

$$: \frac{Trucks\ consumption\ [KBEP]}{Convertion\ of\ TJ} * IPCC\ factor * Global\ warming\ potencial$$

The emissions generated by the fright transport in Quito are:

	Emissions [kton]
CO_2	740.48
CH_4	0.82
NO_2	3.10

After this analysis is necessary to recommend urban logistic models to implement in Quito, knowing the geography of the city, vehicle fleet and the consumption as well emission that are produced by the freight urban transport.

D. Models of Transport of Urban Load

The urban logistics studies are mainly concentrated in cities with very high economic activities, since cities with low economic development rates have lower dynamics in cargo transport and therefore the delivery of cargo at urban level it does not require studies and strategies as complex as those used in cities with high rates of development [3].

The difficulty in the modeling of freight transport begins in the consideration of the location of intermediary and final markets for the products, the variety in the production of goods, the characteristics and nature of the raw material and the final products, the size of the company and its distribution policy, zonal variations in demand and cost factors [14].

In various studies of urban freight transportation, different methods, approaches and models have been used that, according to the study objective, have been of fundamental support to evaluate this type of transport, providing valuable information, both qualitative and quantitative [15].

The transport models study the transport plan of a certain merchandise or product that is mobilized from various sources to the respective destinations taking into account the characteristics of the different zones. Thanks to this, adjustments and improvements to the network and the logistic process can be made [3].

1. Generation and Attraction of Cargo

In the use of this type of model, the quantities of goods to be transported from different origins and the quantities to be transported to different destinations are determined [3].

There are four types of models:

- Input-output models
- Dynamic systems models
- Models of zonal travel rates.
- Trends models and time series

Input-output models link economic activities to cargo flows for which the flows of the import and export market must be identified.

Models of dynamic systems are fed by economic, statistical or territorial submodels. The parameters for the use of this type of models are based on the error-test, configuring initial values and verifying the behavior of the results.

Models of zonal travel rates deal with a cross classification that determines the number of trips or volumes produced and attracted according to attributes of the homogeneous zone analyzed but has little perspective and limited scope for policy purposes [3].

Trend models and time series use historical statistical information or different time series to determine growth factors or perform regressions. *"Time series information has been used to develop models of various degrees of sophistication, ranging from models with a simple growth factor to complex models such as the average of autoregressive variables. This latter model uses only information from truck flows and is mainly used for short-term estimates. This model has also been developed with* *other variables such as the Gross Domestic Product-GDP"* [16].

Within the models of trends and time series we have several models such as:

- Quick Response Freight Manual
- Hutchinson Model
- Ogden model

For the Metropolitan District of Quito it is important to implement and use a model that includes several aspects and variables such as: changes in urban development patterns, location of terminals and transfer points, land use patterns, economic changes and industry costs, labor practices, technological innovations in movement of goods, effects of government policies, financial aid, and regulation of the movements of goods, and environmental and social elements [17].

Precisely the Hutchinson Model takes into account all these aspects that are proper for each city making the analysis more complete. With the Hutchinson model, variables that can be considered when determining the generation and attraction of trips are presented, and the number of truck trips that are generated can be defined without having to take an additional step to define the modal distribution [17].

2. Load distribution (gravity models)

This is where it has truly had specific developments in freight transport. Below are several models that exist for urban freight transport. There are four types of load distribution models [18].

- Growth factor models.
- Input-output models.
- Synthetic formulations of origin-destination.
- Spatial interaction models.

Growth Factor Models (Fratar) are simple models that use the base distribution of a certain matrix and with the projections of generation and attraction, the growth factors of each zone of origin and of each destination zone are calculated. Given that the factor is doubly restricted, these factors must be found in an iterative process that balances both factors [19].

Input-output models are the same model used in the generation and attraction stage, which is based on economic aspects to determine the attraction and generation values of the sectors [3].

Synthetic formulations of origin-destination have the purpose of obtaining the origin-destination matrix corresponding to secondary information established as traffic behavior [18]. The most representative models of this type are linear programming, entropy models and equilibrium models.

Spatial Interaction models are models that explain the distribution of trips based on interactions with space. Among these models are the gravitational models, the models of opportunities intervened and the models of direct demand.

Gravitational Model

This model uses the following equation:

$$V_{ij} = \frac{O_i D_j F_{ij}}{\sum_{j=1}^{n} D_j F_{ij}}$$

Where:

V_{ij} = Trips produced in zone i and attracted in zone j
O_i = Total trips produced
D_j = Total trips attracted
F_{ij} = Friction factor or impedance

$$F_{ij} = e^{-\left(\frac{1}{k}\right)*t_{ij}}$$

Where:

k = Average distance between zones
t_{ij}= measurement of impedance between i and j expressed in distance or in time.

This model is widely known and the one that by its characteristics can be implemented in the DMQ for transport planning processes.

IV. CONCLUSIONS

The analysis of several models of Generation and Attraction models as well as Distribution models was carried out, looking for characteristics that allow their application in the Metropolitan District of Quito.

It is important to keep in mind all the factors in order to suggest a solution model, and as well how are the emissions of that transport sector in order to be more efficient and environmental friendly.

As model of Generation and Attraction it was identified that the Hutchinson Model is one of the most suitable for its implementation and use in the DMQ since it takes into account variables such as changes of patterns in urban development, location of terminals, land use patterns , economic changes among others, which are relevant aspects of urban freight transport.

As a distribution model, it was identified that the Gravitational Model, which is a spatial interaction model, is especially suitable for urban freight transport planning processes.

It is important to mention that urban freight transport has a diversity of logistics chains in the MDQ and that they have characteristic behaviors that are specific to the economic variations of the related sectors.

REFERENCES

[1] IEA. (2017). Key World Energy Statistics.
[2] MERNNR. (2017). Balance Energético Nacional 2017.
[3] Kairuz Díaz, K. R. (2014). Estudio y Aplicación de los Modelos de Transporte de Carga Urbano: Generación, Atracción y Distribución de Transporte de Carga en la Ciudad de Bogotá. Universidad Nacional de Colombia.
[4] BID. (2013). Distribución Urbana de Mercancías: Estrategias con Centros Logísticos.
[5] CEPAL. (2015). El complejo rompecabezas del transporte urbano de mercancías.
[6] MDMQ. (2012). Plan Metropolitano de Desarrollo del Distrito Metropolitano de Quito. Quito.

[7] MDMQ. (2014). Situación económica y productiva del DMQ. Quito - Ecuador.
[8] Menoyo, E. . (2006). La Logística Urbana: conceptos básicos y proposiciones.
[9] Marcário, R., Galelo, A., & Martins, P. M. (2008). Business models in urban logistics.
[10] CAF. (2012). Logística Urbana. Montevideo.
[11] INEC. (2010). Censo de Población y Vivienda del Ecuador.
[12] Cherrett, T. (2012). Understanding urban freight activity-key issues for freight planning. Journal of Transport Geography, (24), 22–32.
[13] Taniguchi, E., & Thompson, R. . (2015). City Logistics: Mapping The Future. CRC Press.
[14] Gouvea, V., & De Melo, I. (2004). Análisis de la Demanda de Transporte de Carga en Área Urbana bajo el Punto de Vista de la Producción y de la Atracción de Viajes.
[15] Ojeda Toche, L., & Tovar Plata, L. (2016). El análisis espacial como una herramienta para el estudio del transporte de carga urbano. Valencia.
[16] Jong, Gunn, & Walter. (2004). National and International Freight Transport Models: Overview and Ideas for Further Development.
[17] Hutchinson, B. (1974). Principles of Urban Transport Systems Planning. Washington DC.: McGraw-Hill Book Company.
[18] Holguín-Veras, J., List, G., & Meyburg, A. (2001). An Assessment of Methodological alternatives For a Regional Freight Model in the NYMTC Region.
[19] Ortúzar, J. de D., & Willumsen, L. (2011). Modelling Transport. United Kigdom.