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Evaluating the economical and environmental impact of a cargo cycle urban distribution – a case study

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Assinatura:

Nothing is offered to us for free.

Everything is conquered.

You work get what you have.

Lebron James

“*This is book of the law shall not depart out of thy mouth; but thou shalt meditate therein day and night, that thou mayest observe to do according to all that is written therein: for then shalt make thy way prosperous, and then thou shalt have good success.*”

Joshua1:8(NVI)

To my wife, Alessandra,

everything.

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ABSTRACT

The urban distribution of goods is a function of the economic needs of cities, whether imposed by industries, or by commercial establishments and by their inhabitants. This type of transport has become more critical, with the growth of urbanization, which has negative impacts on the environmental, social and economic elements. One of the possible solutions allows the reduction of air pollutants, noise and congestion, making the quality of life of society improve without compromising the economic development of the city: the replacement of fossil fuel-diesel vans by using the electric cargo tricycles.

The literature review of these electric vehicles and their benefits for freight transport in urban areas is far behind in Brazil and Latin America when compared to cities in Europe, Asia and the USA. It is this gap that this work intends to study, as a way to mitigate the environmental impact, making the urban distribution of goods more sustainable and viable. For that, a case study was selected in a company in the segment of courier, express and parcel delivery (CEP) located in the city of São Paulo, Brazil.

Required data for the study has been obtained from company sources or collected through direct observation and empirical surveys by the author of the dissertation. From the experience observed in the field, it was perceived that there is, in fact, little knowledge of the economic benefits that the implementation of new technology transport means (and alternative distribution strategies) can provide. This perception can be altered by the resuts of this work.

The results show that replacing diesel vans by electric cargo tricycles along with adequately new distribution strategies can represent savings of up to around 31% in operating costs and approximately 20 tonnes of CO_2eq emissions per year, reducing by at least 97%, they can be used with this solution. The figures are significant, for clear potential in reducing impacts to citizens. Achieving virtually eliminate emissions of greenhouse gases, air pollutants, reduce noise in the operation of the distribution of goods in urban areas.

KEYWORDS

Urban freight distribution; Electric cargo tricycles; Urban consolidation centre (UCC); Environmental and economical sustainability.

RESUMO

A distribuição urbana de mercadorias é função das necessidades economicas das cidades, sejam estas impostas pelas indústrias, como também pelos estabelecimentos comerciais e por seus habitantes. Esse tipo de transporte tornou-se mais crítico com o crescimento da urbanização, por trazer impactos negativos aos elementos ambientais, sociais e económicos. Uma das possíveis soluções permite a redução da poluentes atmosféricos, poluição sonora e do congestionamento, fazendo com que a qualidade de vida da sociedade melhore sem comprometer o desenvovimento económico da cidade: a substituição de vans alimentadas com combustível fóssil (diesel) pelo uso dos triciclos de carga elétricos.

A revisão da literatura destes veículos e os seus benefícios para o transporte de mercadorias em áreas urbanas encontra-se muito defasada no Brasil e América Latina, quando comparado com cidades da Europa, Asia e USA. É esse gap que o trabalho pretende mostrar como forma de mitigar o impacto ambiental, tornando a distribuição urbana de bens mais sustentável e viável. Para tal, foi selecionado um estudo de caso em uma empresa no segmento de Courier, Express and Parcel Delivery (CEP) localizada na cidade de São Paulo,Brazil.

Os resultados mostram que a substituição dos furgões diesel por triciclos de carga elétricos, juntamente com uma estrutura de distribuição adequadamente nova, pode representar economias de até 31% nos custos operacionais e aproximadamente 20 toneladas de emissões de CO2eq por ano, reduzindo em pelo menos 97%, com esta solução. Os números são significativos, para um claro potencial na redução de impactos para os cidadãos. Os resultados mostram que se consegue praticamente eliminar as emissões de gases de efeito estufa, poluentes do ar, reduzir o ruído no funcionamento da distribuição de bens em áreas urbanas.

PALAVRAS-CHAVE

Distribuição Urbana de Mercadorias; Triciclos elétricos de carga; Benefícios Económicos e Ambientais; Centro de consolidação Urbana.

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CEP – Courier, express and parcel

CH4 – Methane

CO – Carbon monoxide

CO2 – Carbon dioxide

CO2eq – Carbon dioxide equivalent

DC – Distribution centre

GHG – Greenhouse gases

GIS – Geography information system

GWP – Global warming potential

HORECA – Hotels, restaurants and cafes

ICT – Information and communication tecnhnology

ITS – Intelligent tranportation system

N2O – Nitrous oxide

NMHC – Non-methane hydrocarbons

NOx – Nitrogen oxides

PM – Particulate matter

RCHO – Aldelydes

SOx – Sulphur dioxide

UCC – Urban consolidation centre

VLC – Light vehicle of cargo

VOC – Volatile organics compounds

VUC – Urban vehicle of cargo

B2B: Business – to Business to -client

B2C – Business –to- Client

TNT- Thomaz National Transport

CH_4: Methane

EPE: Energy research company

E-CB: Eletrically Cargo Bike

E-Bike: Electric Bicycles (incluind cargo-Bikes) and Electric Mortorcycles

HGV: Heavy Goods Vehicles

LEV: Light Electric Vehicles

LGV:Light Goods Vehicles

SEV: Small Electric Vehicles

LP: Logistic Profile

RSHO: Aldehydes

SO_2: Sulphur Dioxide

TTW: Tank-to-Whell

TW- Two –weheels- Bicycles/ Cargo Bike

3W – Three weheels – Cargo tricycle

UCC: Urban Consolidation Centre

WTW: Well-to-Wheel

WTT: Well-to-Tank

OECD: Organization for Economic Cooperation Development

1. INTRODUCTION

Dried fruits, vegetables and other perishable products are available on the market at certain times of the year due to seasonal patterns of growth and the lack of natural coding for agricultural production. Yet, many products are offered at any time, in different locations around the world. Fast deliveries at reasonable prices put those perishable products in markets that would not have them available. South American bananas are found in New York in January; New England live lobsters are served throughout the year in restaurants in the city of Kansas; and Hawaii orchids are plentiful in the eastern United States in April. An efficient and effective transportation system makes this possible (Ballou, 1993).

1.1 Dissertation context

The physical distribution of goods in urban areas is a fundamental activity in the transportation system of a city. It is responsible for the inductive functions of a region and is a vitally important component in the process of economic planning and development of a society (Russo and Comi, 2010).

Despite this, the problem generated by the movement of goods in urban areas is not a recent one, but it has been rarely considered in the classic urban transport planning, where the attention of the local authorities was directed towards the transport of passengers. This view has been changing quickly, due to the growing awareness of citizens about the major problems arising from this activity: increased congestion, high-energy consumption and emission of pollutants.

In order to identify techniques and strategies for freight transport in urban areas, the European Commission (2015) has adopted some key issues, from which environmental gains and competitiveness can be expected for the actors involved in the change process. According to this study, five of the good experiences observed for the transport sector are: less polluting engines, training of personnel, use of environmentally cleaner transportation means, reduction of the number of heavy vehicles circulating and the use of the concepts of city logistics.

In this sense, in the late 1990s, a new way of improving the distribution of goods in cities came: the concept of city logistics, whose goal is to support the sustainable development of cities and seek solutions for problems caused by the movement of goods in the cities. According to Taniguchi *et. al.* (2001), city logistics should be a process of optimization of logistic activities in urban areas, considering social, environmental, economic, financial and energetic impacts. For this, sustainability measures were adopted in some cities to mitigate those distribution problems.

According to Dablanc (2007), a large number of different types of goods flows constantly cross the urban environment, consumer goods, building materials, medicines, waste products, postal mail and others. These flows occupy about a quarter of the street traffic of a typical city. In addition, cargo materials require loading and unloading, storage, consolidation and packaging, which require even bigger use of urban space. All these movements of urban goods are the result of logistical decisions, which is the processes necessary to organize the movement of goods efficiently in the system of goods production. These logistical decisions are based on the demands of the production and distribution sectors, which depend on the behavior of the economic agents, such as households and companies. These interactions give complex characteristics to the urban mobility.

In order to meet this demand, a significant number of trucks with fractional loads compete with vehicles, narrow streets, mixed traffic, urban furniture, pedestrians, motorcycles, buses, an increasingly scarce space in urban centres, or, for parking, for the purpose of loading and unloading the goods (Dablanc, 2007). In addition to the impacts on traffic, the urban distribution of goods generates environmental problems, such as congestion, high-energy consumption and emission of polluting gases.

One way to alleviate the problems generated by the demand for the distribution of goods in urban areas is the implementation of urban consolidation centres (UCC) for goods, supported by electrically supported charging or human propulsion. The idea of the UCC is to separate distribution activities into two parts: inside and outside the city, i.e.long-distance transport and transportation within the urban area, respectively (Quak, 2008; Van Rooijen and Quak, 2010). The objective is to minimize the distance traveled by freight vehicles in urban areas, also reducing congestion and emission of pollution (Van Duin *et al.*, 2016).

In view of the above, the realization of this study has crucial importance in the current Brazilian scenario, as the number of emissions of atmospheric pollutants and emission of greenhouse gases are increasing. It is necessary to study economically and environmentally viable solutions and alternatives for the transportation of cargoes in urban areas, presenting the advantages and disadvantages of each alternative.

In this context, the motivation for this dissertation is to compare (evaluate) the traditional fleet of physical distribution of goods through fossil fuels (diesel vans) with alternative technologies, namely electric cargotricycles, estimating travel times, costs, and pollutant emissions in the last mile of delivery, seeking a response to the following research question:

Is it possible to reduce costs and reduce or eliminating negative externalities by replacing fossil-fuelled vans and trucks for electric cargo tricycles in the urban distribution of goods?

Hypotheses

The main hypothesis of this study is that, based on the analysis and comparison of the performance of the use of electric cargo tricycles as a support to urban consolidation centres, the method developed is capable of defining feasible alternatives from the economic and environmental point of view to the issue of cargo transportation in urban areas.

The secondary hypothesis is that the alternatives presented are capable of competing with current alternatives, in order to maximize resource utilization and the operation of the urban cargo transport system and to mitigate environmental impacts without causing damages to the economic activities and, consequently, increase the improvement of eco-efficiency, generating positive contributions to the perception of society.

Basic premisse

It is possible to promote the sustainable mobility of transport in urban areas through an efficient integrated planning in the process of the operation in the physical distribution of goods using the electric cargo tricycles as an alternative mode in the distribution of goods in urban areas.

1.2 Objectives

This study aims to evaluate and quantify the potential economic and environmental performance of the freight transport operation in urban areas using two distribution strategies: the first is to compare deliveries on a route using diesel powered vans with electric cargo tricycles from a UCC; the second strategy is to compare the deliveries and pick-up's of last mile goods made by electric cargo tricycles from a terminal transhipment supplied directly from a distribution center (DC), as a way to mitigate the environmental impact, making the urban distribution of goods more healthy and viable. The study is applied to the case of a parcel transport company located in the Metropolitan Region of São Paulo. More specific objectives are:

- In economic terms, to investigate whether the use of cargo cycles, as a support of the UCC, considerably reduces the operational costs relative to fuel consumption and vehicle maintenance;
- In environmental terms, to contribute to reduce the emission of atmospheric pollutants and greenhouse gases and sound pollution in the logistic activity, and, consequently, to contribute to the improvement of the environmental performance.
- To promote the improvement of transport mobility in urban areas and to mitigate their environmental impact, by proposing an integrated planning in the process of the transport operation of physical distribution of goods in an UCC using motorized or human propulsion as support in the deliveries and collections of goods in the process of the last mile.

1.3 Methodology

In order to carry out this research, it is proposed to conduct a descriptive and exploratory study, by using a quantitative approach applied to a real case study of an urban distribution company. Required data has been obtained from company sources or collected through direct observation and empirical surveys by the author of the dissertation.

The hypothesis and the premise of this study are tested by comparing alternative scenarios/strategies of distribution of goods in urban areas, using the truck and diesel (traditional practice) with the cycle cargos (alternative) in a case study of distribution operation carried out by a transport company in the city of São Paulo.This study is supported and complemented by a review of the existing literature, based on research articles from indexed scientific journals, theses, dissertations, books and technical reports.

Alternative distribution strategies (and technologies) are evaluated in terms of their economical and environmental performance. Technologies proposed are based on electric cargo tricycles.

1.4 Structure of the dissertation

This dissertation is divided into 6 chapters (Figure 1). In this first, the problem was framed and the main objectives that are expected to be achieved are presented.

Chapter 2 has as main objective the description of the literature review on the themes adjacent to the main theme of the dissertation. In this sense, it presents the urban distribution theme, the state of the art and the new tendencies of this process. Next, it characterizes the system of physical distribution of goods in urban area, presenting methodologies and projects developed for analysis and the solution of problems related to urban distribution. At the end of the chapter, there is an approach to mobility and sustainability related to distribution of goods in urban area. Environmental aspects will be addressed, namely the emission of greenhouse gases and atmospheric pollutants. Later, it is detailed to the concept of city logistics, presenting the methodology to establish this new trend of urban distribution and the relationship between those involved in the process. Subsequently, the segments of the urban distribution of goods, the characterization of the agents involved, the new practices developed in Europe and the problems of urban distribution are discussed.

Continuing with the literature review, Chapter 3 presents the concept of the UCC, the problem of last mile delivery, as well as home deliveries. It presents cycle logistic as a new trend for urban logistics. Specifically, in this chapter, more than a collection of electric vehicles' characteristics, the potential for electric vehicles to substitute conventional vehicles is analysed for urban logistics. Features like price, fuel consumptions, maintenance cost, insurance and taxes were investigated, along with the characterization of electric tricycle cargo and its benefits.

In Chapter 4 presents the case study and the methodology that will be applied to estimate the savings that a alternative technology shift can represent in the company.

Chapter 5 reports the application, results and discussion of the case.

Finally, Chapter 6 draws the main conclusions of the dissertation, the limitations of the study, and gives some suggestions for future work.

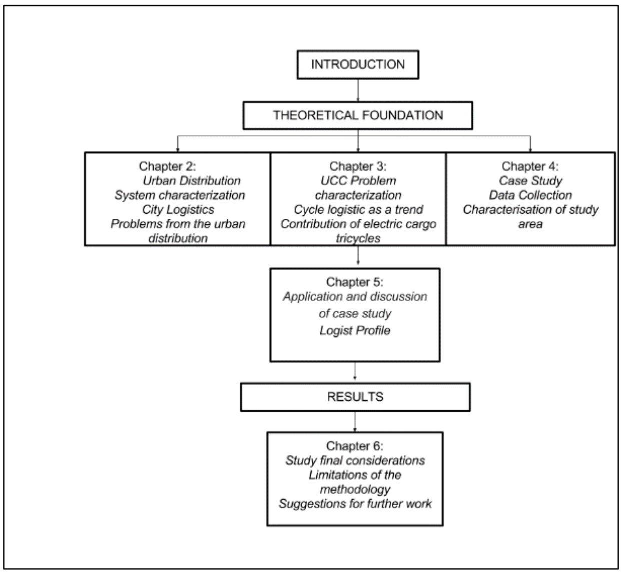


Figure 1 – Dissertation structure

2. THE URBAN DISTRIBUTION SYSTEM

"Urban distribution is a fundamental part of the production and distribution process." Portal (2003)

This chapter presents the definition of urban distribution and the different ways in which it can occur. Next, it characterizes the system of goods physical distribution in urban area, presenting methodologies and projects developed for analysis and the resolution of problems related to urban distribution. At the end of this chapter, it is described an approach on technical and operational aspects as well as some concepts of mobility and sustainability related to the transport of goods in urban areas aligned with city logistics.

2.1 Introduction

Transportation is the displacement of people or freight (products, goods, waste etc) from one place to another of space. The transport of goods is of great importance in the progress of cities around the world, with the function of supplying producers and cities, being a fundamental activity in sustaining the life of a society. In addition, it plays an important role in the logistics costs of the companies, reaching to act strategically in its supply chain.

According to Morlok (1978), transportation is an integral part of the functioning of any city and has an interconection between the populations's lifestlye, reach and place where the production activities take place and the services and goods will be available for consumption. That is, transport has a structuring role in the development of a society. According to the same author, a transport system allows an object to be moved from one place to another along a path, through a technology. Its components are freight and people, path, vehicle, container, costs, terminals, and plan of operation.

The urban transport system represents a relevant component in the economic development of a society. The distribution of goods in urban areas is characterised by the concentration of residences and commercial activities. However, the consequences of those activities, such as congestion, pollution, noise, and vibration, reduce the well-being, accessibility and attractiveness of urban areas.

There is a consensus that today's world cities are dependent on the harmonious and efficient performance of transport systems, and that freight transport in urban areas plays a relevant role. In fact, a quarter of road traffic is represented by commodity flows (Dablanc, 2007). Not only are they responsible for urban traffic but also for externalities, that is, undesirable environmental impacts such as air and noise pollution, congestion and accidents (Visser *et al.*, 1999).

In a competitive and dynamic market, improving the level of customer service in line with cost reduction is a major differentiator for transport companies, generally driving the aircraft closer to its customers, reducing distances and improving freight rates. Therefore, while the population is disliked by negative externalities from transport, population growth and the constant growth of the world economy, there is a significant and growing demand and flow of goods to be distributed in the urban centres, causing an impact on the quality on population’s life (McKinnon *et al.*, 2013).

In view of this fact, good transport planning for sustainable and clearner development is essential. According to the Bureau of Public Roads (1963 apud Mello, 1981, p.26):

"*The transportation planning process concerns all the facilities used for the movement of goods and people, including terminals, parking facilities, public transportation and traffic control systems. The process is based on the collection, analysis and interpretation of data on existing conditions and their historical development, on the goals and objectives of the community, on the prediction of future urban development and future demand for transport. It includes not only the preparation of the planning, but also periodic revisions and modifications resulting from the modifications that occur.*"

Transport planning for goods must be dynamic to facilitate, in an orderly manner, the progressive development of an integrated transport system, in harmony with the overall objectives of a community or geographic area. In this sence, there should be designed plans to provide efficient movement of people and goods through all forms of transportation, and these plans shoud be environmentally and socially sustainable. There should be a healthy interrelationship between land use and transport.

Mitchell and Rapkin (1954) noted that "*specialisation of urban activities is necessary for their establishments and their members to communicate with one another, and consequently the tendency of these establishments is to make accessibility consideration of the place to be chosen.*"

For Wingo (1972), a transport system should be seen as "*a set of facilities and institutions organized to selectively distribute a quality of access in an urban area*".

In order to try to reduce this inconsistency, a new integrated planning of the urban transport system on the question of sustainability is necessary. However, usually, the increase of efficiency will only occur when the transport of googs is contemplated in this planning.

Transportation planning analyses often assumes that individuals want to minimize the generalized costs of travel, often measured time or travel distance (Iseki *et al.*, 2014). Using this assumption, it is expected that a driver will make the choice for the shortest distance offered by a street network.

2.2 Urban freight transport

Many flows of different types of cargo constantly enter, cross and leave urban areas, including, for example, consumer goods, medicines, construction materials, waste deliveries, parcels and mail (Dablanc, 2007). According to the same author, urban distribution of freight is the circulation of goods within the urban environment, carried out by/for commercial establishments, due to their economic needs, as well as home deliveries. In this way, the movement of freight is not an end in itself, but the physical reflection of a global, national and local economic process (Czerniak *et al.*, 2000).

Charter transportation is an important user of limited urban space (Zanni *et al.*, 2010).

Service providers and operators move behind cities, competing for space with other stakeholders including taxi drivers, public transport vehicles, cyclists and pedestrians, and a large number of different types of goods that are not transported to and through narrow streets, but also packed, stored, loaded, unloaded at these places (Dablanc, 2007).

Ogden (1992) defines the transport of goods in urban areas as the transport and movement of goods, for various urban destinations serving the most varied purposes. Thus, the role of cargo transportation is to make the product available to other sectors of the economy available to be used, processed, repaired, modified, stored or consumed. That is, transport, in itself, only adds the spatial value to the product, but makes it part of the economic process of production and consumption.

For Nuzzolo *et al*. (2011), urban activities are accompanied by large charter movements characterized by delivery trucks that move between distribution centres, warehouses and retail activities.

According to Novaes (2001), the physical distribution of goods refers to the operational and control processes involved in the displacement of the goods from the place where they are produced to the final consumer.

The transportation ensures the connection between supply chain links by providing added value by creating the usefulness of place and time: moving products to the right place at the desired moment and in the desired conditions (quantity and quality) intended.

For Ballou (1993), time and place are key factors for transportation, establishing a flow of goods and services with quality, the so-called service level.

The major objective of freight transport in urban areas, from the point of view of the political orientation of planning, is to minimize total social costs. Ogden (1992) divided this general objective into six others: economic, efficiency, road safety, environmental, infrastructure, and urban structure objectives. Thus, according to the same author, the viable solution for urban freight transportation is in the balancing between these objectives by planners. The author suggests a set of six specific policy objectives:

1. Macro-economic performance of the public sector - to contribute to the economic performance of the various levels (local, regional, national);

2. Cost and quality of freight services - increase the efficiency and productivity of cargo by reducing transport operating costs, especially those associated with traffic congestion;

3. Environmental - minimize the adverse effects of cargo activities (terminals and transportation), specially noise, emissions, vibration and intrusion within residential areas;

4. Infrastructure and management - provide and manage an adequated infrastructure especially that focused on the provision and maintenance of the road and terminal system, and appropriate regulation of the cargo operations by trucks;

5. Road safety - to minimize the number and severity of accidents by trucks;

6. Urban structure - contribute to the desired urban structure, especially in the location of load-generating activities and terminals.

It is important to analyze the various factors that affect the operation of urban cargo transportation, as delivery and collection activities, services and goods flow. The characterisation of the flow of vehicles, and specifically of trucks (quantity, type, number of axes, dimensions and weights, etc.) becomes an important factor for proper road planning (sizing of pavements and parking spaces etc.)

According to Portal (2003), urban freight transport is an integral part of the transport chain and has its own characteristics and, although the integration has a fundamental role for the coordination of the chain as a whole, currently this chain is not integrated. In the context of urban freight transport, a transport chain consists of a sequence of organizational and technical events through which goods are moved.

Also with regard to the flow of goods, Portal (2003) presents the main types of delivery (Figure 2 schematically shows these concepts):

- Single-step system or (direct) - goods flow between supply point (origin) and reception point (destination) is direct. This system has the advantage that the goods flow between supply and reception points is unbroken. With this, no additional storage or movement process is necessary;

- Multi-step system (indirect) - here, goods flow between supply point and reception point is indirect, i.e.goods flow is interrupted in at least one place. At this interruption point(s), distribution or aggregation processes take place to carry out the consolidation and deconsolidation of the load.

- Combined system - simultaneous direct and indirect goods flows are possible and consists of simultaneous and direct flows of goods. With great distances, the goods flow can be, for example, too slow to cover the resulting needs at the reception point on time. The distribution points have the character of a regional warehouse. Multi-step systems are also recommended by the fact that the economics of a goods flow generally depends directly on the volume.

The movement of load involves several actors, with different activities, interest and responsibilities. Figure 3 shows the relationships between the process participants and their activities. Therefore, the management function in the conciliation of divergent interests becomes essential to the good progress of the activities.

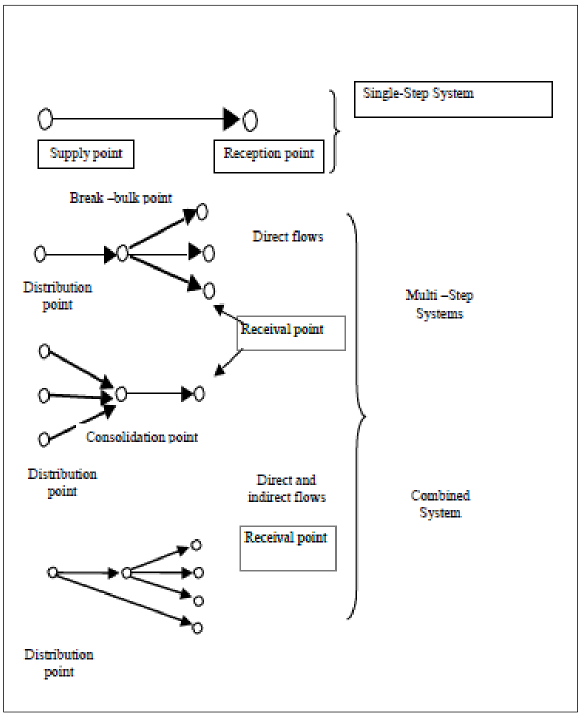


Figure 2 – Goods flows and freight transport (source: Portal, 2003)

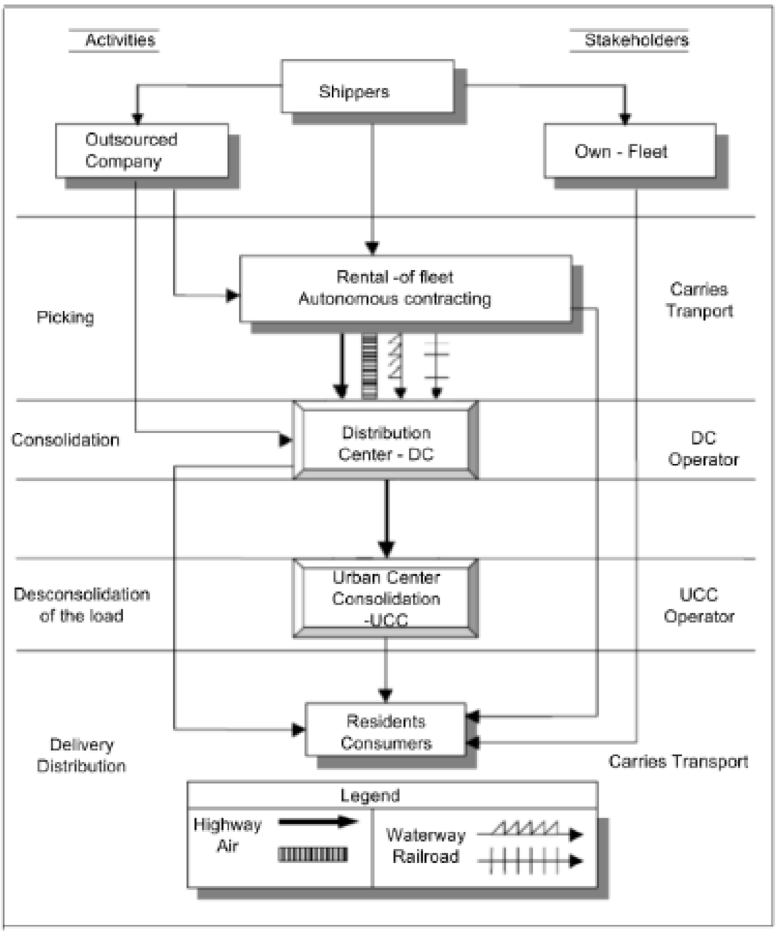


Figure 3 – Load handling process (adapted from DUTRA, 2004)

2.3 Urban logistics

There has been a trend towards a greener world today. Raising concerns about rapid urbanization and aging populations. About half the world’s population lived in urban areas in 2010 according to the United Commision (2016) survey and this is predicted to become more than 60% by 2030. Globally, the proportion of people over 65 was 7.6% in 2010 and is expected to become 18.3% by 2060.

Under such demographic conditions, the issues of urban freight transport have become more important to support a better life for people as well as a better environment in urban areas. Urban freight transport is not only essential for economic growth, but also for better harmonization of the environment itself (Taniguchi, 2014).

However, logistical activities sometimes generate congestion, air pollution, noise and accidents in urban areas. It is therefore necessary to balance smart economic growth and cleaner, quieter, and safer communities. In addition, in facing higher risks of disasters due to global climate change and the aging of societies, urban freight transport must incorporate these risks to the creation of more sustainable and viable cities (Taniguchi *et al.*, 2014). To solve these complex problems, Taniguchi *et al.*(2001) proposed the concept of urban logistics. A number of political measures of city logistics have been implemented in cities around the world. Modeling techniques were also developed to plan and evaluate the city's logistics policy measures.

The rapid growth of e-commerce demand, the ease of the consumer to make a purchase without having to move to a physical establishment, also makes city logistics activities very important, since this type of transaction is changing the logistical activities of the prioritization of demand of consumers. The development of these policies is an alternative to improving the efficiency of the urban distribution system, making it more environmentally friendly.

Taniguchi *et al.* (2001) define urban logistics as a set of strategies to improve the efficiency of cargo distribution in urban areas, mitigating congestion and environmental externalities. A process of total optimization of logistics activities, performed by entities (public and private) in the structure of the economic market.

Czerniak *et al*. (2000) attest that the urban distribution of goods is not an end in itself but the reflection of a global, national and local economic process. For Crainic *et al.* (2009) the concept of urban logistics aims to optimize urban transport systems, considering all the actors involved and all movements in urban areas. The coordination of shippers, transporters and movements, as well as the consolidation of loads of different customers and shippers, are indispensable for this concept to be implemented.

For Muñuzuri *et al.* (2010), city logistics is the term used to denote specific logistic concepts and practices involved in the distribution in urban areas congested with their specific problems, such as delays caused by congestion, not suitable place to park, among others.

According to Ricciard *et al.* (2004), the concept of city logistics surrounds the domain of ideas, studies, policies, models and methods that allow the following objectives to be achieved:

- Reduce congestion and increase mobility by controlling the number and size of cargo vehicles operating in urban centres, reducing the number of "empty" journeys and improving the efficiency of cargo handling;
- Reduce levels of pollution and noise, helping to achieve the Kyoto Protocol objectives and improve the quality of life of the inhabitants.

Thus, integration, coordination and consolidation are fundamental concepts to develop projects and operations based on city logistics, involving the integration of the various actors involved in the decision making process in urban cargo transportation, coordination of the planning and decision process regarding shippers and the consolidation of different products in the same vehicle between the points of consolidation and final delivery.

Three elements are essential to promote city logistics (Taniguchi et al.,2004)

- Application of innovative technologies, such as Intelligent Tranportation System (ITS) and Information and Communication Tecnhnology (ICT);
- Change in the mentality of public managers;
- Public-private partnerships.

Firstly, the application of innovative ITS and ICT technologies in urban freight transport enables precise data collection on the movement of collection and delivery trucks in low cost urban networks. The digital data can be fully utilized to optimize vehicle routing, vehicle scheduling and local routing problems and to plan dynamically and stochastically (Taniguchi *et al.*, 2004; Taniguchi *et al.*, 2006). This type of optimisation of vehicle operations can help reduce logistics costs, reduce carbon dioxide (CO2), nitrogen oxides (NOx) and particulate matter (PM) emissions, as well as alleviate traffic congestion. Therefore, both private companies and society, in general, can benefit from the application of innovative technologies in terms of logistical efficiency as well as mitigating environmental externalities.

Secondly, a change in the mentality of logistics managers is central to urban logistics, since logistics managers are the main players in urban freight transport operations. A number of transport and logistics companies have achieved ISO 9001 (quality management) and ISO 14001 (environmental management) certification. This certification offers logistics companies a good opportunity to train employees on actions to develop more eco-logical logistics systems. For example, eco-driving collection and delivery trucks is beneficial in reducing fuel costs and crashes by a smoother driving mode. The green image of companies can help them get a good reputation in the market. For small and medium-sized enterprises, a similar but less expensive certificate.

Finally, Browne *et al.* (2004) consider public-private partnerships (PPP) are a central element for city logistics. In traditional transport planning, transport managers primarily develop transport plans based on their own surveys and data, and then sometimes listen to public authorities and residents. In the meantime, public-private partnerships allow all stakeholders to participate in the development of urban freight transport plans from the outset.

Data sharing between private companies and the public sector is quite useful to understand the situation of the distribution of goods and related problems. During the discussion, managers can understand the expected reaction of trasport companies to measures of city logistics policy. This procedure is effective to avoid any unexpected side effects of policy measures.

These elements contribute to the efficient management of the movement of goods in the cities, promoting innovative responses to customer demand.

City Logistics solutions manifest themselves in different formats, such as advanced information systems, cargo transport cooperation systems, public logistics terminals, shared use of cargo vehicles, underground cargo transportation systems and areas with access control, among others. They have been implanted alone or together, according to the particularities of the area to be treated (Taniguchi *et al.*, 2001).

2.3.1 Segments of urban goods distribution

Cities are places of consumption, production and distribution of material goods. Urban logistics includes all activities ensuring that the material demands of these activities are met. As a city home to a large number of different economic sectors, it is provisioned by hundreds of different supply chains, making urban logistics very complex and diversified. However, each economic activity occurring in an urban environment may be associated with a specific load-generation profile, which is constant from one city to another (Dablanc, 2011), although cities around the world are different in terms of size, geographical and economical conditions, and cultural and political values. The following categories of urban logistics with common transport characteristics can be identified:

Retail. From a logistical point of view, two different types of retailers with different supply systems can be distinguished. The first is retail chain, which are served by centralized delivery systems. Large retail stores are usually serviced through a centralized distribution centre, making use of consolidated deliveries on larger vehicles on a scheduled basis, which helps limit the number of deliveries required. The second group involves independent small and medium specialized stores. Their logistics differ significantly from the main retail chains in the delivery organization, as they are not served through centralized distribution systems. The offer is usually organized directly by its various suppliers, often using their own account vehicles. As a result of the decentralized supply system, independent retailers typically receive between three and ten deliveries per week (Dablanc, 2011), which is about three times the number of deliveries to chain retailers using centralized delivery systems (Cherrett *et al.*, 2012). Independent retailers are therefore the largest generators of freight traffic, accounting for 30-40% of all deliveries in one city (Dablanc, 2011).

Consumer shopping trips. Products sold at retail stores are usually brought home by the consumer on their own, using passenger cars, public transportation or walking and cycling. These consumer shopping trips, including travel to the retail store to purchase the product and travel to transport it home, may account for a significant portion of the energy used to transport cargo from the supply chain, from the primary sources (raw material) to the retail stores (consumer product), depending on the mode of transportation, the quantity of goods transported and the distance of travel attributable to purchases (Browne *et al.*, 2006).

Courier, Express and Parcel (CEP) delivery. The CEP is one of the fastest growing urban transport sector. Courier and express services deal with the fast transportation of documents and lighter parcels with additional value, while package services are concentrated in heavier parcels of up to 30 kg (MDSTransmodal, 2012). CEP operators maintain a global network of cross-docking terminals where shipments are consolidated for delivery tours in urban areas using large vans or small or medium-size trucks. One segment of the business is home delivery. While conventional retail channels include delivery from a distribution centre to a retail outlet and a consumer shopping trip from a retail store to a residential home, domestic deliveries include a single trip from a distribution centre to residential areas. Online shopping has grown significantly and represents 5% of all retail in Europe (Dablanc, 2011) and 8% in the US (Rodrigue, 2013). Household deliveries are challenging operations characterized by high delivery failures, empty travel rates, and critical mass shortages in areas with limited demand, resulting in higher cost of distribution and emissions (Gevaers *et al*., 2011).

Hotel, Restaurants and Cafes (HORECA). Food deliveries are an important generator of urban goods traffic. HoReCa's industrial sector prepares and delivers food and beverages to hotels, bars, canteens and restaurants. End customers typically require specific services that present different logistical and organizational difficulties for HORECA distribution channels. The sector is usually characterized by unpredictability and therefore orders are usually very small and deliveries are often required on a just-in-time basis, which leads to frequent deliveries (MDSTransmodal, 2012).

Construction. The urban infrastructures of roads, homes, offices and retail are constantly being built, renovated and repaired. These activities are material intensive and should be provided in an irregular manner, both in terms of time and location of services (Rodrigue, 2013). Construction sites generate up to 30% of the tonnage transported in cities (Dablanc, 2011).

Waste. Urban activities generate large amounts of waste, which must be collected and transported to recycling facilities and disposal sites. Recycling requires dedicated vehicles and dedicated tours (Rodrigue, 2013).

Transportation of industrial cargo and terminal. Cities are not only places of consumption but also places of production and distribution. Production facilities are often elements of global supply chains, supplying parts from suppliers, and distributing intermediate and finished products to customers around the world. In distribution facilities, i.e. warehouses and distribution centres, distribution activities are carried out: consolidation, deconsolidation, cross-docking and storage. These facilities are commonly found near highways, ports, airports and rail terminals, which are transit points for regional or global transportation networks. They generate both parts and unit loads (containers and truck loads) from districts or manufacturing terminals (Rodrigue *et al.*, 2013).

For purposes of this dissertation, we will analyze, exclusively, the distribution of goods, through the CEP channel (courier, express and parcel deliveries).

2.3.2 Actors involved in urban goods distribution

The main actors involved in an urban goods distribution system are identified and related in Figure 4. Shippers are the actors that are at the origin ("shipper") or at the destination ("receiver") of the shipment. They can be industrial or craft producers, logistics providers or retail activities. They provide the product to distributors, retailers and wholesalers. They are the intermediaries (connecting link) in the supply chain, so that their products can reach the final consumer.

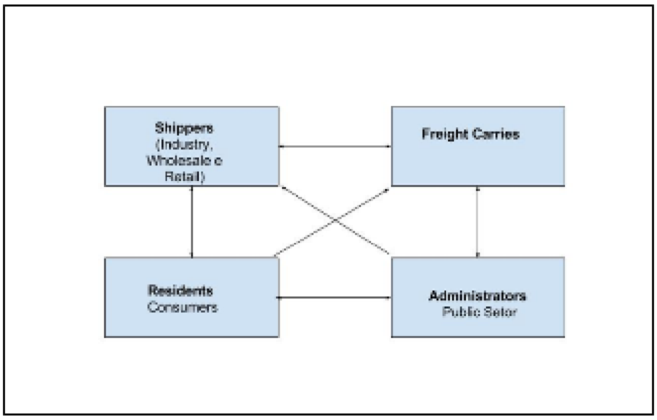


Figure 4 – Key stakeholders in city logistics (source: Taniguchi *et al.*, 2001)

Another important category are carriers, which can be shippers who carry out own transport operations, or third-party carriers, as well as mail operators, currier, and integrated logistics solutions providers, as TNT, DHL, FedEx and UPS. A third category is real estate agents, who are the "owners and management companies" of urban logistics facilities.

Public authorities, both local and regional, have mandates for granting the built environment, which strongly influences how urban logistics activities are carried out. They use land use and traffic planning to improve the built and social environment of urban regions. They provide land for economic facilities and transportation infrastructure, for example, roads and rails in which vehicle movements occur.

The objectives of the local authorities are, firstly, the following: for economic reasons, they aim at a high accessibility of their city-region to the supra-regional transport network and an effective intra-urban transport network to increase their attractiveness to the activity, becoming a generator of regional welfare. Secondly, for social and environmental reasons, they aim to reduce the impacts of freight traffic by imposing freight rates and restrictions, as demands of people living and working in cities, for a higher quality of life (Behrends, 2016). Lastly, the resident population are the people who live, work and consume in urban areas. They suffer the negative externalities arising from the movement of cargo around their homes. However, due to the large number of stakeholders and different economic objectives and interests, they make the distribution process costly, often below the minimum economic and financial viability. Good management of the adopted practices is important for all those involved benefit some way (Macário *et al.*, 2008).

2.3.3 Pratices and trends in city logistics

In the urban distribution of goods, the road mode appears to be dominant in urban mobility. However, this trend is changing. European cities are moving towards more sustainable, quiet, healthy, cleaner, smoother mobility with low emission levels, as far as the urban distribution of goods is concerned. The innovative city logistics of zero or low CO2 emissions can contribute to this goal, particularly in dense urban areas where freight journeys are mostly short. In this context, it is natural for delivery companies such as DHL, UPS, TNT FEDEX to be seriously involved in the last part of the last mile consumer delivery, by means of electric bicycles or human propulsion, conditioned by cost, environmental concerns, health and well-being of employees and organization's public image.

2.4 Overview of European UCC's

The use of the literature and the evaluation of other European reference projects will give an overview of the possible UCC concepts. Studies and data collection activities have taken place in several countries and cities such as Utrecht, Leiden, Nijmeng, Bristol, Kassel, La Rochelle and Malaga (Ruesch *et al.*, 2008; Schoemaker *et al.*, 2006). The consolidation centres analyzed are all in Europe. Much of the information is derived from practice. The great amount of research in consolidation centres makes it possible to identify the factors of success and failure in the implementation of the urban distribution of goods, both literature, reference projects and by experts in practice.

Utrecht (the Netherlands)

Quak (2012) analyzed the European Citylog project pratices already adopted and under way in the Netherlands in a collaborative research project on sustainable land transport. The author points out the conflict between local authorities, who are interested in a habitable city with good air quality, traffic flow, and transporters. For transporters, governmental restrictions, such as hourly restrictions on the movement of cargo vehicles, restrictions on access and parking in certain areas, are seen as a difficulty.

The Beer Boat and “Cargohopper” projects were analysed. In the case of the Beer Boat, the municipality rents the boat, mainly for companies that supply drinks and food to more than 70 companies along the city channels (Figure 5). In the case of Cargohopper, a private transport company introduced a new mode of transport that is a 16-meter long, narrow, solar-powered multi-trailer rail that rides on tires (Figure 6).

With all these sustainable alternatives, it found reductions in the order of 11% in terms of distance traveled and less CO2 emission and 25% volume increase considered. There is also a low pollution area where heavy pollutants are not allowed, promoting the use of cleaner products.

Figure 5 – Beer boat, Utrecht, Netherlands

Figure 6 – Cargohooper, Utrecht, Netherlands

Van Duin *et al.* (2010) analyzed six UCCs in Europe in different cities, detailing the characteristics of each project, especially the reduction of the distance traveled, which serves as a parameter for economic analysis.

In 1994, the initiative of the County of Leinden began in a public-private partnership (PPP) with the county, a consultancy, a real estate company, a carrier and a re-organization organization. The transporters could leave their freight at the UCC with five electric vehicles, the freight was transported to the city centre of Leinden or by vehicles belonging to the transport company with distribution license (Schoemaker, 2003, Project City Ports, 2005). The electric vehicles were obtained from the funds of the European Commission. Van Rooijen and Quak (2010) evaluated the case of the city of Leinden, where the service area was planned to be only in the center, time windows were implemented and, due to some participating shops, the service area was extend throught the city. The attempt failed because of the low profitability and the low participation of the of the retailers of this centre, with the number of deliveries falling below expectations, because the companies were not willing to collaborate with their competiors. In another study, Van Duin et al., (2010), held in the city of the Hague, they point out that the two major difficulties of implementing a UCC are an allocation of costs and benefits and a willingness to cooperate with transport companies. Both the company and the financing company can benefit financially from the use of UCC. The UCC operator, however, incurs costs. The municipality must an impotant role in bringing costs and benefits together.

Nijmeng (The Netherlands)

Van Rooijen *et al.* (2010) analyzed the most recent town distribution initative in the Netherlands is the 'Binnenstadservice.nl' project in Nijmegen. "Binnenstadservice.nl" is a city consolidation centre opened in April 2008 as an initiative of two entrepreneurs. UCC is still in the test phase and started with 20 end users (tenants). Traders who use UCC change the delivery address for their suppliers to the UCC address. The packages are grouped in the UCC and twice a day the packages are delivered to the stores. Currently, local subsidies pay for the service. Although it was initially thought that subsidies would only be needed during the initial phase, second-year funding is still not fully completed. When shop owners want to use UCC storage options, or want extra transactions done (value-added logistics like making ready-to-store products), they need to pay for those services.

"Binnenstadservice.nl" uses a courier bike and a van to deliver the goods to UCC stores, located in a business area near the city centre. One disadvantage of location is bad connection of the infrastructure for nearby routes. The van runs on natural gas. The service area is in the the city of Nijmegen.

Some pitfalls of the past are foreseen in this project. Provision of subsidies and the provision of value-added services are important elements for success. Providing a way to deal with different goals and visions and continuously tracking the attitudes of the parties involved seems to be a recipe for success as the growth of participating merchants has increased from 20 stores to 98 shopkeepers within a one-year period. The distance potential traveled in the central area of the city by up to 20%, depending on the parameters adopted and the tenants' adherence to the project (Hans Quak *et al.*, 2016).

Bristol (United Kingdom)

In 2004, the municipality of Bristol took the initiatives to start a UCC, operated by a DHL Exel supply logistics service provider. Currently, 63 of the 300 stores in the “Broadmead" shopping centre receive consolidated UCC deliveries. The users are medium-sized retailers and their products are non-perishable and low value-added products. Suppliers can deliver their products 24 hours a day, 7 days a week to UCC. DHL groups the goods and make the delivery to stores. DHL guarantees 100% on-time delivery. More than half of retailers save more than 20 minutes per delivery (Hapgood, 2006).

The cost efficiency for DHL is good because the funding is fully covered by subsidies from the VIVALDI CE project (Civitas, 2012). The UCC is located 10 miles from the service area. This is a 25-minute drive. The UCC is located near the M4 and M5 highways. The distribution is made with a vehicle of 9 tons and a vehicle of 17.5 tons. A successful four-month test was conducted with a 9-ton electric truck. No accompanying measures were implemented by the municipality.

The service area has an area of approximately 1.5 km^2. Despite the low turnout of shopkeepers, only 21%, the program has been profitable and reduced time, with more than half of the deliveries showing reductions of 20 minutes per trip. The 'Broadmead' shopping area is being expanded and it is expected that the number of users will increase in the near future (Hapgood, 2006).

Kassel (Germany)

The private iniation encouraged the installation of a UCC in 1994 in Kassel, Germany. Ten transport companies that delivered to the centre of Germany decided to cooperate (Köhler, 2004). During the first years, the UCC was subsidised by the county. In 2005, it already presented results in the order of 60% in reduction of the distance traveled by the vehicles and increase of the occupation of the vehicles of load, from 40% to 80%.

As in 2008 the UCC started to be paid by the cooperating transport companies, a slow collapse can be observed due to the high costs for the transport companies, since now the benefit has stopped. An incentive for the cooperation was the introduction of a pedestrian zone in the city centre of Kassel (Van Duin et al., 2010).

La Rochelle (France)

The La Rochelle project started a UCC in France in 2001 and serves 13.000 companies. The manager - Tranports Genty - is a private company. About 30% of deliveries to the city centre are handled by the UCC. Every day 450 orders are made and between 5 and 10 pallets per day. The delivery of the UCC to the city centre costs 3.75 euros per order. UCC deliveries are carried out through nine electric vehicles. Subsidies are provided by the local government for infrastructure and a lump sum per package. Time windows have also been set up and the UCC is located 1.5 km south from the city centre.

According to Patier (2006), the project reached levels of 60% in the reduction of kilometers traveled by cargo vehicles in the central area, but the project has not yet reached financial sustainability, needing help of the government. Carriers can avoid wasting time in the city centre, while retailers and residents enjoy better traffic and stagnation conditions, noting the improvement of the local environment (Browne et al., 2005). The success of La Rocelle's UCC is first and foremost due to the shared sense of urgency of all stakeholders. The initiator, the municipality, involved stakeholders in the process at a very early stage. The savings (of time) for the operators are greater than the costs of using the UCC.

Málaga (Spain)

The UCC in Málaga is a cross docking building at the outskirts of the historic centre. The municipality was the first promoter of the initiative. All stakeholders were questioned and, in this way, involved from the outset. Cross-docking activities are managed by a private urban transport organization. The UCC is basically a cargo park that transporters can use to overflow goods. Nevertheless, cross-docking activities are performed by the same agents that were active in the logistic chain before. The municipality owns the land, and the transporters are responsible for managing the entire process. A company based on the participation of distributors manages the centre. An accompanying measure by the municipality is the establishment of a pedestrian zone where only vehicles coming from the UCC can enter. For distribution, electric and conventional vehicles are used. Although the service area has been expanded to the entire city, there is a low use of the UCC. Only one third of the capacity is used (Browne *et al.*, 2005).

Quak (2008) highlighted a significant reduction with negative externalities of the urban distribution of goods, increasing safety levels and economic efficiency when a UCC is implemented. Reductions in energy consumption and in-load vehicles are also pointed out by the author as benefits that improve, albeit indirectly, the economic aspect of using a UCC.

L'Hospitalet de Llobregat (Barcelona, Spain)

Balm *et al.* (2014) evaluated the impacts of one of the Straightsol projects operated by DHL, funded by the European Commission, to improve the performance of last mile freight deliveries in a city south of Barcelona. The objective was the implementation of an UCC to improve the performance of the last mile freight deliveries in L'Hospitalet de Llobregat.

The transportation situation in the inner city is characterized by low utilization of vehicle capacity, high operational costs in the last mile of distribution, severe traffic congestion and excessive greenhouse gas emissions (GHG). In the greater metropolitan area of Barcelona there is a general lack of clear and uniform regulation which would favour efficient urban delivery strategies. To improve the performance of urban freight deliveries in L'Hospitalet de Llobregat, DHL's ' Supply Chain Spain' (DHL SC Spain) set up an urban consolidation centre (UCC) to reduce the number of vehicles entering the defined inner urban area (or last- mile distribution area) while maintaining required service levels. The shipment consolidation achieved by the UCC consisted of the delivery loads of several carriers to retailers located in this commercial city centre area.

One of the challenges of the demonstration is finding enough retailers to participate. The local partner is the Consorci Centre D'innovacio Del Transport (CENIT).

City Porto (Pádova, Italy)

Gonzalez-Feliu and Morana (2010) analysed the case of cityporto, in the city of Padova, Italy, where the local administration encouraged the establishment of deliveries with ecological vehicles from an UCC. In this case, research was carried out on the estimated parameters and the government subsidized the project for 2 years. The share of retailers increased 150% in 2 years (20 to 50), showing that success is possible for the city's logistics schemes and its financial viability can be assured, increasing the objectives of all those involved (Gonzalez-Feliu & Morana, 2010).

Finally, with respect to the operating regime, the UCC can operate 24 hours a day, seven days a week, allowing times when delivery vehicles are normally prohibited, such as night deliveries (Allen *et al.*, 2010).

2.5 Overwiew of cycle logistics in Europe

Melo *et al.* (2014) analyzed the use of small electric vehicles (SEVs) as tricycles and other vehicles as cargo cycles in the city of Porto, Portugal, from the perspective of the industry in terms of operational and external costs. The authors suggest that SEV's are a viable solution to satisfy public and private stakeholders. The conclusion of the study pointed to a reduction of 16% in distance traveled and 7% in speed, a market penetration of 10% and a reduction in delays of 10%.

The existing studies range from making a clear distinction between "cargo cycles" and electrically assisted cargo cycles – electric cargo bikes (E-CB), small electric vehicles (SEVs) – or referring to both of them. Overall, studies have found that the use of cargo cycles represent a viable solution for urban freight transport (Schliwa *et al.*, 2015).

Gruber *et al.* (2014) and Gruber *et al.* (2013) analyzed the study through the technical potential, user requirements, replacement of vehicles for combustion by electric cargo bikes in the city of Berlin, Germany. These measures contributed to prove that great distances (19% - 48%) could be made by electric bicycles. The locals seem to be supportive.

According to this author, the average delivery weight for one of the most common customers of the urban delivery company is 5.65 kg and the average bulk volume is 37.5 liters. These values correspond to only one customer, but usually one trip corresponds to at least two or three clients. With respect to all market segments, cargo cycles have the capacity to execute each of those services, provided that its capacity is suitable and their its transportation model are adapted to each niche market.

Regarding the average speeds, it is worth state that in urban environment, the average speed of a car is about 14 km/h (Dekoster & Schollaert, 2000) which is lower than the average speed of an E-CB.

2.6 Problems due to urban distribution

Ogden (1992) identifies as problems related to the distribution of goods in urban areas, congestion, poor road network and inadequate loading and unloading operations due to factors such as size of vehicles, saturated traffic in main urban avenues, failures in projects, poor maintenance of roads, deteriorated pavement, projects with inadequate turning radii and inadequate traffic programming.

The conflicts between urban activities and the distribution of goods generate social, environmental and economic externalities, requiring that solutions for the rationalization and efficiency of cargo transportation are aligned with mobility, quality of life and sustainability (Macharis & Melo, 2011).

The operation of loading and unloading in cities, because it competes with other urban activities, is often impaired, greatly diminishing its efficiency. According to Allen *et al.* (2000) in London, 87% of the total time of delivery of goods is spent in the search for a place to park the cargo vehicle, being only 10% of the time spent in the round trip to the delivery of the goods. In São Paulo, approximately twenty minutes per operation are spent only in the search for a vacancy available for loading and unloading.

Figure 7 briefly presents the problems arising from urban freight transport.

Several influential agents are responsible for changes in the behavior of cargo movements in the last decades: globalization of the market, current production and distribution practices, based on low inventories and just-in-time deliveries, the increase with the environmental issue and the emergence of new technologies such as B2B (business to business), the significant growth of e-comerce, retailers with the intention of not maintaining high inventories, make smaller and more frequent orders (Quispel, 2002). These changes have altered the size of the deliveries, resulting in a greater number of trucks in the roadways (Crainic *et al.*, 2004).

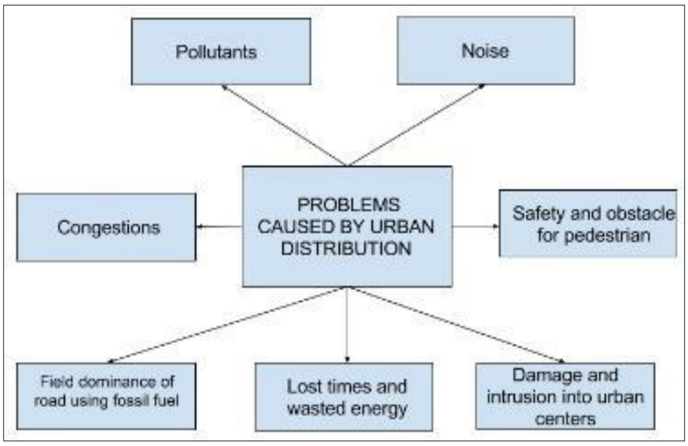


Figure 7 – Problems on urban freight (source: Quispel, 2002)

Hesse (1995) states that a series of logistical improvements have been created to mitigate the impacts caused by the movement of cargoes in urban mobility. However, they run into a problem: the efficient application of these measures does not depend only on transport companies. For example, many companies transfer the collection and delivery service to the night, but other members of the distribution chain also need to be prepared to act together, which in general makes the action unfeasible (Fontes Lima Jr *et al.*, 2015).

2.7 Freight movement and sustainability

As the demand of the consumers grows and the transformations in the area of technology cause deep changes in several segments, the pressure of society and of groups related to the environment also increases, in order to minimize the negative impacts of the activities of load, increasingly intense. However, in spite of these negative impacts, urban freight transportation has a significant contribution to the vitality of cities economy. Therefore, the transportation of markets faces the challenge of overcoming the load versus sustainability paradigm, with the provision of cleaner and less polluting means of transport, in order to reduce its impacts on the environment.

Gatti Junior (2011) states that freight transport in urban areas causes a number of environmental impacts, which affect traffic, infrastructure, finance, energy consumption, and the environment. As a result, transport creates disruptions to cities such as reduced capacity and road safety, increased urban congestion (due to loading and unloading along the roadway) and miscellaneous damage to the furnishings of urban centres as well as high consumption non-renewable energy, high operating costs, high emission levels of atmospheric pollutants and emission of greenhouse gases, noise pollution, etc.

According to Campos (2013), sustainable urban mobility in the socioeconomic context can be seen through actions on land use and occupation and on transport management. These actions aim to provide access to goods and services in an efficient way for all inhabitants, and thus, maintaining or improving the quality of life of the current population without harming the future generation. In the environmental context, the transport technologies stand out as an element that has its contribution in the impact on the environment. This impact can be associated with factors such as energy consumption, air quality and noise pollution.

According to the Word Commission (1987), sustainable development seeks to meet the needs of the present without compromising the needs of future generations. Therefore, developing a sustainable urban cargo transport system involves decisions on a variable geographical scale (local, regional, national, international and global) with their respective economic, environmental and social impacts.

According to Gatti Junior (2011), the urban transport of goods causes a great variety of negative impacts and problems on traffic, infrastructure, finance, energy consumption and environment (Table 1).

Growing traffic in cities and urban centres has a strong impact on sustainable development. Congestion, as well as air and noise pollution has been worsening every year. The lack of city planning results in the deterioration of urban mobility. Urban mobility accounts for 40% of carbon dioxide emissions and 70% of other pollutants resulting from road transport (European Commission, 2014). The importance of the urban load on these unsustainable impacts in relation to passenger transport is growing. The significant increase in the proportion of diesel-powered engines in urban freight transport leads to pollution caused by emissions of greenhouse gases including carbon monoxide (CO), carbon dioxide (CO2), nitrogen (NOx) and particulate matter (PM).

As confirmed by several empirical studies, urban transport vehicles represent between 6 and 18% of total urban travel (Figliozzi, 2010), 19% of energy consumption and 21% of CO2 emissions (Russo & Comi, 2012). Lindholm (2010) argues that this is a common problem in all European cities, even though they are different in geographical, historical and cultural terms.

According to Gatti Junior (2011), these scenarios have led large Brazilian cities to adopt restrictive traffic measures. Although these measures are essential, they generate new impacts on urban traffic. Quak *et al* (2009) argue that measures that substantially register the fleet of large vehicles result in increased product costs, limit the supply of goods, increase the risks of lack of inventory and generate more pollution.

According to Hesse (1995), the fundamental objectives for the development of sustainability, according to the UK planners are:

- Conservation of natural resources to ensure supply for present and future generations;
- Planning and development of buildings to ensure that the development and use of the built environment respect and harmonize with the natural environment;
- Environmental quality to prevent and reduce processes that degrade and pollute the environment, protect the regenerative capacity of ecosystems and prevent development that is harmful to human health or that reduce the quality of life;
- Social equality to prevent any development that increases the gap between rich and poor and to encourage development that reduces social inequality;

• Political participation to change values, attitudes and behaviors, encouraging increased participation in policy decisions and environmental improvement initiatives.

Table 1 – Impacts and problems caused by freight urban transport (source: Gatti, 2011)

Type of impact	Impact	Problems generated
Impact on traffic	Reduction of road capacity	The loading and unloading process can reduce the capacity of the path by forming an operational bottleneck.
	Congestion formations or aggravation	Cargo vehicles usually have low operating speeds.
	Commitment to road safety	Due to its characteristics of weight, size and operation, the occurrence of accidents involving trucks is significant and commonly serious, and may cause damage to the urban structure and involve victims.
Impacts on infrastructure	Reduced pavement life	The trucks represent the main demand suffered by pavements, being the main cause of damages due to fatigue. When the operation is performed with excess weight, there is still a significant reduction in pavement life.
Financial Impacts	Operating Costs	Costs with salaries of equipment and vehicles operators, insurance policies, employee capital, fuel, lubricating oils, repair and maintenance, tires etc.
Impacts on energy consumption	Energy consumption	High fuel consumption.
Environmental Impacts	Emission of greenhouse gases and atmospheric pollutants	Emission of greenhouse gases, such as carbon dioxide and methane and other gases harmful to humans such as carbon monoxide, non-methane hydrocarbons, aldehydes, oxides of nitrogen and particulate matter.
	Emission of noise pollution	Noises and vibrations resulting from the operation of trucks interfere with the quality of life of the population, impairing sleep, causing difficulty in concentration and reduction of reasoning capacity.
	Vibrations	

Continuing along this same line of thinking, Hesse (1995) states that the transport sector is an important field for developing sustainability strategies, as it causes serious environmental, social and economic problems.

For Allen *et al.* (2000), to make urban freight transport more sustainable, it is necessary to define the problems and their possible solutions, to analyze which aspects of the operation need and can be modified in order to reduce the environmental impacts and analyze the conflicts between economic and social objectives. It is therefore important to distinguish between public authorities and the private sector. According to the same author, the changes made by the public power will be affected by the introduction of measures that force transport companies to change their actions in order to become environmentally and socially more efficient. Among the strategies that can be taken by the public authorities are traffic management, zoning, development and improvements in infrastructure, licensing and regulation, taxes, taxes and public transhipment terminals.

Transport companies, on the other hand, may adopt initiatives aimed at reducing the costs of their operations, in order to obtain advantages with this change of behavior. Among the initiatives adopted by the companies are: increasing the amount of cargo transported by vehicles in urban centres, through the consolidation of goods; extended delivery times; use of vehicle routing and programming software; vehicle improvements in fuel efficiency, design and use of special equipment; vehicle communication system; and other improvements in the collection and delivery system (Julian Allen *et al.*, 2000).

Some sustainability policies for urban distribution have already been implemented by public authorities, in some countries. In the United Kingdom, for example, the government is considering and addressing supply chain needs, where the following objectives are identified (Julian Allen *et al.*, 2000):

-Increasing distribution efficiency by improving competitiveness and economic growth;

- Minimize the social and environmental impacts of distribution by improving indices.

Because of this new thinking, local authorities have included the issue of sustainable distribution in local transport planning, in resource allocation programs for projects. However, the policies implemented so far have not addressed the issue of vehicles in urban centres, dealing with other measures such as tolling in London.

For Hesse (1995), a successful strategy for urban distribution policies depends on the ability to find a consensus among the actors involved, managing the following measures and instruments:

- Management of highways and railways and transportation planning:
    Integration of urban distribution into transport planning policies;
    Management of specified vehicles;
    Infrastructure of delivery in public spaces;
    Regulation of delivery for industry and retail;
    Improvement of the rail transport system.
- Time Management:
    Management and application of time window for deliveries;

Application of speed limits for vehicles;

Organization of traffic of heavy vehicles outside the peak period.

- Terminals and infrastructure:

  Planning of the location of load terminals;

  Planning of the location of logistics sub-centres;

  Telematics infrastructure for the terminals;

  Integration of railway infrastructure supply.

- Facilities Planning:

  Planning of the location of commercial and industrial facilities;

  Planning of the location of logistic companies;

  Planning of the location of places of community use.

- Local and regional fiscal strategies:

  Tolls.

- Improvements in vehicle speed and technology:

  Presentation of advantages such as low emission of pollutants and noises in public areas.

- Distribution of hazardous products:

  Definition of routes for the transport of dangerous products;

  Definition of restrictions on the transport of dangerous products.

- Cooperation between transport companies and communities:

  Development of a cargo transportation information system.

The influence of the road network on the role of cargo transport takes on great proportions in that the road system of a city is composed of old roads, almost always of limited size and without capacity to meet the large flows of vehicles. In order to obtain better operational efficiency of the road system, considering its various urban functions and the variations of its physical characteristics, it is necessary to analyze some basic attributes, such as the accessibility and mobility of cargo vehicles that directly interfere in the panorama of the road network and of urban transport.

One can consider that the concept of accessibility is directly related to the existence and management of road communication systems. Infrastructure and how they are managed defines the accessibility of cities, that is, the capacity they have to connect with the immediate environment, with the further and with the outside.

According to the Ministry of Cities (2004), the term mobility refers to the ease (or difficulty) with which shifts are made between different urban areas and depends crucially on the transport networks that serve them, and the availability of means that should be able to satisfactorily meet the different flows. It further states that mobility covers a set of transport, movement, accessibility and transit policies (Ministry of Cities, 2004).

Yet, according to the Mobility Master Plan (PlanMob, 2007), developed by the Ministry of Cities, through the National Transportation and Mobility Secretariat (SeMob), the concept of sustainable urban mobility is the result of a set of transportation policies that aim to provide broad and democratic access to urban space through the prioritization of collective and non-motorized modes of transport in an effective, socially inclusive and ecologically sustainable way.

2.8 Environmental aspects

The organization of the freight transport system has to be fully integrated with the urban planning effort and not only to consider the economic efficiency of the operations but also to respond to growing environmental and sustainability concerns. Among the environmental externalities produced by freight transport operations in cities, CO2 emissions, air pollution and noise are particularly important. In this context, alternatives arise to try to circumvent such operational restrictions and make it possible to maintain the physical distribution of products in urban areas.

According to Chopra *et al.* (2013), the issue of environmental sustainability has become a priority in the planning and operation of supply chains in the 21st century. According to the authors, sustainability has become the centre of attention, especially in large countries with significant economic growth, such as the case of Brazil, China and India.

For Donato (2008), a significant portion of the air pollution currently present in urban centres comes from the burning of fossil fuels in motor vehicles. The transport sector is responsible for about 45% of national CO2 emissions, and, considering the modes of transport that make up the transport sector, road transport is the main responsible for the emissions of the main greenhouse gas, to cite, CO2 (EPE, 2016).

Due to the restrictions of movement within cities, the fleet of urban light vehicles increased and consequently the number of trips within the cities increased, the number of stops among customers increased, and the distance travelled, polluting the chain.

The greenhouse gases (GHG) - Carbon Dioxide (CO2) and Methane (CH4) are responsible for the degradation of the Earth environment, as it intensifies the so-called greenhouse effect, which is the capture of sun radiation, keeping it inside our atmosphere, increasing the global temperature. On the other hand, pollutant emissions are the trully enemy for the human and are: Volatile organics compounds (VOC's), respectively, Carbon Monoxide (CO), Hydrocarbons not Methanes (NMHC), Aldelydes (RCHO), Nitrogen Oxides (NOx), Sulphur Dioxide (PM) and Particulate Matter (PM).

Based on the assumption that motor vehicles are the main agents of air pollution in the urban environment, any indication of an increase in emission concentrations is a cause for concern, and discussions and attempts to reduce them are justified. Air quality in urban centres is also considered a serious problem, since it causes damage to the health of the population and, consequently, to economic expenditure of public health funds. Table 2 shows a summary table of the main air pollutants and greenhouse gases emitted by the transport sector.

The emission of CH4 should show a decreasing tendency, since the increment of vehicles equipped with control technology to reduce the emissions of hydrocarbons also leads to a decrease in the emission of that compound. An exception to this trend could come from a possible intensive use of NGV in automobiles, due to the higher emission of CH4 by these vehicles, explained by the very composition of the NGV, mostly methane.

On the other hand, the emission of N2O should show an upward trend because its emission is associated to the presence of three-way catalytic converters that equip light vehicles. The emission of these two gases represents a small portion of the total GHG emitted.

In addition to the preference for the use of non-fossil fuels and alternative forms of automotive traction (electric or human propulsion), efforts are needed to improve the energy efficiency of vehicles by the automotive industry, such as vehicle weight reduction, optimization combustion process, reduction of volumetric displacement of engines, among other advanced technologies.

Table 2 – Framework of atmospheric emissions from the transport operation (source: author)

Greenhouse gases GHG	
Methane (CH4)	The combustion process can lead to the generation of metano, the simplest form of hydrocarbons. It is considered an expressive greenhouse gas by the time it takes to be processed into the atmosphere after it is emitted.
Carbon Dioxide (CO2)	Product of complete carbon oxidation present in the fuel during its burning. It is considered the main greenhouse gas in terms of the amount emitted from the burning of fossil fuels.
Atmospheric pollutants VOC Volatile Organic Compounds	
Carbon Monoxide (CO)	CO emissions result from the incomplete combustion of the carbon contained in fuel.
Non-Methane Hydrocarbons (NMHC)	Incomplete burning of the fuel in the engine generates NMHC emissions. The classification of these compounds covers the full range of organic substances present in nature in fuels as well as organic by-products derived from combustion, except methane. Precursors to the formation of ozone at the tropospheric level.
Aldehydes (RCHO)	The combustion process can lead to the generation of compounds with the carbonyl radical, the most common are acetaldehyde and formaldehyde. They also participate in the formation of ozone at the tropospheric level.
Nitogen Oxides (NOx)	Group of highly reactive gases, composed of nitrogen and oxygen in varying amounts. They are formed by the reaction of oxygen and nitrogen present in the air under conditions of high temperature and high pressure. Together with non-methane hydrocarbons (NMHC) and aldehydes (RCHO), they are precursors of ozone formation at the tropospheric level.
Particulate Matter (PM)	They are particles of solid or liquid material that may contain a variety of chemical components. They are classified according to their size, and a large part of the PM of vehicle origin has a diameter smaller than 2.5 μm, and can be referred to as PM2.5.

The growing number of trucks and the lack of fuel economy standards for commercial vehicles have too much impact on CO2 emissions, particularly in non-OECD economies (ETP, 2012). An aggravating problem of the high fuel consumption of the Brazilian fleet is the high average age of the fleet (about 18 years), which makes it very inefficient at the energy level (CNT, 2013) and is highly polluting. Most vehicles have archaic technologies (MMA, 2013; Anfaeva, 2017).

With economic growth and cities, there is a greater demand for resources, such as energy and water consumption, as well as pollutant emissions and waste production. This makes sustainability become a key factor in ensuring the growth process.

These data are important for guiding public policies and subsidiary studies that seek to evaluate more sustainable alternatives to the emission of pollutants and gases. From these analyzes it is also possible to see how studies aimed at evaluating the eco-efficiency of different transport alternatives for the physical distribution of goods in urban areas are relevant. In this sense, this study aims at comparing and analyzing two alternatives based on the emission of atmospheric pollutants and GHG, namely the traditional distribution configuration using the diesel van versus the electric cargo bikes.

According to Souza *et al.*, (2013), vehicles equipped with otto cycle engines, with the exception of flex fuel vehicles, have emission factors of CO and HC, superior to vehicles equipped with diesel cycle engines. On the other hand, diesel-powered vehicles have higher NOx and PM emission factors than vehicles with Otto cycle engines. The RCHO are related to the use of both hydrated and anhydrous ethanol.

2.9 The case study case of São Paulo: current emmissions

In order to compare different modes of transport in terms of pollutant emissions, Table 3 takes up the reference values of the emission factors for the case of Brazil. These values differ according to factors such as vehicle age, total distance, distance per year, if it runs the maximum (and how much) in urban areas.

According to data from the National Energy Balance of 2016, there is a dependence on the consumption of fossil fuels by road mode (EPE, 2016). Road mode is the main mode of transportation of cargo and passengers in Brazil and accounts for about 92% of total fossil fuel consumed in the transportation sector, accounting for 47% of national CO2 emissions (EPE, 2016).

Table 3 – Driving emission factors, Brazil (adapted from: MCTI, 2013; Henrique & Carvalho, 2011)

	GHG	**Volatile organic compounds VOC**				**Income km/l**
	(kg/ltrs)	**Atmospheric pollutants (g/km)**				
Category of vehicle	**CO2eq**	**CO**	**NOx**	**NMVOC**	**MP 2.5**	
Diesel Cargo Van	2,66	0.120	0.771	0.027	0.003	8.5
Gasoline Cargo Van	2,28	0.25	0.003	0.014	0.0011	10,5
Motorcycle (gasoline)	2.307	0.57	0.008	0.16	0.0035	35
Costs	35 Euros/ton	-	0.0066 Euros /gr	0.0015 Euros /gr	0.1305 Euros /gr	-

In the state of São Paulo, according to data from the last Cetesb (2015) report 82.22% of the CO emissions in 2015 were issued by automobiles and motorcycles. The projections suggest a slight decrease in this value, which will reach 76% in 2030. The fuel that contributes most to the emission of CO is gasoline, being responsible for 66% of the emissions of this pollutant in 2015.

In this report also, it states that 80.47% of total NOx emissions in 2015 in São Paulo came from heavy trucks and bus. These numbers could reach 88% in 2030. The main responsibility for the emission of this pollutant is the burning of diesel oil, which in 2015 accounted for 85% of total emissions of this pollutant.

Regarding the emission of particulate matter (PM), it is noteworthy that the largest emission share of this pollutant in 2015 in São Paulo came from buses and heavy trucks (87.3%). There is a tendency to reduce to 82% by 2030. The burning of diesel fuel accounts for 94% of PM emissions.

Unlike PM and NOx, RCHO are emitted mainly by vehicles equipped with Otto cycle engines that use ethanol as fuel (69%). Ethanol contributes 59% of total RCHO emissions in São Paulo and it is estimated that this will reach 88% by 2030.

According to a report issued by Cetesb (2015), in São Paulo, 81% of NMHC emissions come from automobiles, light-duty vehicles and motorcycles, of which 60% of emissions come from the use of gasoline, according to 2015 data.

With regard to GHG, emissions of CO2, CH4 and N2O were estimated. The total emission estimate is presented in carbon dioxide equivalent (CO2eq), using the Global Warming Potential (GWP) methodology in a 100 year horizon, as provided by the IPCC - Guidelines for National Gas Inventories.

In 2014, there was a tendency to decrease CO2eq net emissions, in particular by reducing the consumption of diesel and gasoline, partially replaced by the use of biofuels (hydrated ethanol and flex fuel). The total value exceeded 40 million tons of CO2eq, with the most contributory category being trucks with 37%, followed by automobiles in 30%. Although the truck fleet is considered low, only 3% of the total fleet, the vehicles are diesel driven, with a fossil parcel of 93% by volume. In addition, it has high usage intensity, making its share of the issue very relevant. It should be noted that for GHG, unlike local pollutants, the geographic location of the emission does not interfere in the impact, since the consequences of this emission are accounted for globally (Cetesb, 2015)

In the case of cars, participation in the fleet is predominant (66%). Even using larger parcels of renewable fuels (27% of the volume of gasoline and 100% of the volume of ethanol consumed) the impact of using gasoline is still significant. This is the only pollutant that tends to have growth in its emission. This will be a reflection of the growth of the economy and, consequently, growth and greater fuel consumption by the transport sector in São Paulo.

2.10 Electricity supply chain – the Brazilian case

In Brazil, about 32.5% of the final consumption of energy is related to the transportation sector, and the energy consumption by transportation is largely 81%, in the form of burning fossil fuels (EPE, 2017). The energy demanded by the transport sector, 41.6% is destined to the transportation of cargo, vital activity for the economic development of society, carried out, as a priority, by road mode (EPE, 2017). Conventional sources of energy for road transport, all over the world, have been gasoline and diesel oil, petroleum-derived fuels.

Electricity is considered as an alternative source of clean energy for cargo vehicles. Electricity can come from a variety of sources, such as nuclear, fossil (such as oil, coal and natural gas) and renewable (such as wind, solar, biomass (cane products and vegetable oil), firewood charcoal and hydroelectric). These primary sources are converted into electricity, a source of secondary energy, which flows through power lines and other transmission infrastructures to their final destination.

Electricity assisted cycles do not produce greenhouse gases, GHG, or atmospheric pollutants in their activity (end-use of energy), however, it is important to consider the source of electric energy sources which supplies it. In order for the use of E-CBs to be considered an environmentally sustainable alternative, it is necessary that the source from which the electric energy originates is renewable. Figure 8 illustates the share of each source in the generation of electric energy in Brazil

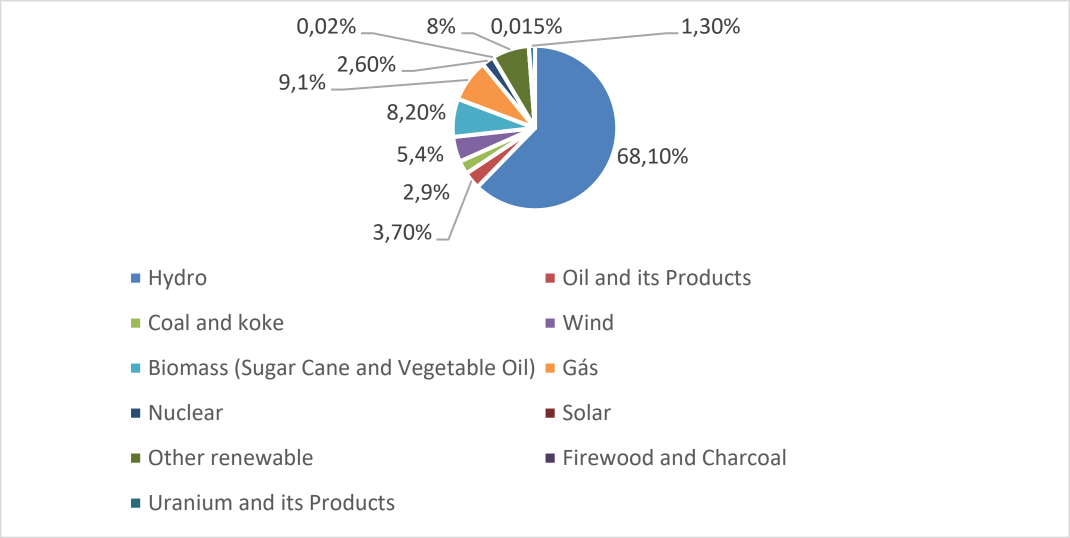


Figure 8 -Share of each source in the generation of electric energy in Brazil

According to the National Energy Balance of 2017 carried out by the Energy Planning Company (EPE), hydroelectric power predominated, with 68.1% in 2016. This participation was already much larger, reaching 79.3% in 2013 and 84.5% in 2012, but the country experienced a water crisis. Even so, Brazil is the second largest producer of hydroelectric power in the world with 139 Mtoe (106 tonnes of oil equivalent) per year, second only to China (Word Energy Resources, 2014).

With a considerably lower energy availability of hydroelectric plants, it was decided to use a greater amount of energy from thermoelectric power plants, whose source is non-renewable and emits gases into the atmosphere.

Between 2015 and 2016, solar and wind energy together showed a 100% increase in installed capacity (EPE, 2017), which should reflect, in a trend of growth of participation of these energy sources in the Brazilian electricity matrix over the years. Making the Brazilian electrical matrix cleaner and, consequently, its use for the transport sector should be considered as an environmentally sustainable measure.

Figure 9 illustrates the relative share of the various sources in the energy matrix in Brazil.

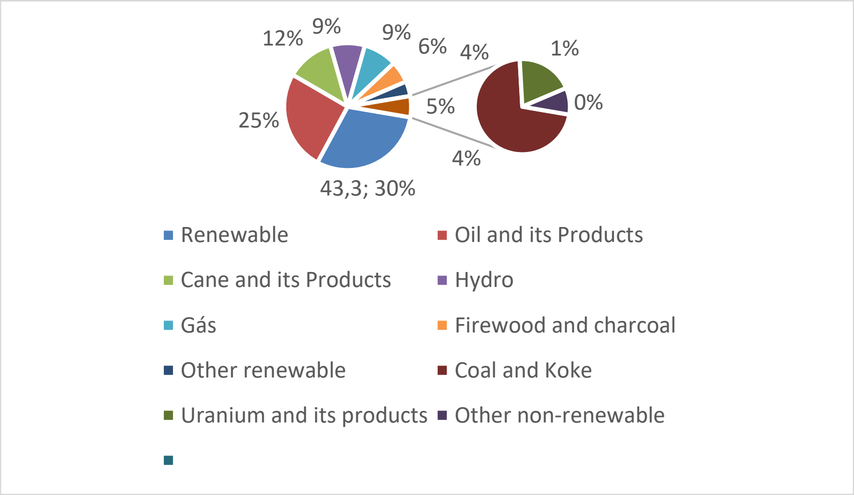


Figure 9 - Brazilian energy matrix

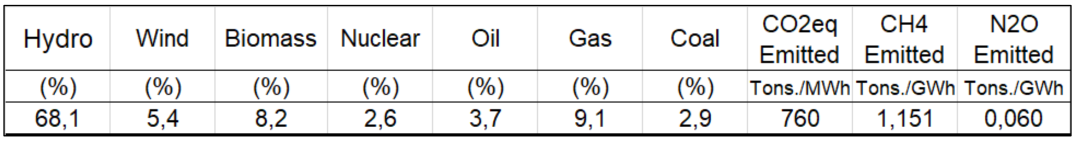
From the analysis of the graphs above, it can be observed that, among the renewable ones, the hydraulic energy remains stable while the participation of cane and other renewable derivatives increases significantly. On the other hand, the largest reduction occurs in the share of oil and oil products. This can be explained by the change in the demand of the transport sector, with decrease in the use of gasoline and greater use of ethanol and electricity.

Regarding the total energy balance, according to Baran (2012), even if there was a significant increase in the fleet of electric vehicles, the increase in the demand for electricity would not be equivalent to the fossil energy that would no longer be consumed, since the electric vehicle is more efficient, generating energy savings. Sperandio, Saldanha and Basso (2012) suggest that the interface of the electric vehicle with the network is controlled so that it could provide energy at critical times and recharge at times when there is low demand, such as at dawn, when the cars are parked in the garage

However, it is necessary to pay attention to the power required at the time of vehicle recharging. According to public policy suggestions for the segment of Vaz *et al.* (2015), if 20% of the entire fleet of light vehicles in Brazil were electric, energy demand would be equivalent to less than 2% of the total, but if these vehicles were recharging at the same time, a much higher power would be required, which could generate impacts of up to 20% on the maximum energy demand, depending on the mode of load.

Emissions rates are provided for four GHG that are emitted in significant amounts due to the production of electrical energy in Brazil: CO2, CH4 and N2O in Table 4.

Table 4 - Percentages of energy source and CO2 emissions rates in Brazil (source: SEEG Brasil)



Hydro	Wind	Biomass	Nuclear	Oil	Gas	Coal	CO2eq Emitted	CH4 Emitted	N2O Emitted
(%)	(%)	(%)	(%)	(%)	(%)	(%)	Tons./MWh	Tons./GWh	Tons./GWh
68,1	5,4	8,2	2,6	3,7	9,1	2,9	760	1,151	0,060

These numbers will be used in the next chapter to estimate well-to-tank pollution emissions of electric cargo tricycles that are proposed to operate in future scenarios of the TNT urban distribution in São Paulo.

3. URBAN CONSOLIDATION CENTRE AND LAST-MILE E-CYCLE DELIVERY

In order to carry out the bibliographic review about the use of UCC and the logistics cycle in the process of physical distribution of products in urban areas, it was decided to do the research using as a priority the main databases of publishers and library services available, such as Elsevier, Science Direct, Emerald, Proquest, Springer, Wiley and Scopus, Web of Science and Google Scholar. This choice was made based on the fact that they are scientifically reliable sources and consider relevant journals and academic publications in the area.

To date, there is a lack of structured research on the use of cargo cycles in the city logistics research field (Decker, 2012; Gruber *et al.*, 2014; Lenz & Riehle, 2013). This chapter presents the results of a systematic literature review that summarizes the existing research and identifies the potential of cargo cycles in sustainable urban logistics supported by UCC.

The research was carried out using the terms in english in the field of sustainable transport of goods in urban area: bicycles, cargo bikes, cargo tricycles and electrically assisted pedal cycles, city logistics, urban freight transport, urban goods, urban distribution, sustainable freight transport, city distribution, urban freight delivery and last mile; cargo cycles; last mille and tricycle and UCC and electric two-wheelers. In some European cities there are several projects and results using deliveries through electric bicycles or human propulsion, considering the particularities of the analyzed cities.

3.1 The concept of Urban Consolidation Centre (UCC)

The providers of courier, express and parcel delivery services (CEP) operate on worldwide networks. The first and last mile are integral parts of these networks, but can be a real challenge when they occur in an urban environment. Urban areas are characterized by narrow streets, street furniture, mixed traffic and congestion. In addition, city heavy vehicles are confronted with vulnerable users like pedestrians and cyclists, who share the urban infrastructure with freight transport. This makes it difficult to keep deliveries and collections in the city centre reliable, accessible, and fast. At the present, most of these deliveries are made by trucks and vans on diesel or gasoline. In Italy, for example, 88.5% of the fleet of cargo vehicles that consume diesel and 11.5% on gasoline (Schoemaker *et al.*, 2006).

The number of alternatively propelled or powered distribution vehicles is relatively low. In 2012, the share of renewable energy in transport fuel (passenger and freight) in the 28 EU countries represents 5.1%, ranging from 0.0% in Cyprus to 12.6% in Sweden (Eurostat, 2016). The high share of diesel combustion engines in urban transport leads to pollution caused by emissions of greenhouse gases, which includes, among others, CO, CO2, NOx and PM (BESTUFSll, 2007).

In response to this negative environmental impact, it is expected that the number of cities with some form of congestion charge or apply road traffic restrictions in the near future, which would make the first and last mile even more challenging. That is, why there is an interest in alternative solutions that can handle all these restrictions?

A new concept of urban freight transport has to be more profitable and should enable the service provider to maintain the same level of customer service. At the same time, it would have to be cleaner, respecting the environment, avoiding congestion and preparing the provider of logistics services for toll collection or traffic restrictions.

One possible solution, within this concept, is to use an UCC in combination with electrically supported load cycles or human propulsion. The idea of a UCC is to separate distribution activities into activities inside and outside the city. The UCC collects shipments in a specialized warehouse on the outskirts of the city, consolidate and plan the product delivery, before shipping it to the urban area for delivery of the last mile (or transporting them in larger vehicles in the case of converse flow). The goal is to increase the use of the vehicle to optimize the total distance covered, which benefits from congestion and pollution.

The basic idea behind the implementation of a UCC is to create a transition of freight flows analogous to that observed in the main passenger transport interfaces, where people arrive in the city by train, bus or plane and move to an urban subway or terminal, where they receive other transportation (public or private) to reach their destinations. Thus, freight transport from two cities is divided into two parts: long-distance transport and transportation within the urban area (Quak, 2008). Upon receipt at the consolidation centre performed by heavy vehicles, the goods are transhipped to smaller vehicles or freight wagons that transport them to the final client, retailer or household, according to the order. Subsequently, the goods can be stored or consolidated according to the different customer and its surroundings, following the delivery windows.

Currently, the designation of UCC has assumed several meanings. Different terminologies have been used for the same concept over time and from country to country. Definitions are often vague and ambiguous, such as public distribution warehouse, point of deconsolidation of goods, urban transhipment centre, shared storage bin, logistics platform, consolidation centre (retail or construction), and cooperative distribution systems, among others.

It is sometimes difficult to identify the border between UCCs and other similar devices such as express mail distribution hubs, collection centres for home deliveries, intermodal terminals or wholesale distribution centre. The concept is focused on shared operations, deconsolidation and transhipment of heavy vehicles to smaller ones.

According to Ruesch *et al.* (2008), in the definition of the best practices presented in the BESTUFS project there is the following definition for UCC:

"*A logistical device situated relatively close to the geographical area that it intends to serve (whether the central area of a city, its entirety or a specific location as a shopping centre), in which various logistics companies deliver goods destined for this area, from which consolidated deliveries are made and in which a wide range of logistical operations, value added and services to retailers are provided.*"

Figure 10 presents a graphical model of an UCC with major transport of flows. Subsequently, the merchandise can be stored or consolidated according to the different customers and their surroundings, following the delivery windows (if there are).

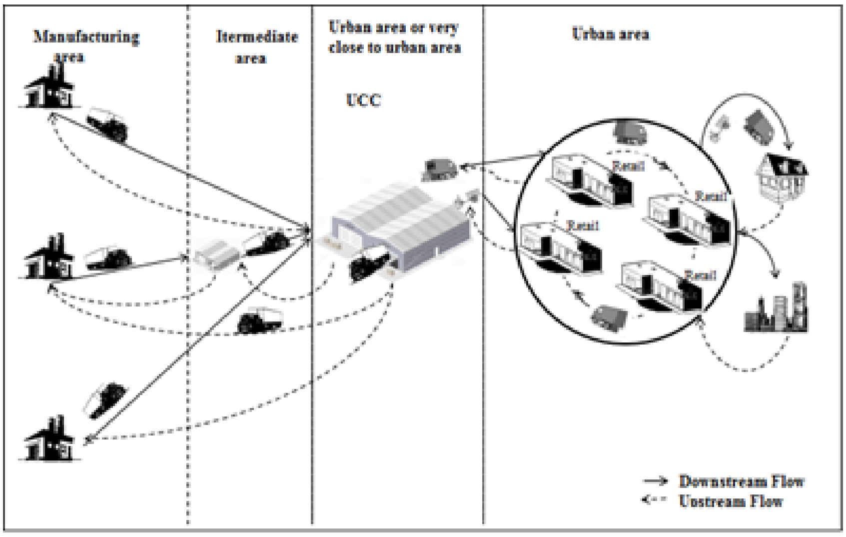


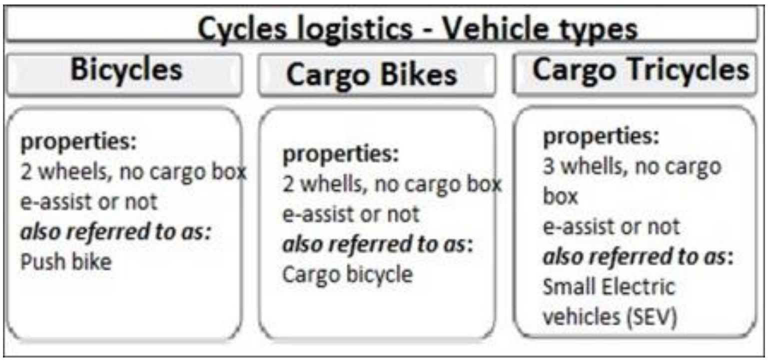
Figure 10 - UCC logistical model (adapted from Quak *et al.*, 2010)

3.2 Cycle logistics as a trend of city logistics

With the global look focused on the environmental aspect, the companies of transportation of goods in urban areas have been innovating in the search of alternative technologies in the fight against the emission of greenhouse gases and atmospheric pollutants. In this sense, cycle logistics have the ability to contribute to a cleaner and smoother environment. In addition, cycle logistics has the ability to overcome many of the negative obstacles to the last part of the delivery, the so-called last mile: smaller vehicles do not need parcels to reach a higher load factor, they do not take up much space when they park , do not pay to park and even on the street itself, helping to lessen the congestion.

Thus, a solution that addresses some important concerns in the transportation of goods in urban areas is cargo cycles, such as bicycles, cargo bikes and cargo tricycles, that can be electric powered or not. The existing literature is still weak and very recent in the diffusion of this innovation. In addition, in some cases, because the concept is rather new and high technology applied, prices are too high to attract potential consumers. Existing studies range from making a clear distinction between charge cycles and electrically assisted charge cycles: electric cargo bicycles/bikes (E-CB), small electric vehicles (SEV), two wheelers electric (TW) or referring to both.

The term cycle logistics includes all types of pedal cycles (regardless of the number of wheels), as well as electrically assisted or not. Figure 11 shows three different types of cycle logistics vehicles found in the literature and Figure 12 and Figure 13 show pictures of cargo bicycles and cargo tricycles in action.



Cycles logistics - Vehicle types

Bicycles	Cargo Bikes	Cargo Tricycles
properties: 2 wheels, no cargo box e-assist or not ***also referred to as:*** Push bike	**properties:** 2 whells, no cargo box e-assist or not ***also referred to as:*** Cargo bicycle	**properties:** 3 whells, no cargo box e-assist or not ***also referred to as:*** Small Electric vehicles (SEV)

Figure 11 - Vehicle types in cycles logistics (source: Schliwa *et al.*, 2015)

Figure 12 - Examples of two whell cargo bikes and a 3-wheel tricycle in Germany

Figure 13 - Examples of two whell cargo bikes and a 3-wheel tricycle in Germany by DHL

Considering the established terms and frequency, this dissertation describes this research area as follows: cycle logistics describes the use of standard human or electrically assisted bicycles, cargo bikes and cargo tricycles for the transportation of goods between A and B, mainly in urban areas (Lenz & Riehle, 2013).

The cargo cycles are electric tricycles with foot pedal assistance, with capacity of up to 1.5 ton and autonomy of 4 hours of circulation. It has the advantage of the possibility of circulation in pedestrian areas, avoiding congestion, operating with lower operating costs and permission of circulation in bus routes, in addition to a sustainable character. Considering that 80% of urban cargo movements are distances of less than 80km within European cities (Ruesch *et al.*, 2012), an application of UCC's for logistics operations may be an operationally viable option.

With respect to the environmental benefits of the electrically assisted cargo cycles or E-CBs, it is worth noting that these vehicles are not entirely non-emitters. It is true that, unlike fossil fuel vehicles, E-CB emissions do not emit tube end gases when the vehicle is on, when it is moving, or when it is stationary. However, it is during the electricity generation process that CO2, SO2 and NOx emissions can occur, depending on the source (e.g. wind, sun, waves). The greater the percentage of electricity generated from renewable, the lesser are the emmisions at the energy generation phase.

There are two phases of use where all emissions are emitted: the first is from well-to-tank (WTT), when emissions include all emissions in the energy supply chain. Diesel and electricity chains are analyzed individually. The second is tank-to-wheel (TTW) or the use phase. TTW considers tailpipe emissions due to fuel consumption. The diesel fuel consumption value shown in Table 3 is based on Mercedez Bens Brasil (2015). In this study, emissions related to vehicle maintenance are omitted because their value is an insignificant comparison with other stages of the life cycle.

It is under these conditions that a substitution of a fossil-fueled (diesel) van for a cargo cycle-assisted or non-electric has a potential impact on reducing pollutant emission levels. Brazil stands out because it has an energy matrix with a large share of renewable sources, since, in 2016, 43.5% of the total energy generated by the largest national electricity producer was derived from renewable sources, including hydroelectric, biomass, solar and wind energy (EPE, 2016). During the use phase, emissions from the cargo cycles are mostly non-exhaustive (as a result of abrasion, brake and tyre wear). For that matter, it is expected that emissions caused by these vehicles will decrease in 92.5% (each gas) until 2030 only due to thecnological improvement based on European directives. Today, there are several brands selling and improving technology of these types of vehicles all over the world, as result, each model of each brand has its own features. In the logistics of the city, these services have been identified to provide a cycle logistics market, since the operations require density to obtain economic advantages of this mode of transport. The cargo cycles is an alternative of zero emission for light vehicles in urban centres.

According to Decker (2012,), in Germany, for example, the Federal Ministry of the Environment has created a similar pilot project, called "Ich ersetze ein Auto" (I replace to car), which started in 2012. Unlike the European-wide project, it is aimed exclusively at courier services and make use of electric assist cargo cycles. Forty vehicles are used in nine major German cities. The cargo bikes can carry a load of 100 kg and a volume of 250 liters (0.25 m^3). Because these loads can also be moved by non-assisted cargo cycles, the electric assist is aimed at further increasing delivery speeds and extending the driver’s range.

In Berlin, it has been found that charging cycles using electrical assistance can replace up to 85% of car trips performed by courier services. This was demonstrated during an experiment in Berlin using an additional city hub to coordinate the distribution of goods (the 'Bentobox'). The German pilot project resulted in a research paper detailing the economic potential of load cycles, energy savings and emissions and the necessary improvements in infrastructure and legislation.

The focus of cycle freight is on the "first mile" and the "last mile". The goods are delivered by vans and trucks to a distribution centre (central), from where they are taken to their final destination by cargo cycles (or vice versa). An alternative is to use vans (or even boats or cargo trams) as mobile hubs. UK based courier service "Outspoken Delivery" uses folding bicycles in combination with trains for fast delivery between Cambridge and London. Freight cycles as a last-mile city transportation option combine very well with research on "trolleytrucks" for freight transport over longer distances. Of course, cargo cycles can also be complemented with fully electric electric vehicles in the city, such as Cargohopper.

The potential of the cargo cycle is still unclear. Research is currently very scarce. This is remarkable since no other technology seems to offer so many benefits for urban freight transport. However, the possibilities of load cycles will depend on several factors, which may make them less suitable elsewhere. All cities where the cargo cycles have descended to some degree are flat. Having to pedal a cargo cycle up a hill will greatly increase delivery times, which means time wasted compared to motorized options. Electric assistance may help, but there may be better options for transporting city cargo in mountainous regions, such as gravitational ski lifts and aerial ropeways.

Secondly, cargo cycles are especially useful in European cities with their large historic centres, which consist of narrow winding streets. In North American cities, the average speed of motor traffic in cities is generally higher because of much wider roads, and the advantage of cargo cycle speeds may disappear. Population density also influences the usefulness of load cycles, which again become the hands of European cities. A third observation is that cities where freight cycles are in use have already had a relatively strong bicycle culture and decent cycle infrastructure prior to their arrival. If there is no space (safe) for the load cycles, they cannot be used.

On the issue of safety, it is much smaller compared to other modes: according to the Commission Europe (2015), cycling drivers are much more exposed to road accidents than motor vehicles: 82.4 between 2010 and 2014, against 29.3 in light-duty vehicles in Europe. Soft modes have a higher security cost than motor vehicles. In contrast, the role that the E-CB plays in the national economy must be taken into account. The less time lost by the citizen in traffic, the better is his time to produce work, shopping, leisure, generating the development of the national economy. In addition, the smaller the number of motor vehicles, the smaller and less sophisticated infrastructures will be required, which in a financial analysis results in lower road construction and maintenance costs and fewer occupied spaces. These reductions are essential to achieve lower rates of energy spending and lower public health costs, since citizens will feel happier and more productive by spending more time with their friends' family. It is a cultural change.

Considering all the previous features, it becomes clearer what are the E-CB potential advantages in urban freight transportation. Plus, they are silent and because E-CB are small sized, they are easier to park than cars or vans and their smaller capacity opens the possibility to a higher load factor, increasing their efficiency rate. All these advantages are common to tradi-tional modes (non-powered vehicles such as bicycles). What electric power has in favour is the possibility to help couriers transporting heavier loads and riding sloped areas.

3.3 Electric cargo bikes

Lenz and Riehle (2013) suggest that cycle freight can form around 25% of city centre, commercial traffic in medium term that a potencial market does exist. The recent outcome of the European Project "*Cyclelogistics*" indicates an even higher potential satting that in average 51% of all motorised trips in European cities that involve transport of goods could be shifted to bikes or cargo bikes.

An important operational consideration here is that E-CBs are positioned between bikes and cars in terms of cost, payload and range, which makes them well suited to specific logistical challenges (Lenz & Riehle, 2013).

As refered in Section 2.5, the average delivery weight for one of the most common customers of urban delivery companies - offices - is 5.65 kg and the average volume volume is 37.5L (Gruber et al., 2014). Even in this situation, the e-cargo tricycle would have the ability to carry these parcels, as suggested in Table 4. For all the market segments explained in the Section 2.3.1, the e-cargo tricycle has the ability to perform each of these services, provided that its capacity is adequate and its logistics model is adapted to each niche market.

Conway *et al.* (2011) reported on a comparative analysis of operations in Paris, London, and New York to identify Manhattan's potential by using tricycles to support urban micro-consolidation (UMC) and last mile. The freight can be shifted to tricycles without increasing overall costs and at the same time reducing social externalities. Public financial support for UMC's serving single or multiple-carrier operations could be justified by traffic and environmental improvements and job creation.

Maes and Vanelslander (2012) report an exploratory study carried out in Belgium and the Netherlands on the professionalisation of courier messengers in logistic companies, that is, "chiken-egg-problem", and doubts about the link of the profession. In the same study, the authors estimated possible annual fuel savings in the range of 8,500,000 liters of diesel, or 21,000 tonnes of CO2 (Maes & Vanelslander, 2012). Existing research suggests that companies do not feel that bike couriers are sufficiently connected to the global network, but are relatively local or at best regional to ofter the kind of same day delivery services that underpin much e-comerce (Maes & Vanelslander, 2012). However, more recently large logistics companies increasingly consider cycle logistics solutions and local small and medium enterprises (SME's) throught the UK have started to work with DHL and the like which indicates a shift within the industry (Armstrong, 2015).

In Paris, two experiments that used the UCC as an alternative to meet the great demand of goods delivery: Chronopost and La Petite Reine. The first is a subsidiary of the La Poste Group, one of the largest express carriers in Europe. Currently, the company participates in the delivery of trade products between the companies and the trade between company and customer. With 3,500 employees, the company delivers, on average, 240,000 orders a day worldwide (TURBLOG, 2011).

In view of the increased demand and dispersion of logistics facilities in Paris metropolitan region, Chronopost has changed its operating logistics. Previously, the company owned an UCC near Paris, in Charenton, from where the goods were transported to various destinations in the city. Since 2005, a UCC has been created in a parking lot in central Paris, which has become an intermediary between the UCC and the customers, to serve the 7th and 8th districts of Paris (TURBLOG, 2011).

The company La Petite Reine was created in 2001 dedicated to the transport of goods inside the centres of great population density. According to TURBLOG (2011), the company makes 2,500 daily deliveries using two UCC's (one near the Louvre museum and another located in the 6th district) and electric vehicles called cargocycles. Currently, it is a Star Service company, with distribution with cargocycles in different regions of Paris. The cargocycles are electric tricycles with assistance to pedal, with a capacity of 1.5 m^3 and an autonomy of 4 hours of circulation. It has the advantage of being able to move in pedestrian areas, avoiding congestion, operating with lower operating costs and permitting traffic in lanes for buses, besides having a sustainable character.

A study accomplished out between 2003 and 2005 revealed that in one year 600,000 tonnes of cargo per useful kilometer were no longer transported by vans, 203 tonnes of carbon dioxide were avoided, there was a considerable reduction of noise in the city and 89 tonnes of oil were avoided by engines (Turbolog, 2011).

Also, in terms of decarbonization, Browne *et al.* (2011) evaluated the Gnewt Cargo Project in the city of London, replacing diesel vans by electric vans and tricycles operating from a micro-consolidation centre. The authors reported that the total distance travelled and CO2eq emissions for parcel delivered fell by 20% and 54%, respectively. However, the author also alerts that a complete usage of them is only possible with the corresponding thecnologic improvements and policy regulation.

In this specific case, electrically assisted cargo tricycles could play a role in reducing GHG emissions. Cargo tricycles are the ideal low-emission alternative to transport light goods in city centres, not only because their lack of tailpipe emissions, but also because their small size and easy access to compact, congested tows and cities. Unlike conventional diesel-powered vans, cargo tricycles can legally use bicycle path and lanes allowing for faster access to congested downtow or pedestrians areas (Browne *et al.*, 2011). Cargo tricycles operations are not significantly affected by congestion or lack of loading / unloading parking areas. Other advantages are noise reduction through the use of quieter vehicles, improved pedestrian safety and less traffic conflicts with passenger cars and other road users in general (Browne *et al.*, 2011).

Verlinde *et al.* (2014) examined the use of a mobile tank combined with bicycles and electric tricycles to deliver and withdraw parcels as part of a European PP7 Straightsol project, tested by TNT Express, in the city of Brussels, Belgium. The mobile depot looks like a trailer truck and has all sorts of deposit facilities. From here, electrically supported tricycles can perform last mile deliveries without being disturbed or contributing to congestion. The local partner is Vrije Universiteit Brussel. The results found a considerable reduction in the current number of km to diesel of 1.34 km per stop in the current business to 0.52 km per stop in the Mobile-Depot scenario. This decrease can be associated with a positive environmental impact, such as 24% CO2 emission and up to 59% less particulate matter emission (PM) (Alves *et al.*, 2016).

Schliwa *et al.* (2015) have analysed initiatives in European cities to delivery of urban goods the last mile using bicycles and electric tricycles, and emphasize that this is an opportunity to make urban logistics more sustainable, whose main obstacles to its implementation are infrastructure and safety.

As regards the environmental benefits of e-cargo tricycles, it should be noted that these vehicles are not entirely non-emitters. It is true that, unlike fossil-fueled vehicles, electronic tricycles do not emit final gases when the vehicle is switched on, or when it is moving or stopping. However, it is during the electricity generation process that CO2, SO2 and NOx emissions can occur, depending on the primary energy source, if it is renewable (eg wind, sun, waves), there are no emissions related to operation of the vehicle once. For this, the greater the percentage of electricity generated from renewable sources, the greater the importance of the dissemination of electric vehicles. It is under these conditions that a replacement of a fleet fueled by fossil for electric cargo tricycles has a potential impact on the reduction of levels of emission of pollutants.

3.4 Transhipment terminals and electric bikes

Previous real-life experiences were developed mainly in Europe BESTUFS ll (2007), with different attempts to implement alternative long-term systems. Urban Consolidation Centres were deeply explored. However, experiences failed mainly because the business model required direct subsidies from the public sector. Recently, in the context of the STRAIGHSOL (2014) Project, a mobile depot was used in combination with electric tricycles that was tested in the city of Brussels. The environmental benefits were clear, but the system was not eficiente in terms de cost. Cargo-bikes have proved to be viable solutions in different cities. In Paris, the electric cargo tricycles in combination with special delivery areas were successful, starting with only five employees in 2011 and potentially expanding. Gnewt Cargo has been operating for more than four years in London, where electric cargo tricycles are used in combination with other electric vans (Sugar, 2011). An overview of the relevant articles related to the subject can be found in (Tryantafyllou *et al*., 2014).

The concept idea of the combination of electric cargo tricycles with the transhipment terminal tested in Barcelona and Valencia arose from the need of these cities to promote the Ecoefficiency of transport in the physical distribution of goods, making it more viable and friendly to the environment and society, without stifling economic development. In this context, six Mediterranean cities (Barcelona, Bologna, Piraeus, Rijeka and Valencia) collaborated with the purpose of contributing to the improvement of energy efficiency in urban freight transport the part of SMILE (2015) Project (SMart green Innovative urban Logistics Models for Energy efficient Mediterranean projects), funded by the MED Program. The SMILE project aims to improve the energy efficiency of Mediterranean cities through the promotion of innovative 'green' and cost effective solutions for urban freight logistics, addressing the target of green and smart urban development.

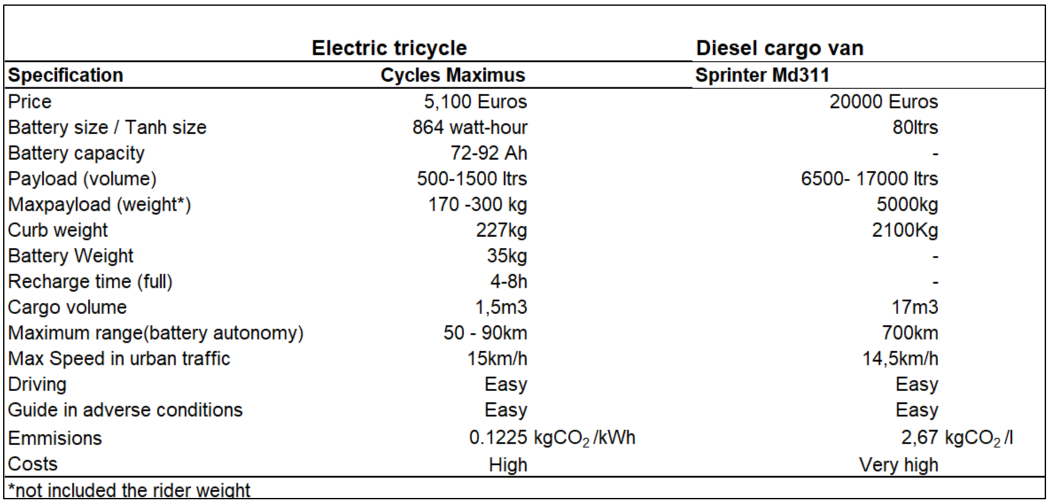
As previously mentioned in the introduction, last-mile urban distribution is an essential activity that generates high costs and external impacts to the city. In particular, large cities have a complex urban configuration that complicates the deliveries of the last mile. A significant number of trucks with fractional loads compete with vehicles, narrow streets, mixed traffic, urban furniture, pedestrians, motorcycles, buses, increasingly scarce space in urban centers or, for parking, to load and unload goods. Traffic restricted only to neighbors and specific urban elements such as road slopes are the main problems faced. This configuration limits the use of private vehicles and therefore is more problematic for vans. The urban distribution of goods generates environmental problems, such as congestion, the emission of greenhouse gases and air and noise pollutants. For these reasons, municipal administrations are taking steps to redirect activity to reduce external impacts.

3.5 The advantages and disadvantages of using e-cargo tricycles

According to Decker (2012), cargo cycles can bring important economic advantages to traders, artisans and service providers. Cargo transportation in cities is extremely inefficient. As currently, almost 100 percent is done by motor vehicles, ranging from personal cars to commercial delivery vans and trucks. However, these heavy vehicles usually carry very light goods. The average payload transported in European cities weighs less than 100 kg (220 lbs) and has a volume of less than 1 m^3. For example, of the 1,900 vans and trucks that enter the city of Breda in the Netherlands each day, less than 10% of the cargo being delivered requires a van or truck and 40% of deliveries involve just one box (De Decker 2012). This means that a large portion of the cargo being moved in and out of cities cities could be transported by cargo cycles.

La Petite Reine and Cycles Maximus are two important manufactures of cargo tricycles. Electric cargo tricycles have a capacity greater than 170-300kg and their maximum speed is approximately 15km/h (Gruber *et al.*, 2014). Using a tandem configuration and/or an electric power assistance can raised the load capacity even further, to about half a ton. Cargo volume ranges from at least 0.50 m^3 to more than 1.5 m^3 for larger electric cargo tricycles. Differences between cargo tricycles and diesel vans can be identifield in Table 5, where vehicles specifications of a typical cargo tricycles and van are shown.

Table 5 – Vehicle characterisation (adapted from Esteruelas, 2016; Lia *et al.*, 2014; Browne *et al.*, 2011; Gruber *et al.*, 2014)



	Electric tricycle	**Diesel cargo van**
Specification	**Cycles Maximus**	**Sprinter Md311**
Price	5,100 Euros	20000 Euros
Battery size / Tanh size	864 watt-hour	80ltrs
Battery capacity	72-92 Ah	-
Payload (volume)	500-1500 ltrs	6500- 17000 ltrs
Maxpayload (weight*)	170 -300 kg	5000kg
Curb weight	227kg	2100Kg
Battery Weight	35kg	-
Recharge time (full)	4-8h	-
Cargo volume	1,5m3	17m3
Maximum range(battery autonomy)	50 - 90km	700km
Max Speed in urban traffic	15km/h	14,5km/h
Driving	Easy	Easy
Guide in adverse conditions	Easy	Easy
Emmisions	0.1225 $kgCO_2$ /kWh	2,67 $kgCO_2$ /l
Costs	High	Very high

*not included the rider weight

Cargo tricycles have many advantages. Because of their small size, tricycles require minimal parking space and can be parked legally on and off the street, on the sidewalks or inside the customer's own (Tipagornwong *et al.*, 2014). A diesel van would need to park on the street, increasing the walking time and distance to make a delivery, and generally requiring the vehicle to be idle while waiting for a parking space. The driver of a delivery van has to cross a long route to get a suitable place to unload, and this can sometimes take 15 to 45 minutes, which increases the cost, emissions and traffic congestion. Using tricycles, customer service times can be reduced.

In terms of maneuvering throughout urban areas, tricycles also tend to have a distinct advantage because there are dedicated bicycle lanes that a tricycle can use to circumvent traffic congestion at all times, unlike the van it always has that make the same direction of the route. In addition, the ability to simplify and shorten the route crossing pedestrian areas or to mount unidirectional streets on a sidewalk in the opposite direction makes the tricycle a perfect vehicle to deliver in dense centres. Finally, a tricycle has better fuel economy in terms of energy because of its lower weight and because pilots need to pedal.

Wilson *et al.* (2004) point out that it is perfectly feasible for an average man or woman to ride a 75-watt bike without fatigue for 7 hours. The human contribution is not insignificant because the power exercised by the pilot could reduce the required battery size by about 500 watts-hours during a 7-hour day, and the battery capacity is about 850 watts an hour.

Freight traffic takes up a large proportion of total daytime road transport in cities, often as high as 50% in large cities, and up to 90% in very large cities such as London and Paris (Browne *et al.*, 2005). The last mile is currently considered one of the most expensive, least efficient and most polluting sections of the entire logistics chain. This is because traffic congestion makes the driving cycle very irregular, leading to very high fuel consumption and a waste of time.

The positive ecological and social consequences of replacement load cycles for delivery vans are obvious: important fuel economy, less pollution, less noise, more space in a nicer city, less congestion and less serious accidents. There are also so many economic benefits as well as ecological and social benefits, although they are not so obvious at first glance.

Second, the cargo cycles are much cheaper than the vans. The purchase price of an average load cycle does not exceed 3,000 euros, and the largest three and four-wheeled cargo cycles with electric assisted sell for about 5,000 to 8,000 euros. Buying a van sets an initial cost of at least 20,000 euros. However, for either mode of transport this cost is small compared with the running and staff costs. The real advantage of the cargo cycle lies in its low cost of use. A car, van or truck consumes fuel; a cargo cycle does not. In addition, taxes, insurance, storage and depreciation are lower for cycles than for vans, which can result in significant cost savings (Mayor, 2013). Together, a cargo cycle can be up to 98% cheaper per km than other alternatives.

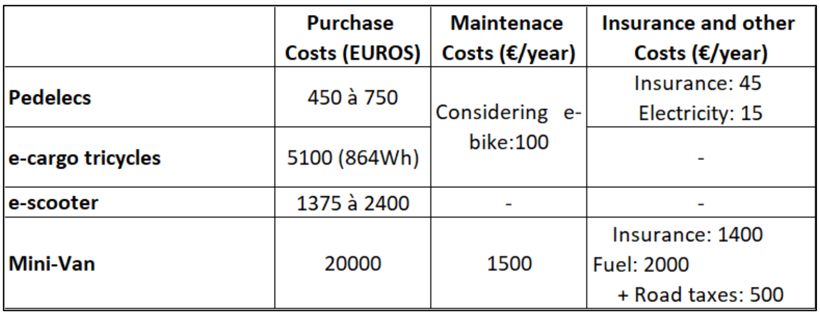
In Europe, authorities clearly recognize the economic and ecological potential of cargo cycles. In general, cycle logistics projects aims to reduce energy used in urban freight transport by replacing unnecessary motorised vehicles with cargo bikes in European cities. According to surveys carried out by the project, cyclists could easily move 25% of all loads in cities considering loads up to 250 kg (Cycles Maximus, 2012).

Cycle logistics will motivate municipalities to create a regulatory framework and policies for load cycles, and they will be testing and reporting various models of cargo bicycles, promoting their acceptance by consumers, authorities and businesses. UK research has found that perception is probably the single biggest factor that inhibits the use of cargo cycle (Mayor, 2013). The reluctance to use cycle freight is due more to the lack of information on the vehicles and the options now available rather than due to rooted attitudes to the use of cycle power.

Although there are many advantages to cargo tricycles, there are also disadvantages. Since tricycles have limited loads and volume capacities, there are times when freight is not deliverable due to excess vehicle limits, both in weight and volume. Limited travel range and low speed under free flow conditions are also crucial disadvantages. Therefore, tricycles only fit as an urban delivery vehicle in certain contexts, that is, small volumes and low weight parcels when a diesel van delivery process is limited by the limitations of the urban structure.

Table 6 presents a comparison of costs between the three types of vehicles (e-bikes and conventional) by the component of financial economic sustainability.

Table 6 – Financial economic sustainability: vehicles costs comparison



	Purchase Costs (EUROS)	**Maintenace Costs (€/year)**	**Insurance and other Costs (€/year)**
Pedelecs	450 à 750	Considering e-bike:100	Insurance: 45 Electricity: 15
e-cargo tricycles	5100 (864Wh)		-
e-scooter	1375 à 2400	-	-
Mini-Van	20000	1500	Insurance: 1400 Fuel: 2000 + Road taxes: 500

3.6 Barriers

Currently, there are few infrastructure or legal barriers that prevent companies from introducing an electric fleet charge- bikes or tricycles. Companies can continue delivering perfectly by electric cargo tricycles to carry volumes of clients and small parcells throughout the city. The main barriers reside in the cyclelogistic circulation of a niche commodity movement mode to a mode widely adopted for last mile deliveries.

In order to make the movement of goods by e-bike two wheels or three wheels viable for large volumes, it is necessary to regulate the electric cargo tricycles that facilitate the speed of the pilots in the intersections of traffic, manage the topography of the city (slope) and take care of the safety of drivers. In addition to infrastructure, the main barrier is a cultural shift to recognize that e-bikes and cargo tricycles are a viable option for moving not only people but also goods.

There is no provincial classification of electric vehicle trycicles vehicles weighing more than 120 kg, since these fall between an electric bike and an electric van. In Brazil has already allowed the circulation of electric cargo-tricycles vehicles on the public path.

With regard to road infrastructure, it is not considered a major barrier to the electric cargo trycyle, as the cycle lanes can accommodate the e-bikes or cargo tricycles and the company can carry out its route planning. It is also important to consider that there should be space on the sidewalks to park a electric tricycle for safe storage in a short space of time to unload and deliver the goods.

The important factor to be taken into consideration by companies when it comes to replacing the current fleet by the electric cargo tricycles is regarding reliability and tracking of the load. There are many software available in the IT market for asset tracking, proof of delivery (POD), routing, scheduling and accounting.

The electric cargo tricyle is penalized by limiting the weight of the load. They return more frequently to the UCC (short routes, on average 6 to 7 km) to match the same level of service performed by the truck or a van, to reload the tricycle with a new delivery request, causing this to increase the distance traveled.

3.7 Summary

As we can see from the literature review and several European case studies, there is a significant potential for cargo cycles to replace the huge amount of motorized vehicles in the last mile of the distribution of goods in urban areas, in an attempt to increase the sustainability of this type of operation. However, the main obstacles encountered are the perception of the jobs cycles as an appropriate means of transportation and their acceptance by potential customers, CEP, B2B and B2C. Perhaps because this is a recent field of study, there are a wide variety of definitions and terms used to describe the use of cargo bikes and electric cargo tricycles for urban freight with little logic in how they are are used (Riehle et al., 2012). A similar problem was identified in the field of urban freight transport by Lindholm (2013).

For the development of this literature review was based on publications in the period 2010 to 2017. In summary, Table 7 presents a synthesis and analysis of the state of the art in the field of urban freight transport, and, in particular, cycle cargo logistics practice in last mile operations.

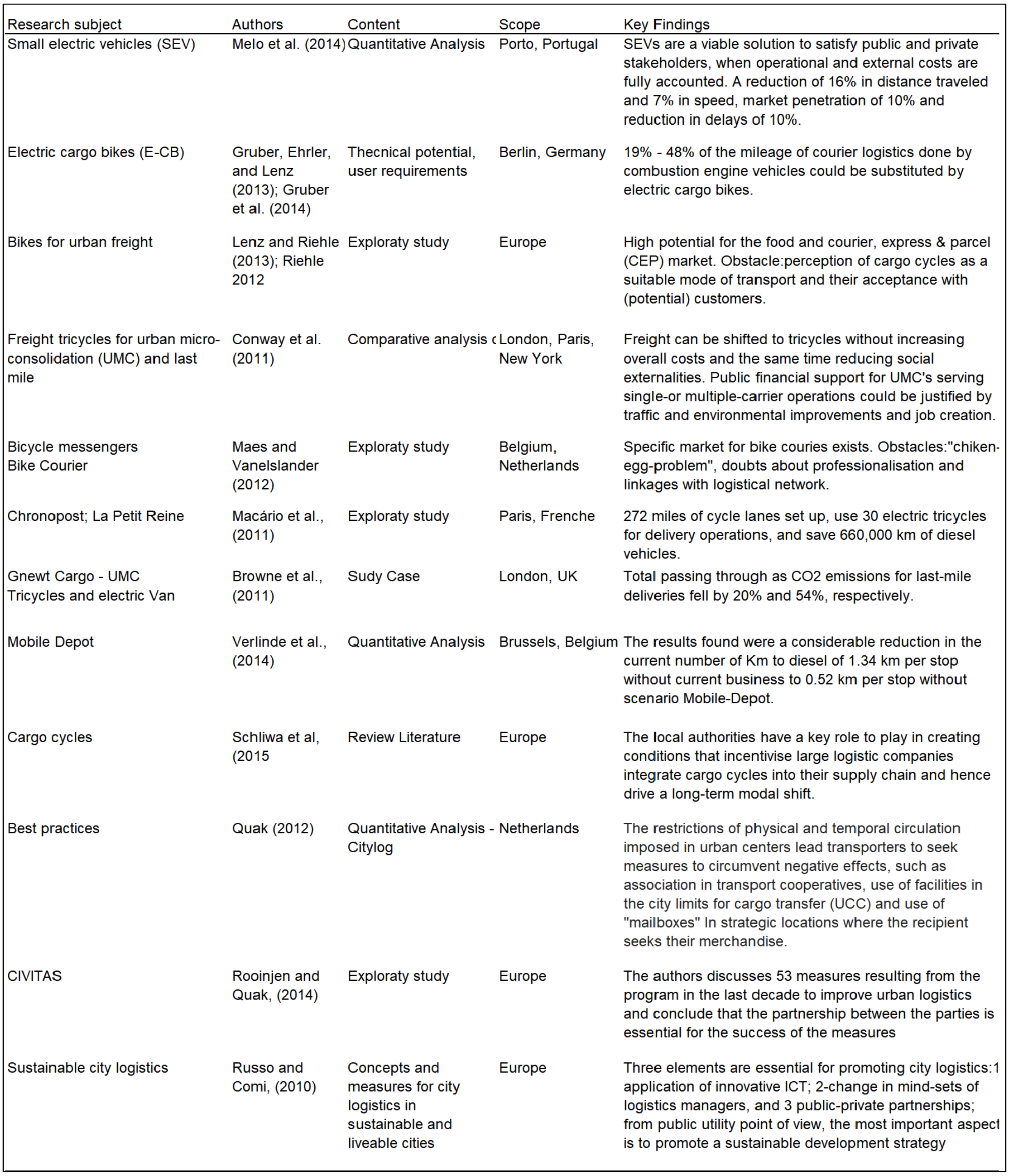
In summary the Table 8 presents an overview of the key references and projects on the use of UCC and electric cargo tricycles in sustainable city logistics, reviewed in the scope of this study.

The graph below (Figure 14) shows the geographical distribution of case studies found in the literature review of the logistics of cycles of electric cargo tricyles and cargo bikes in the urban distribution of goods to las mile. It can be observed that there is a gap between European

Union (mainly United Kingdom and Netherlands), and other continents (Asia, USA, and Latin America).

Finally, it can be concluded that there are numerous research opportunities in this field of knowledge, from the prediction of the advent of new technologies, to the understanding in which contexts can be applied and explaining the differences in the social acceptance of these technologies, as well as the restrictions and motivations associated with its adoption.

Table 7 – Overview of key references and projects on the use of cargo cycles in sustainable city logistics.



Research subject	Authors	Content	Scope	Key Findings
Small electric vehicles (SEV)	Melo et al. (2014)	Quantitative Analysis	Porto, Portugal	SEVs are a viable solution to satisfy public and private stakeholders, when operational and external costs are fully accounted. A reduction of 16% in distance traveled and 7% in speed, market penetration of 10% and reduction in delays of 10%.
Electric cargo bikes (E-CB)	Gruber, Ehrler, and Lenz (2013); Gruber et al. (2014)	Thecnical potential, user requirements	Berlin, Germany	19% - 48% of the mileage of courier logistics done by combustion engine vehicles could be substituted by electric cargo bikes.
Bikes for urban freight	Lenz and Riehle (2013); Riehle 2012	Exploraty study	Europe	High potential for the food and courier, express & parcel (CEP) market. Obstacle:perception of cargo cycles as a suitable mode of transport and their acceptance with (potential) customers.
Freight tricycles for urban micro-consolidation (UMC) and last mile	Conway et al. (2011)	Comparative analysis	London, Paris, New York	Freight can be shifted to tricycles without increasing overall costs and the same time reducing social externalities. Public financial support for UMC's serving single-or multiple-carrier operations could be justified by traffic and environmental improvements and job creation.
Bicycle messengers Bike Courier	Maes and Vanelslander (2012)	Exploraty study	Belgium, Netherlands	Specific market for bike couries exists. Obstacles:"chiken-egg-problem", doubts about professionalisation and linkages with logistical network.
Chronopost; La Petit Reine	Macário et al., (2011)	Exploraty study	Paris, Frenche	272 miles of cycle lanes set up, use 30 electric tricycles for delivery operations, and save 660,000 km of diesel vehicles.
Gnewt Cargo - UMC Tricycles and electric Van	Browne et al., (2011)	Sudy Case	London, UK	Total passing through as CO2 emissions for last-mile deliveries fell by 20% and 54%, respectively.
Mobile Depot	Verlinde et al., (2014)	Quantitative Analysis	Brussels, Belgium	The results found were a considerable reduction in the current number of Km to diesel of 1.34 km per stop without current business to 0.52 km per stop without scenario Mobile-Depot.
Cargo cycles	Schliwa et al, (2015	Review Literature	Europe	The local authorities have a key role to play in creating conditions that incentivise large logistic companies integrate cargo cycles into their supply chain and hence drive a long-term modal shift.
Best practices	Quak (2012)	Quantitative Analysis - Citylog	Netherlands	The restrictions of physical and temporal circulation imposed in urban centers lead transporters to seek measures to circumvent negative effects, such as association in transport cooperatives, use of facilities in the city limits for cargo transfer (UCC) and use of "mailboxes" In strategic locations where the recipient seeks their merchandise.
CIVITAS	Rooinjen and Quak, (2014)	Exploraty study	Europe	The authors discusses 53 measures resulting from the program in the last decade to improve urban logistics and conclude that the partnership between the parties is essential for the success of the measures
Sustainable city logistics	Russo and Comi, (2010)	Concepts and measures for city logistics in sustainable and liveable cities	Europe	Three elements are essential for promoting city logistics:1 application of innovative ICT; 2-change in mind-sets of logistics managers, and 3 public-private partnerships; from public utility point of view, the most important aspect is to promote a sustainable development strategy

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Table 8 – Overview of key references and projects on the use of UCC’s in sustainable city logistics.

Research subject	Authors	Content	Scope	Key Findings
Ultrecht - Cargohopper and Beer Boat	Quak (2012)	Exploraty study - Citylog	Netherlands	From a UCC, deliveries were made by Beer Boat and Cargohopper - sustainable alternatives, found reductions in the order of 11% in terms of distance traveled and less CO2 emission and 25% volume increase considered. Better traffic flow with good air quality for the population
Leinden - Hague	Van Duin et al, (2010)	Comparative analysis	Netherlands	In Leiden, the attempt failed due to low profitability and the weak participation of the retailers of this center, with the number of deliveries falling below expectations.In the Hague, the study revealed that the use of a UCC allied to non-peak delivery has potential savings of up to € 3.2 per m 3 of goods transported
Nijmeng - Binnenstadservice.nl	Rooijen and Quak, (2010)	Comparative analysis	Netherlands	The replacement of vehicles to combustion by bicycles and electric tricycles, delivering from a UCC, achieved a reduction in the total distance covered by up to 20%. The replacement of vehicles to combustion by bicycles and electric tricycles, delivering from a UCC, achieved a reduction in the total distance covered by up to 20%. First year operating already 98 stores join BSS, wich results in an increasing volume
Bristol	Hapggod (2006)	Exploraty study	United Kingdom	The initiative to implement a UCC in 2004, operated by DHL, with the participation of 63 stores, achieved a reduction of 20 minutes in the course of the total distance traveled. Despite the low adherence of shopkeepers, the program has been profitable
Kassel	Kohler (2004)	Quantitative Analysis	Germany	The implementation of a UCC in 1994, began to give results in 2005, in the order of 60% reduction in the total distance traveled and increase of the occupation of the vehicles of load, from 40% to 80%
La Rochelle	Patier (2005)	Quantitative Analysis	Paris, Frenche	La Rochele, implemented a UCC in 2001, serving 13,000 courier companies, express and parcel installments, supported by electric tricycles, reaching 60% in the reduction of the total distance covered. Time savings for operators are greater than the costs of using UCC
Málaga	Browne et al., (2005)	Exploraty study - BESTUFS	Spain	Successful public-private partnerships (PPP) related to city logistics and sustainability. Establishment of a pedestrian zone where only vehicles coming from the UCC can enter. Only one third of its capacity is used.
L'Hospitalet de Llobrega	Balm et al, (2014)	Exploraty study	Bacelona - Spain	The goal is to reduce the number of vehicles entering the city center while maintaining service levels and traffic flow and good air quality for the population. Multi-carrier charges are consolidated at UCC and then distributed to resellers by DHL. One of the main challenges of the operation is finding a reasonable number of retailers to attend.
City Porto	Gonzalez-Feliu and Morana (2010)	Exploraty study	Pádova - Italy	Establishment of deliveries with ecological vehicles from an urban consolidation center. The share of retailers increased 150% in 2 years (20 to 50), showing that success is possible for the city's logistics schemes and its financial viability can be ensured by raising the goals of all those involved

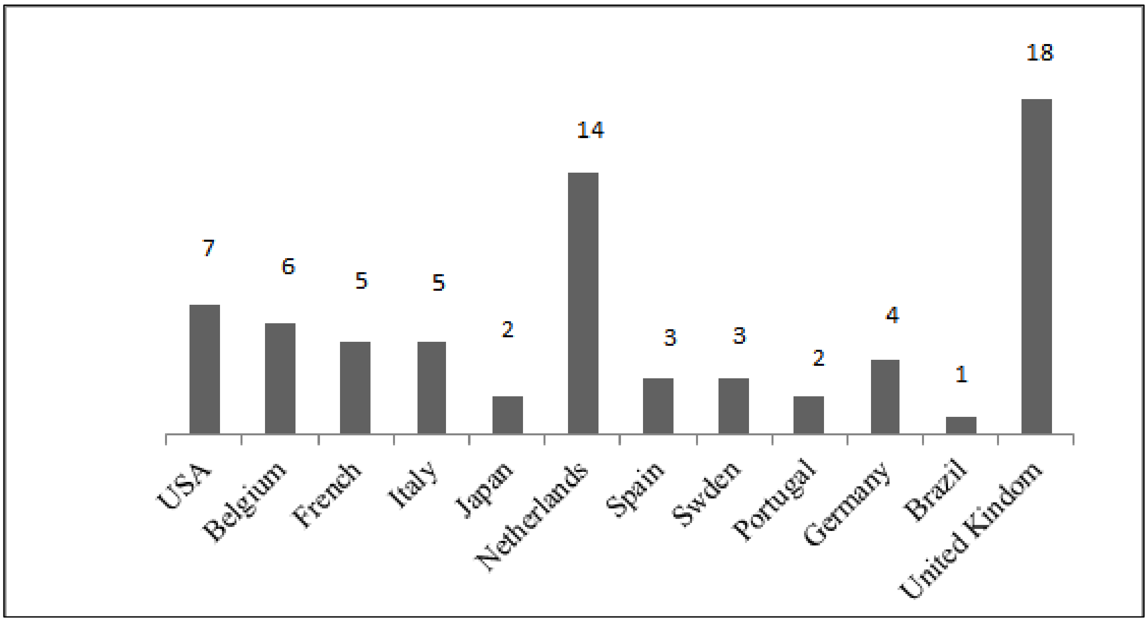

Figure 14 - Number of reported case studies, by country

4. SÃO PAULO CASE STUDY: TNT

This chapter presents the application of the methodology presented in the initial chapter in a case study. Three scenarios of physical distribution of goods in urban areas are considered: the traditional (and actual) distribution by truck, where this vehicle distributes in each customer, and two alternative scenarios, where electric cargo cycles are used.

4.1 Contextualization

São Paulo is the capital of the State of São Paulo with about 12 million inhabitants, with an area of 1,522 km^2 and the first largest Gross Internal Product (PIB) in Brazil, with about 628 billion Reais and 63% of multinational companies installed in the municipality. With 50,800 industries, the municipality is inserted in the metropolitan region that bears its name, together with another 39 municipalities with more than eight million inhabitants (IBGE, 2010). The municipalities that limit São Paulo are Guarulhos, Campinas with more than 1 million people, followed by São Bernardo do Campo, Santo André, São Caetano do Sul, Diadema (Region of large ABC), José dos Campos, Osasco, Ribeirão Preto with more than 500 thousand inhabitants, as well as other cities whiche comprise the urban agglomerate such as Sorocaba and Jundiaí. Figure 15 shows the map of the municipality of São Paulo.

The capital of São Paulo was built with a mixture of different cultures, because of the waves of immigration that occurred in the nineteenth and early twentieth centuries. In the daily life of the city, several accents were integrated: Spanish, Italian, German, Portuguese and Japanese. During the period of immigration, from 1870 to 1889, 208,549 immigrants landed in São Paulo. In the 1920s, the city already had about 580,000 inhabitants, two thirds of whom were immigrants or descendants of immigrants, most of them Italians.

From the 1940s, with the implementation of the radial-perimeter road structure planned by the Avenues Plan, opened new spaces for the expansion of the centre and made possible a new articulation of this with the rest of the city. This accentuated the displacement of centrality beyond Centro Novo, on the southwest course, following the direction of the higher income layers.

Figure 15 – Map of São Paulo area

The 1960s and 1970s mark a new era in downtown life and its relationship with the rest of the city. The consolidation of the automobile and the national automotive industry enabled the creation of new centralities at the same time that the process of metropolization of São Paulo acquired a new geographical scale. At first, it was the street Augusta that robbed to the centre the functions of prestige and vanguard.

The definition of what would be its centre is not something agreed upon by all. From the institutional point of view, as of August 1, 2002, the "centre of the city" was that covered by Sé's Regional Administration, which comprised the 10 nodal districts of the agglomeration. As of that date, the "legal centre" became the Sub-Prefecture Sé, comprising 16 districts, namely: Republica, Sé, Bom Retiro, Santa Cecilia, Consolação, Bela Vista, Pari, Brás, Liberdade, Cambuci, Glicério, Ponte Small, Luz, Campos Elísios, Barra Funda and Santa Ifigênia.

In a more narrow sense, it is understood as a more limited territory, comprised between Parque D. Pedro, Largo do Arouche, Praça das Bandeiras and Luz region. It roughly coincides with the Sé and República districts. This group totals an area of about 17 square kilometers, corresponding to less than 2% of the total urbanized area of the municipality, housing almost 500,000 residents and offering more than one million jobs.

In the city of São Paulo, of the 12 million motorized trips per day, 30% are destined to the central region of the city. In the central area of the City, almost half of these trips are for the Sé and Republica districts. The Central Area is responsible for 850 thousand transfers per day and is the destination of 1.2 million trips per day (9% of municipal trips). As a consequence, the floating population of the Centre, between passers and users, is 1.95 million people per day (PlanMob, 2015)

The metropolitan macro-accessibility of the Central Area is defined by the radioconcentric structure of the road circulation. Collective transportation systems, in turn, are organized in networks concentrated in the Central Area, accentuating the differences of accessibility standard in the metropolis.

The accessibility by public transport is by rail transport, through 14 subway stations and 3 railway stations, and by road transport, through 250 bus lines that are destined to the Centre. The proximity of the Campo de Marte, whose prospects point to the potential of its characteristics as an airport for small aircraft, adds a modality of transport that reinforces the importance of the Central Area.

From a functional point of view, the Central Area concentrates activities of the financial sector, tourism, leisure, commerce and services, small industries, trade centres and specialized services that serve the metropolitan region and other states of the country. The Central Area presents the highest concentration of jobs in the tertiary sector and in some branches of industry, such as textiles and clothing. In relation to the resident population, since the beginnings of industrialization, the Central Area imposes itself as a place of housing for immigrants and, from the 30's, also of migrants. This trait persists in the present, and different ethnic groups have been maintaining or alternating in the occupation of their spaces. They are characterised by the significant presence of houses, which coexist with important centres of commerce and specialized services, and with equipment that extrapolates to the local scale.

4.2 Urban logistics in São Paulo

According to Dutra (2004), the São Paulo administration adopted the delivery night goods, whose alteration in the city's supply routine, despite the increase in labor costs, allowed productivity increase of up to 50% per vehicle, offsetting costs and allowing reduction in the final freight price. However, this measure was not well received by the final customer, having to make staff available to receive it. CET SP Dutra (2004) proposed the use of logistic operators to reduce the problem through a relationship of trust between the parties, so that access to the facilities is free.

In this way, several measures have been taken, with the purpose of restricting the movement of cargo vehicles in certain areas of the city, thus reducing the impacts caused by the circulation of these vehicles. Time windows and hourly driving restrictions are commonly used measures to restrict the movement of cargo vehicles. In addition to these measures, restrictions related to the physical distribution operation, such as service hours, vehicle capacity, maximum duration of travel (time and distance), volume of delivery, among others, are also employed.

For exemple, the Brazilian experience in this field began in 1982, in the city of São Paulo, with restrictions on the circulation of vehicles with a gross weight above 15 tons, from 06 am to 09 am and from 4 pm to 9 pm. Currently, São Paulo has four types of this restriction: (i) Maximum Area of Circulation Restriction (ZMRC), (ii) Special Circulation Restriction Zone (ZERC), (iii) Exclusively Residential Zones (ZER's) and (iv) Restricted Structural Routes (VER) in order to promote environmental safety and / or quality. In order to guarantee distribution logistics, in the area defined by ZRMC, the São Paulo city government allowed the circulation of the so-called Urban Vehicle of Cargo (VUC) and Light Vehicle of Cargo (VLC) Decree nº37185 (November 20, 1997).

However, these restrictions were implemented without technical and logistical arguments, without analyzing their medium- and long-term impacts, not having the desired effect by the local authorities. According to Gatti Junior(2011), the restriction of heavy vehicles in the city of São Paulo increased the use of smaller cars by approximately 20%. This change in the current fleet also resulted in increased costs, reduced productivity and a high increase in the number of congested roads, close to 200 km.

In view of this situation, the municipal government of the city of São Paulo has been carrying out several studies on measures to regulate the circulation of trucks in order to minimize the problem of traffic in the city. Decree nº 48.338 (May 10, 2007), increased the area initially defined for ZMRC (going from 11.4 km² to 24.5 km²) and changed the length of the VUC to 6.30 m, eliminating the VLC. A year later, Decree nº 49.487 (of May 12, 2008), regulated a new ZMRC (now with 100 km² as shown in Figure 16) and also prohibited the circulation of VUCs in the area. The decree also extended the restriction schedule: 5 am to 9 pm Monday to Friday and Saturdays from 10 am to 2 pm.

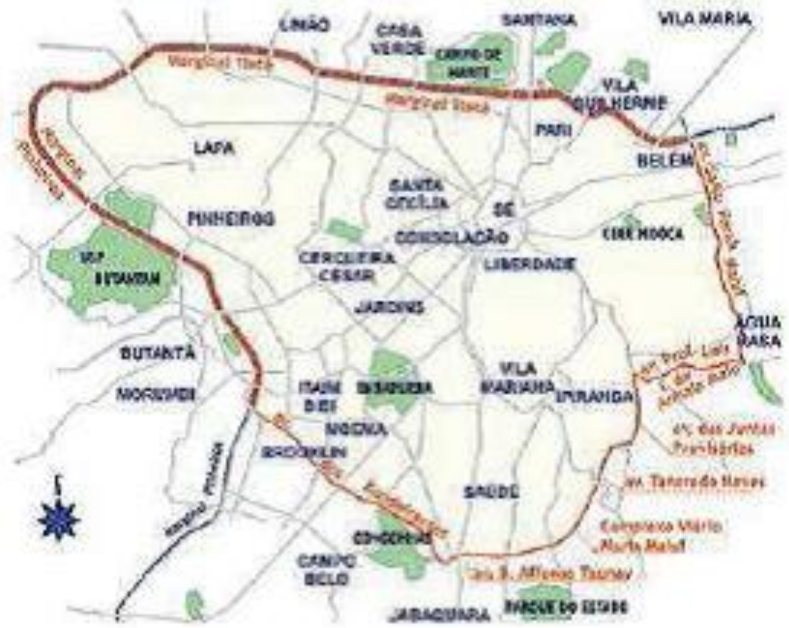

Figure 16 – Maximum area of circulation restriction ZMRC

4.3 The TNT FEDEX (São Paulo)

TNT FEDEX is an express company Business to Business. Established in 1946 in Australia, TNT (Thomas National Transport) is today a global integrator, offering an extensive range of services to meet all the needs of its customers. With the consolidation of other businesses and the great growth of the company, in 1996 the TNT group was acquired by the Dutch Mail, thus giving rise to the TNT Group.

The company operates in Brazil through its TNT Logistics Brazil business unit, starting operations in 1997 to support Fiat in the distribution of parts and accessories to its dealership network. Since then, the company has evolved its operations with other automakers, taking over the industry leadership today, also in the electronics, consumer goods sectors. TNT currently has 30 branch offices and 13 cross-docking centres that allow for smarter, cost-effective operation. It manages more than 440 thousand m²of warehouse and transports more than 250 thousand tons per month. The company operates in three lines of business: mail, express transport and logistics, working in various segments of the retail market from the sending of documents by express transport to items such as textiles and clothing, footwear, pharmaceuticals, electronics and automotive parts.

The TNT Express Canindé operates mainly in the central business area of the city of São Paulo (Centro, República, Sé, Brás, Santa Cecilia, Santa Efigência and 25 de Março) in highly dense areas, relatively flat and slightly sloping streets (Ladeira da Constiuição) and high levels of traffic. Most of its customers are small businesses and textile and clothings merchants who request express mail deliveries (documents or parcels).

4.4 Actual distribution strategy

Thinking of improving its efficiency in the service level, in terms of service and speed in the orders of its customers, the company adopted a new concept of deliveries – courier, express and parcels delivery - in the central region of São Paulo. In September 2015, the company set up an UCC to carry out human-powered cargo-bike deliveries in the Canindé district, 5 km away from the Centre. The installation of this branch is strategic for TNT's plans, with the objective of serving more than 15 thousand zip codes and since the capture in the central region accounts for 18% of the flow of cargo in the city of São Paulo. The new branch has an area of 1,300 m^2 and is strategically located near the main pole of the textile and clothing sector of the city. According to the Sindivestuary, the clothing sector represents 13.1 of the national GDP. This new hub strategy allows for a reduction of around 30% of kilometers per day per vehicle and reduction of emissions of greenhouse gases and atmospheric pollutants.

Prior to the installation of the UCC in Canindé, deliveries and pick ups were carried out by diesel vans, 15 vans per day (on average) to serve the central area of the city of São Paulo of 3.5 gross tonnes leaving a warehouse located 25 km west of the city, in the district of Vila dos Remédios. These vans made multiple delivery trips to customers in the city centre. The delivery area has very heavy traffic flows at the peak of the morning and comprises a mixture of very narrow streets and broader avenues in which no stop is allowed. The vans were loaded at the warehouse at night and the drivers arrived to start their delivery days from 6 am. The vans usually returned to the depot until lunchtime. Up to two additional days of afternoon delivery to the centre of the City of São Paulo were made by vans from the warehouse.

Following the installation of the UCC in Canindé, this new center was used as a transhipment terminal for the transfer of orders from the suburban depot to vans and cargo bicycles and for overnight storage of vans and freight bikes. A heavy goods vehicle of 62 m^3 (10x2,5x2,5) with an average weight of 18 tons is used to transport goods from the company's warehouse, located in the district of Vila dos Remédios, in the western part of the city of São Paulo a distance of 20 km). Making two trips a day to UCC Canindé, in the morning and afternoon, where vans and bicycles are stocked for delivery in the early hours of the following

The Figure 17 shows the route from DC to UCC and the map in Figure 18 shows the route of the Fossil fuelled fleet.

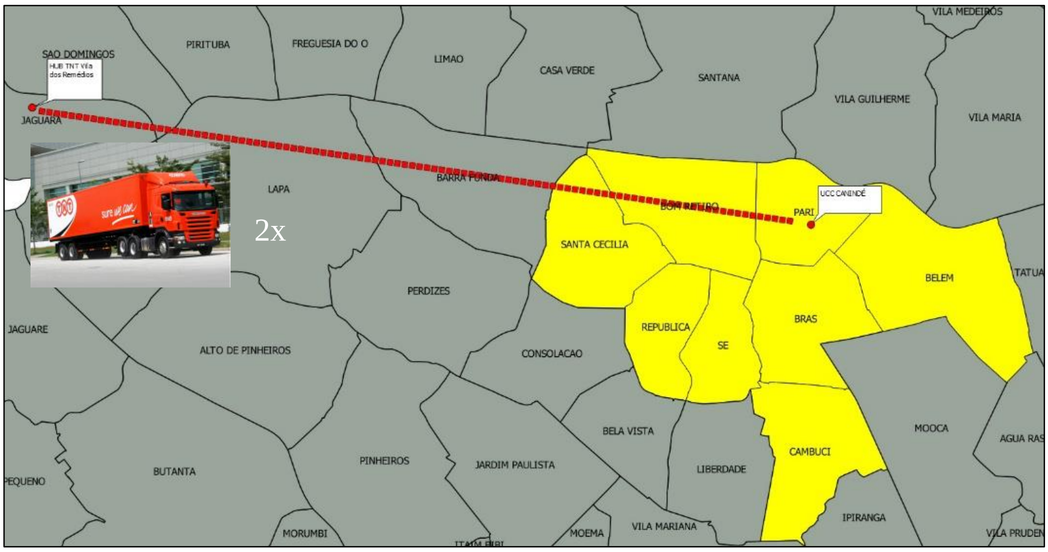

Figure 17 - Vila dos Remédios x Canindé

The goods distribution service is based on the division into "routes" for each zip code. For example, the areas with zip code 3011001 - Route 121, 3019000 - Route 122, 1000000 - Route 123, 1500000 - Route 124, 1100000 - Route 125 and 1200000 - Rota126. Other areas of the city are served directly by the Distribution Centre (DC).

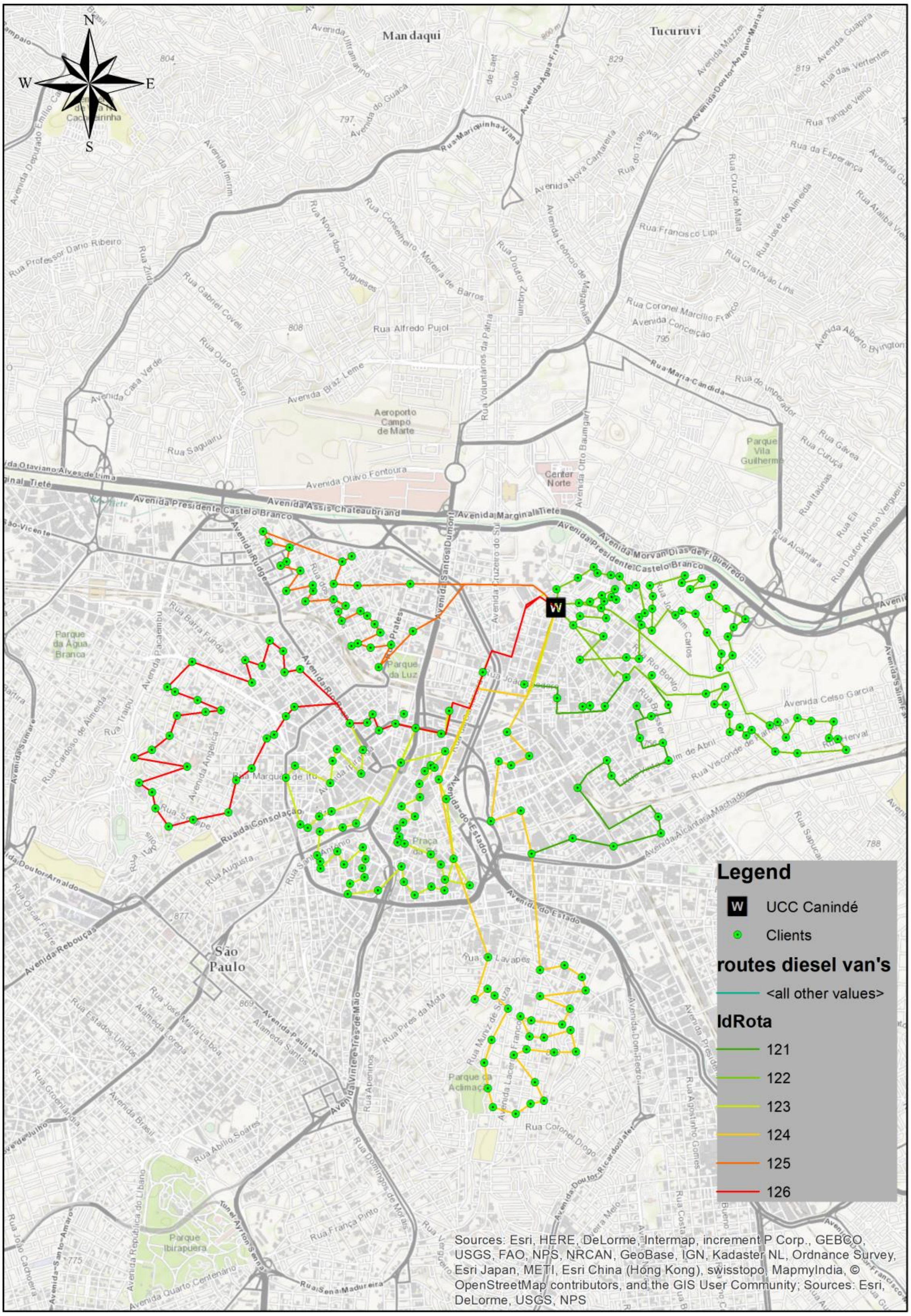

Figure 18 - Routes Diesel van's

In Figure 19, it is possible to understand the digital terrain model of the central region of São Paulo and Figure 20 presented cycle lanes of the Central region of São Paulo

Figure 19 - Digital map of the terrain of the Central region of São Paulo (adapted from Google Earth)

Figure 20 - Cycle lanes of the Central region of São Paulo

This availability of infrastructure obviously helps TNT travelling and parking among high congested areas. One advantage of driving electric tricycles in these areas is that most of these lanes are built on lower flat avenues, as the map shows. In addition, in the central part of the city, there is an hourly restriction of movement and vehicle rotation according to the final number of the vehicle plate. The central area of São Paulo is characterized by narrow streets, mixed traffic, street furniture and congestion; in addition, heavy-duty city drivers are confronted with vulnerable road users, such as pedestrians and cyclists, who share the urban infrastructure with freight transport, as noted in Figure 21. All this makes it difficult to keep deliveries and collections in the city centre reliable, affordable and fast. TNT has this in their favor.

Figure 21 - Dom José de Barros street and Ladeira da Contituição of the Central region of São Paulo

Regarding hourly driving restrictions, it is mainly related to heavy goods vehicles (HGV) being prohibited from circulating in the city centre at certain times. As seen earlier, these city features constitute the majority of advantages of using the eletrically cargo tricycles to perform express deliveries. In addition, as the route is relatively flat (see Figure 18), in a few streets we have an elevation above 15% the electric assistance supports climbing. Obviously, to perform this service, the pilot must be in shape. It is worth mentioning that the empty vehicle weighs 220kg by itself, the average male weight of 70kg and the average weight transported per trip is 14kg, so the messenger must climb more than 200m on slopes with an order of magnitude of 18% (Google Earth, 2017) with 130kg. As human effort is very intense, even with good physical preparation, the electric support helps to ensure that the parcels arrive in time to the final destination without the physical fatigue of the pilot.

4.4.1 The operation of route 123-Centre

The route begins at the TNT warehouse on the Olarias Street in Canindé and end at 25 de Março Street. In addition, both the main avenue between the main customers (Cantareira Avenue) and, in part, the path between the warehouse TNT (in the centre of São Paulo) and the two main customers (São Bento and Benjamim Constan) have cycle lanes appropriate for the cargo tricycles as shown in Figure . These cycle lanes become idle most of the time.

From 8:30 am, the vehicles leave the warehouse to make their respective routes, deliveries and pick ups. There is no predetermined parking place, although the drivers already know some regulated loading and unloading points in the region. In this way, the truck carries the route to the place that will be served using a pre-established route. This route is not necessarily the shortest path to the point of unloading. The criterion for the choice of access routes is made considering the prohibitions of movement of regulated vehicles of the government. Trucks look for a location to park the vehicle next to the customer's shops. This process can take up to 50 minutes per customer depending on the location and the congestion of the street. After parking, helpers deliver and collect goods from customers. More than one customer can be served at each stop if they are nearby. There is no pre-determined parking space, although drivers are already aware of some regulated loading and unloading points in the region. In this way, the truck takes the route to the place that will be served using a route that was previously established.The criterion for the choice of access routes is made considering the hourly restrictions and movement of cargo vehicles regulated by the government. On average, a total of 14 clients are served by route (deliveries and collections), returning to the UCC around 17 h, totaling a distance of 35 km, but there are situations where the van can make more than one trip to the UCC to collect or deliver goods (Figure 22).

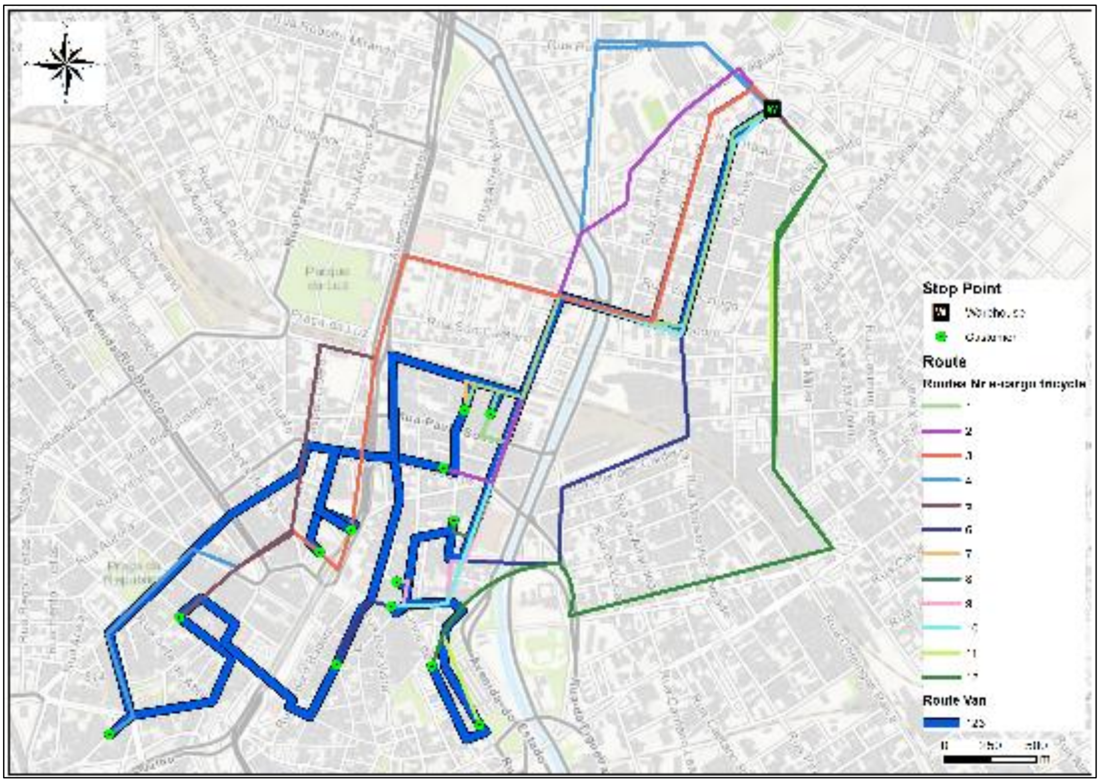

Figure 22 - Map of distribution routes using van and e-cargo tricycles from the UCC

4.5 Data and information collection

In order to perform a comparative analysis of the three distribution configurations (scenarios), it was considered both aspects of the operation and the environmental impact. Firstly, it was crucial to collect the necessary data and information of the actual scenario, in terms of human and technological means, infrastructures, general operation conditions, and performance. Secondly, it was conducted a small survey to get information about electric cargo bike technology that can be used in the future scenarios, and a short documental survey about electric generation sources in Brazil (important to estimate well-to-tank emmissions of electric bikes). All these data and informations are than used in the next chapter to prepare and quantify the different scenarios.

4.5.1 Field (operational) data

As previously mentioned, the tricycle is used primarily in the route that operates in the central region of São Paulo. The central region of São Paulo is characterised by large shopping streets of all types of commerce, from electronics stores to confectionery stores, in narrow, narrow streets. As it is an area with very high traffic flow, the city has decided to create measures to restrict cargo vehicles in this region. Figure 17 show the detail of the neighborhoods that constitute the Central Zone of the City of São Paulo.

The routes that were made available for this analysis were those that serve the district of Centre -123. These routes were indicated by the transport company.

Initially, an unstructured interview was conducted with the TNT-FEDEX logistics manager. We provided data of the routes to be quoted, which routes operate with Vans and which operate with tricycle. The manager informed that the tricycle was incorporated in the operation due to the traffic restrictions imposed by the city hall, as detailed in the introductory chapter of this dissertation.

Considering the information provided, it was decided to carry out field data collection. On the scheduled date, the author (Researcher) was allocated to perform the collection. Arrival at UCC took place around 8 am. The operational manager reported on the possibility of carrying out collections with the researcher embarked on a route that uses only Van, to mention, route Centre and a route that uses the tricycle, in Pari-Belem.

This choice was based on the availability offered by TNT for accompanying routes by the researcher on board and the complexity of the collection (to follow the route on board, for a whole day). The researcher left the UCC at around 9 am with a summary table for data collection (APPENDIX- Summary table of data collection).

The summary table (APPENDIX - Summary table of data collection) for field collection sought to collect information, such as: UCC departure time, time spent from UCC to the first customer, time spent delivering products in each customer, number of customers served, Van occupancy rate and time taken to return to the UCC. For the route that only operates with a diesel van, the information that was in the table was: time of departure of the UCC, time spent until the first customer, time of loading and unloading in client 1, time spent from client 1 to client 2 and so onwards.

The researcher accompanying the route that uses only Van collected time data up to the first customer, time of parade at each point, time of travel between one customer and another. As for the tricycle route, the researcher followed on foot, alongside the tricycle driver to the first customer and so on. The monitoring of operations by the researcher (until the end of the route), allowed to collect information from the time of arrival of the tricycle to the customer, time of delivery of the product to the customer and always annotating time and distance between one client and another as the time and distance of return to the UCC.

These two routes were selected because they had similar operational characteristics (distance traveled, total route time, van size used, service in the same region, to be mentioned, Centre) and because they had more consistent and complex data (the researcher was able to collect all the data operating time).

ArcGis was used to create a georeferenced map, compare and confirm the routes, from the data collected by the researcher in the field. Google Earth was used to visualize the routes, considering the topography and the slope of the terrain, besides creating maps illustrative of the routes. Using the data collected in the field as a parameter, scenarios were created and was used to simulate the traditional route and the alternative routes (E-Bikes), and analyze the potential benefits in terms of costs and emissions of pollutants. From the data collected, we chose to use Google Earth to generate a route map.

4.5.2 Costs and technical data of E-CB's

The cost of purchasing[1] an electric vehicle depends on the power, capacity, brand and other characteristics, so the range of values is wide. According to TEC Mundo a site specializing in urban mobility / smart cities, the cost of an e-bike can range from 1,000 to 2,000 euros. To verify the adequacy of motor vehicle prices in Brazil, the best-selling equivalent vehicles of 2017 (mini-vans and motorized scooters) were used as reference: a Sprinter D311 year-2015 (Mercedes Brazil 2017) costs around 20 00 euros and has a consumption rate of 12 liters/100 km, measuring 6,590x1,85x1,95mm, a maximum weight capacity of 5,000kg (PBT), with a maximum capacity of 17 m^3 (85x40x50cm). A HR 2015 (Hyundai Brasil, 2017) costs around 18,200 euros and has a consumption rate of 11 l/100km, measuring 3,150x1,90x2,00mm with a total gross weight of 3,300 kg (PBT). A Honda CG 125 (Honda Brasil 2017) costs 1,800 euros and a consumption of 45 l/100km. This is a 125cc scooter, which is the scooters stocked equivalent to an electric one.

For analysis level, in this dissertation we will use as reference the average price of gasoline of about 1 euro, so to go a motorcycle to cover a distance of 50 km is the value to be spent. On the other hand, to recharge the battery of an e-bike, you spend nothing more than 0.07 euros per 35 km, on electricity. That means that with 1 euro of gas one can travel 500 kilometers with an e-bike, probably a little less if there is many climbs. With the diesel-powered van, this figure would increase to 8.51 euros per 100km. The economy is almost 85%.

Also, in order to compare the maintenance costs of the different technologies, a direct consultation of two motorcycle repair shops in São Paulo was carried out exclusively for this dissertation and the results can be found in the Table 9 along with the costs representative of four different technologies (all the most representative costs in this framework are charged in Brazil - country where the companies operate). These maintenance costs relate to a five-year vehicle with an annual distance of 20,000 km to 25,000 km in an urban environment. Note the difference in maintenance costs between an electric and a conventional scooter. This gap can be explained by the need for motor vehicles to have to change many mechanical components

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[1] Few companies carry out insurance for e-bikes in Brazil. The values oscillate from region to region, according to the model, only from a certain amount 800 euros with insurance coverage of 5 years in Brazil. The value varies between 5% and 7% of the value of the property. This value is higher than the insurance of a conventional bike and possibly larger than and charge-bikes and e-scooters, as in some regions are considered high-risk areas.

at every revision (e.g. belts, tubes, oils, spark plugs, etc.) than electric scooters. The only part of an electric bike that requires more investment when it is changed is the battery, whose cost varies from 500 to 1,500 euros (depending on the model chosen). However, since the cells usually lose power only after a thousand full recharge cycles, it will only be necessary to change the battery of the e-bike after about three years if you recharge it every day.

Regarding insurance costs in Table 5, there are few insurance companies that offer insurance for conventional e-bikes and bikes and there are even fewer offering distinct services between both models. In Brazil, only four insurance companies have coverage for "cargo cycles" ranging from 45 euros to 65 euros/year. As far as scooters are concerned, in Brazil you have to pay three different taxes. The first of these is the Motor Vehicle Property Tax (IPVA), a state tax charged annually to anyone who owns motor vehicles. It corresponds to 2% of the venal value of the vehicle and, thus, a scooter that costs 1,500 euros will have an IPVA of 30 euros. Another tax that must be paid annually is the license fee of the vehicle, a process necessary for the authorities to verify that the scooter is in compliance with environmental and safety standards, its value is usually 21.60 euros. Finally, we also have Personal Injury caused by Land Vehicle Vehicles (DPVAT), better known as Compulsory Insurance, which is calculated according to the accident rate for each type of vehicle. In 2016, the DPVAT of scooters was 79 euros. E-bikes and e-cargo bikes, on the other hand, are free of these annual taxes. On the other hand, the IPVA for a commercial mini van costs about 521 euros, 5% of the vehicle's value, the license fee of the vehicle costs 23 euros and the mandatory DPVAT insurance for an equivalent five-year commercial minivan costs 18 euros. These data were acquired through direct consultation to be used in this dissertation.

It is also important to consider the economy in the parking lot. (Cargocycles do not pay fee to park to deliver and collect). Finally, it is important to note that the "post-cycles" do not emit greenhouse gases and other types of atmospheric pollutants. For example, on a 45-kilometer journey, a scooter considered lightweight (100 to 250 cc) would emit about 5.94 kg/km of CO2eq, while a mini-van on diesel emits about 21.15 kg/km of CO2eq.

4.6 Estimation of the performance of actual strategy

Goods are carrying out by a fleet of diesel vans from UCC - Canindé, supplied by DC Vila dos Remédios. In the following paragraphs, the differente costs are estimated and explained.

HGV- High goods vehicles input: A 62,600 € diesel Van with the average consumption of 22 l/100km, a maintenance cost of 4,000 €/yr considering it is 5 years old, an insurance cost of 3,000 €/yr and an annual taxation of 500 €;

LGV- Light goods vehicles input: A 20,000 € diesel mini-van with the average consumption of 12 l/100km, a maintenance cost of 1,500 €/yr considering it is 5 years old, an insurance cost of 1,400 €/yr and an annual taxation of 500 €.

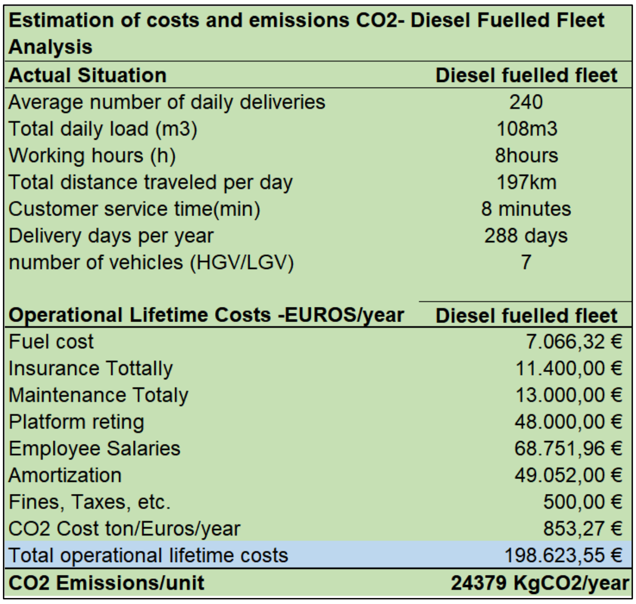
Operation's inputs: Six areas served by diesel vans, which serve on average 240 customers between deliveries and pick-ups daily, with average weight between 3,500 kg and 5,000 kg, with a volume capacity of 18 m^3. By multiplying the volume capacity of each van (18m^3), by the total number of area (6) we obtain the total volumetric capacity of this area of 108,000 liters or 108 m^3. It will be considered a heavy goods vehicle (HGV) carrying 2 trips per day, traveling 80 km per day, consuming a total of 17.78 l/km with a cost of 13.70 €/day. In order to carry out the deliveries and pick-ups on the 6 routes, 6 diesel vans will be considered, totaling 117 km traveled with an average consumption of 8.33 km/l with a cost of 10.83€/day. The total cost is 7,066€/year.

The same considerations as earlier must be reminded: all the calculations were made in constant monetary terms and for all the annual costs, the calculation only includes the sum of the costs paid annually (fuel, depreciation, maintenance and taxes). The remaing costs (CO_2) were only included in the fóssil fuelled fleet average total costs per vehicle and for depreciation a 5 years (138,240 km) lifetime was considered.

This operation will require the hiring of 7 drivers with a cost of 31,346 €/year and 6 helpers totaling 21,951 €/year, 1 warehouse manager in the amount of 4,478 €/year and 3 warehouse helpers with a cost of 10,975 €/year. We also have the rent of the warehouse with an annual cost of 48,000 €/year, 288 days of work in one year, 8 hours per day (six days a week, twelve months per year).

Table 9 presents the results of the estimation for the performance of the actual strategy.

Table 9 – Estimation of costs and emmisions of the actual distribution system of TNT in São Paulo



Estimation of costs and emissions CO2- Diesel Fuelled Fleet Analysis	
Actual Situation	**Diesel fuelled fleet**
Average number of daily deliveries	240
Total daily load (m3)	108m3
Working hours (h)	8hours
Total distance traveled per day	197km
Customer service time(min)	8 minutes
Delivery days per year	288 days
number of vehicles (HGV/LGV)	7
Operational Lifetime Costs -EUROS/year	**Diesel fuelled fleet**
Fuel cost	7.066,32 €
Insurance Tottally	11.400,00 €
Maintenance Totaly	13.000,00 €
Platform reting	48.000,00 €
Employee Salaries	68.751,96 €
Amortization	49.052,00 €
Fines, Taxes, etc.	500,00 €
CO2 Cost ton/Euros/year	853,27 €
Total operational lifetime costs	198.623,55 €
CO2 Emissions/unit	**24379 KgCO2/year**

First of all, some important considerations must be remembered: all calculations were done in constant monetary terms and for all annual costs, the calculation includes only the sum of all annual costs (fuel, depreciation, warehouse retention, maintenance and taxes). The purchase cost was only addressed in the average total cost per vehicle and a 5 years life (283,680 km) was considered for the fossil-fueled fleet. Operating lifetime costs depend on practical aspects such as lifetime mileage, but also depends on aspects such as fuel cost and conversion factors, which are much more difficult to quantify and prove them. In addition to the 117 km daily of the vans, it was necessary to add a distance of more than 80 km/day for the HGV to go twice to DC Vila dos Remédios to supply UCC Canindé. Thus, the final results were modified to include only one vehicle of 60 m^3.

These results correspond to a freight distribution system of diesel van's and a heavy vehicle - current practice - in an express delivery service performed by a courier company six days a week. The vehicles supplied by diesel involve an average annual cost of 7,066 €. With regard to operational lifetime costs, total vehicle insurance costs a cost of 11,400 €/year, in relation to total maintenance, costs about 13,000 €/year. Regarding the salary of the employees, it entailed a total cost of 68,751 €/year and with relation to depreciation generated a total of 49,052 €/year. We also counted the platform reting of 48,000 €/year. Fines and taxes correspond to 500 €/year.

As for the total total costs (average total costs per vehicle), a total of 198,404 €/year. Regarding fuel costs, the seven fossil fuel vehicles spend 7,066.32 €/year on diesel (a heavy vehicle and six mini-van with a fuel consumption of 34 l/100km, with 197 km per 288 days a year represents 9,166 l/year and the conversion factor is 0.1225 kgCO2/kWh).

Finally, with regard to CO_2 costs, considering a service life of 283,680 km, and a conversion factor of 2.66 kgCO_2/l, there is a total emissions of 24, 379 kgCO_2/year and a unit cost of 35 €/ton/year, we reached 853.27 €/ton/year.

Both the heavy goods vehicle (HGV) and the diesel van are sub-used, as they reach the end of their useful life (5 years), fully amortized, but still capable of running more kilometers, since the HGV will do at the end of 5 years 115,000 km, while each diesel van will make 28,000 km in the 5 years (6 vans).

5. APPLICATION AND DISCUSSION

The purpose of the case study is to compare the delivery of goods in urban area using the current practice (fossil-fueled van) with the alternative fleet (electric cargo tricycles) to evaluate their operational costs, and emissions of GHG and air pollutants. For this, two alternative distribution technological scenarios and strategies were defined: (i) maintaining the UCC at Canindé (and all the upstream logistics), and replacing diesel vans on route 123 (Centre) by electrically assisted cargo tricycles to perform the last mile deliveries; and (ii) redesign the distribution network from Vila dos Remédios, by eliminating the UCC at Canindé, setting up a diesel truck fixed-route which feeds a fleet of cargo tricycles to perform all deliveries of TNT in the area of study.

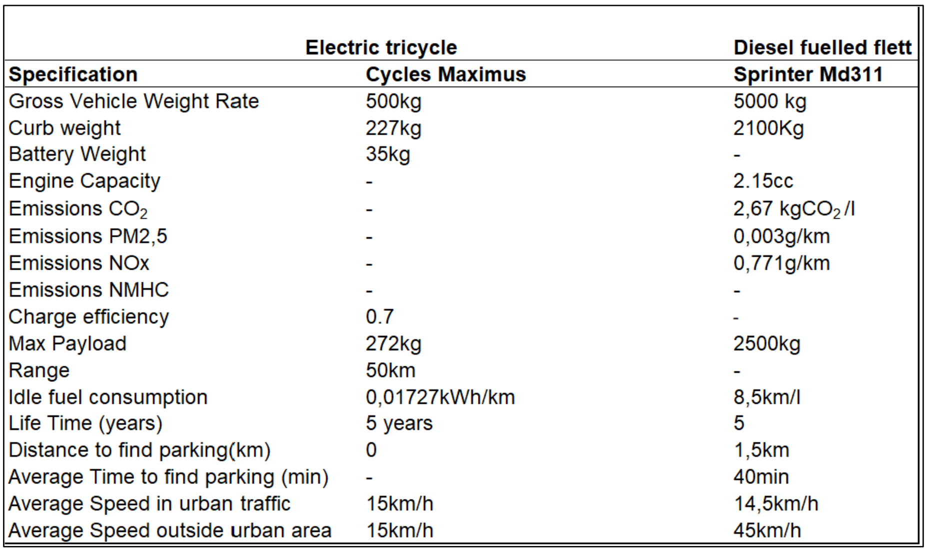
5.1 Proposed e-cargo tricycles

Both future scenarios consider the model of cargo tricycle that Cycles Maximus (2017) has produced for B-Line Sustainable Urban Delivery, located in Portland, Oregon, USA to deliver in the (Figure 23). The tricycle weights 227 kg (e-cargo-tricycle plus battery), has a payload of between 170 and 272 kg and maximum volume 1.5 m ^{3}. It has a maximum weight capacity of between 100 and 300 kg plus the weight of the rider (i.e., plus 70 kg, according to Cycles Maximus manufacturer technical data, 2017). The battery has a capacity of 864 W, a charging time of about 4 to 8 hours, and a range between 50 and 80 km. It is important to note that this vehicle is not electric, but it has electric assistance: the pilot can choose when to turn on the electric assistance and when to turn it off without stopping the vehicle; do not need electric power to start moving, the battery only helps the pilot when he needs to. The battery controller used in this position electrically assisted tricycles has two modes of operation: it alternates whenever the pilot effort exceeds a certain speed limit (25 km/h) and allows the pilot to control the level of assistance he desires.

Figure 23 - Example of three-wheel electric cargo tricycle B-Line in Portland, OR, USA (source: B-Line)

The specifications of this typical electric cargo tricycle and the assumed values for a fossil van are shown in Table 10.

Table 10 - Delivery service and planning parameters (adapted from Esteruelas, 2016; MCTI, 2013)

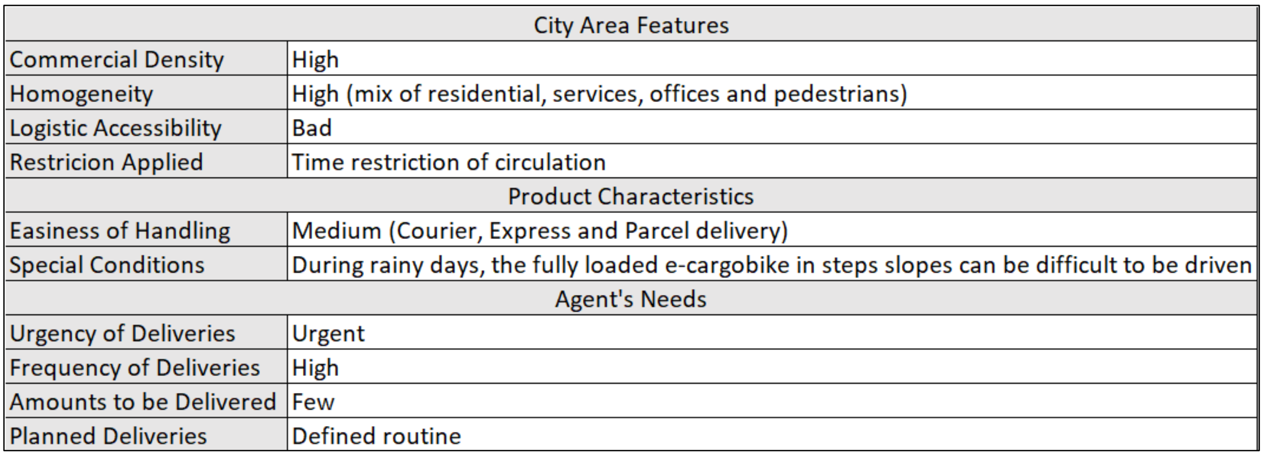


	Electric tricycle	**Diesel fuelled flett**
Specification	**Cycles Maximus**	**Sprinter Md311**
Gross Vehicle Weight Rate	500kg	5000 kg
Curb weight	227kg	2100Kg
Battery Weight	35kg	-
Engine Capacity	-	2.15cc
Emissions CO_2	-	2,67 kgCO_2/l
Emissions PM2,5	-	0,003g/km
Emissions NOx	-	0,771g/km
Emissions NMHC	-	-
Charge efficiency	0.7	-
Max Payload	272kg	2500kg
Range	50km	-
Idle fuel consumption	0,01727kWh/km	8,5km/l
Life Time (years)	5 years	5
Distance to find parking(km)	0	1,5km
Average Time to find parking (min)	-	40min
Average Speed in urban traffic	15km/h	14,5km/h
Average Speed outside urban area	15km/h	45km/h

5.2 Logistic profile of TNT deliveries

TNT Express's logistical profile is presented in Table 11. Generally, all the characteristics described are representative of courier, express and parcel delivery in highly dense urban areas (see Section 2.3.1).

Table 11 – TNT Express Logist Profile



City Area Features	
Commercial Density	High
Homogeneity	High (mix of residential, services, offices and pedestrians)
Logistic Accessibility	Bad
Restricion Applied	Time restriction of circulation
Product Characteristics	
Easiness of Handling	Medium (Courier, Express and Parcel delivery)
Special Conditions	During rainy days, the fully loaded e-cargobike in steps slopes can be difficult to be driven
Agent's Needs	
Urgency of Deliveries	Urgent
Frequency of Deliveries	High
Amounts to be Delivered	Few
Planned Deliveries	Defined routine

The most common product types in TNT services are orders and packages varying between medium and large volumes. Thus, the parcels are mainly average of (average of 0.025 m3 per parcel) and large (average of 20 kg per parcel with a maximum of 30 kg per parcel), relatively easy to transport and to be handled without special conditions. It can be transported in one container, like the one TNT uses currently in man-powered cargo tricycles.

Clients usually have some urgency in their deliveries and request TNT services frequently (daily or 2-3 times a week). The amount of parcels per customer is high (average of 2 parcels per customer) and services are usually planned in advance. In most cases, TNT performs B2C deliveries.

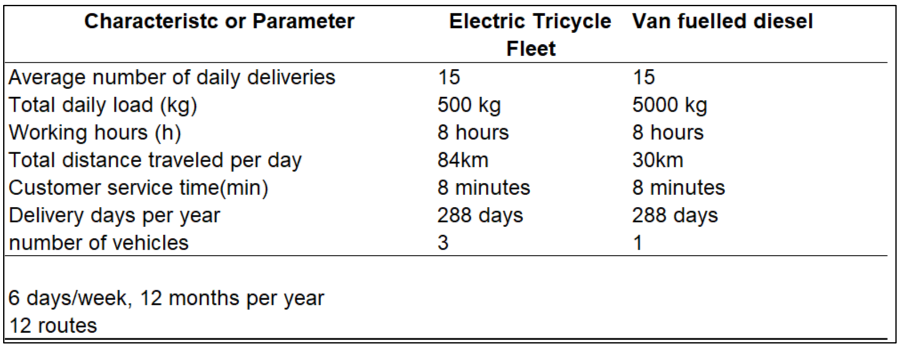
The most common type of products in TNT Express's services are medium packages, electronics boxes and textiles.

5.3 Proposed alternative strategy for route 123

The alternative strategy for route 123 consists of shifting from a conventional distribution by using a diesel van to a distribution by using electric cargo tricycles, but maintaining the actual UCC of Canindé.

Table 12 presents the summary of some key averages that describe in the scope of TNT operations for this route.

Table 12 – Delivery service and planning parameters (adapted from Esteruelas, 2016)



Characteristc or Parameter	Electric Tricycle Fleet	Van fuelled diesel
Average number of daily deliveries	15	15
Total daily load (kg)	500 kg	5000 kg
Working hours (h)	8 hours	8 hours
Total distance traveled per day	84km	30km
Customer service time(min)	8 minutes	8 minutes
Delivery days per year	288 days	288 days
number of vehicles	3	1

6 days/week, 12 months per year
12 routes

5.3.1 Assumptions

Acquisition of the fossil fuel vehicle: a diesel mini-van of 20,000 € (year 2013) with an average consumption of 8.25 km/l, a maintenance cost of 1,500 €/year, considering that it has 5 years, a cost of insurance of 1,400 €/year and annual tax rates of 500 €. With average capacity between 3,500 to 5,000 tonnes, equivalent to 18,000 liters or 18 m3.

Electric vehicle input: electric charge tricycle of 5,100€ (new), average power consumption of 0.01727kWh / km and maximum load capacity of 1.5 m^3 and 300kg (not including pilot's weight). Its maintenance cost is 100€/year, an insurance of 45€/year and, essentially, a tricycle, does not pay taxes. Three electric charge tricycles were purchased, each E-CB performing a course of twelve routes. Totally twelve times 1,5m^3, this corresponds to a total capacity of 18,000 liters 18m^3

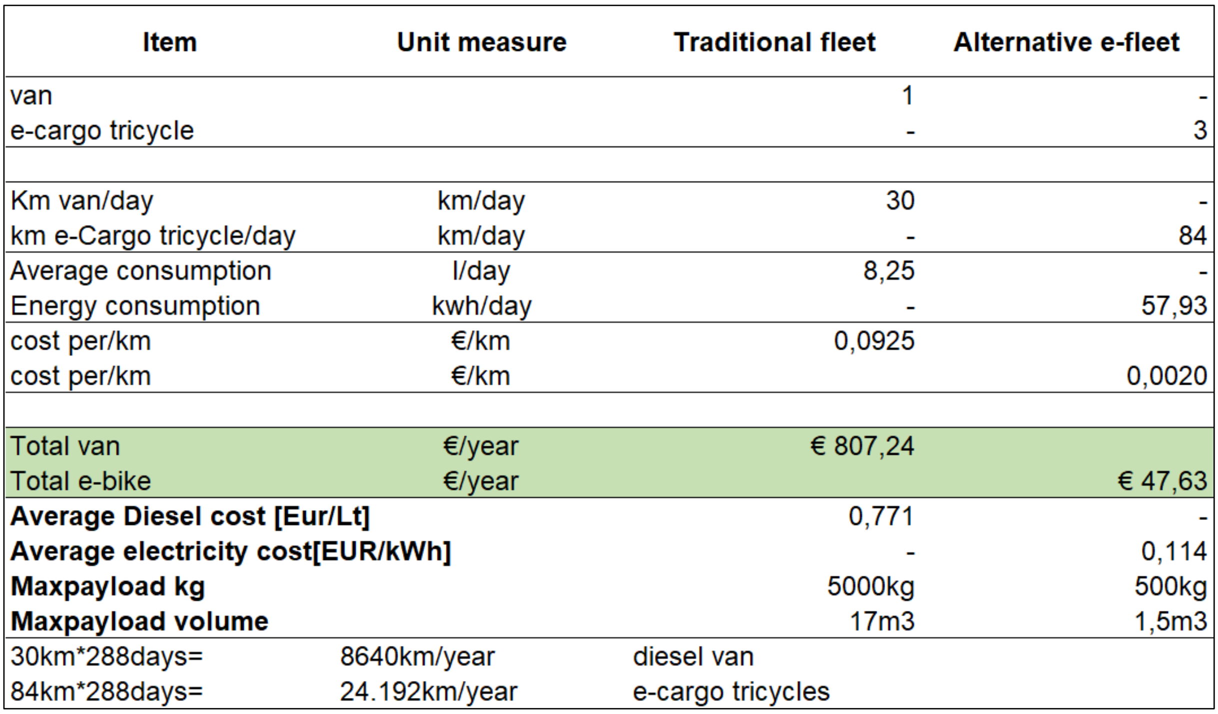
Operational inputs: average daily distance of 30 km with an average load of 25 kg and 1.5 m^3, 288 working days per year (six days a week, twelve months a year). Three electric charge tricycles were purchased, each E-CB performing a course of twelve routes. The twelve routes multiplied by the capacity of the E-CB's (1,5m^3), corresponds to a total capacity of 18,000 liters 18m^3 .

5.3.2 Analysis

For this case, it was considered one conventional vehicle and six and E-Cargo Tricycles (Table 12), since the purpose of this dissertation is to replace the current fleet fueled fossil fuel for the alternative fleet, electric cargo tricycle. The reference value for the average vehicle fuel consumption was 8.25 km/l for the referenced diesel van and 0.01727 kWh/km for the electric cargo tricycle (see Section 5.1). The average distance traveled by vehicle, the average load and volume of load in a working day were calculated for the case study in its form. A single average was performed using all days recorded during the period.

The electric consumption of the electric fleet (Table 13) resulted from the relation between energy supplied by the battery (Kwh) and the total distance traveled recorded. The estimation of the number of routes and the number of bikes is reported in Appendix 2. This energy consumption resulted from the average recorded each day and represents the energy that the battery consumes to allow the vehicle to travel one kilometre. The average electricity cost depends on the country. Because the case study analysed in São Paulo, the corresponding tariff was used. In São Paulo, the unit energy tariff for monthly consumption of up to 220 kWh is 0.114€/kWh (Aneel, 2017).

Table 13 – Energy costs for the two alternatives (source: author)



Item	Unit measure	Traditional fleet	Alternative e-fleet
van		1	-
e-cargo tricycle		-	3
Km van/day	km/day	30	-
km e-Cargo tricycle/day	km/day	-	84
Average consumption	l/day	8,25	-
Energy consumption	kwh/day	-	57,93
cost per/km	€/km	0,0925	
cost per/km	€/km		0,0020
Total van	€/year	€ 807,24	
Total e-bike	€/year		€ 47,63
Average Diesel cost [Eur/Lt]		0,771	-
Average electricity cost[EUR/kWh]		-	0,114
Maxpayload kg		5000kg	500kg
Maxpayload volume		17m3	1,5m3
30km*288days=	8640km/year	diesel van	
84km*288days=	24.192km/year	e-cargo tricycles	

In relation to the global average costs (Table 14) of the fossil fuel fleet, the purchase cost 20,000€ for the Sprinter D311 (Mercedes Brazil 2013), as we have already seen in Section 3.3. On the other hand, the purchase costs of the six electric vehicles were estimated at 30,600 in Cycles Maximum (2015), which produce electric vehicle tricycle loads for B-Line, a North American freight delivery company.The annual quota for the vehicles purcharse is calculate considering a life- time of 5 years.

Because the maintenance cost of an electrically assisted tricycle is the same as a conventional one (only the battery needs to be changed at the end of life). The maintenance cost employee for electric tricycle assisted position was based on the used tricycle model of the B-Line: 100€/year. The maintenance cost of a Sprinter D311 was provided by manufacter and costs 1,500€/year. However, the maintenance cost given to the producer tends to be lower than the actual cost, such as a marketing campaign. Taking this into consideration, a direct consultation with two specialized repairers in São Paulo showed that this type of vehicle, in its first year, can cost 250€, but after four years, which is the reference considered in this dissertation, a cost maintenance of 1,500€/year can be achieved (oil, brake, disc brake and pads, spark plugs, tires). Consider a cost of 1,500€ proposed to be used in this study.

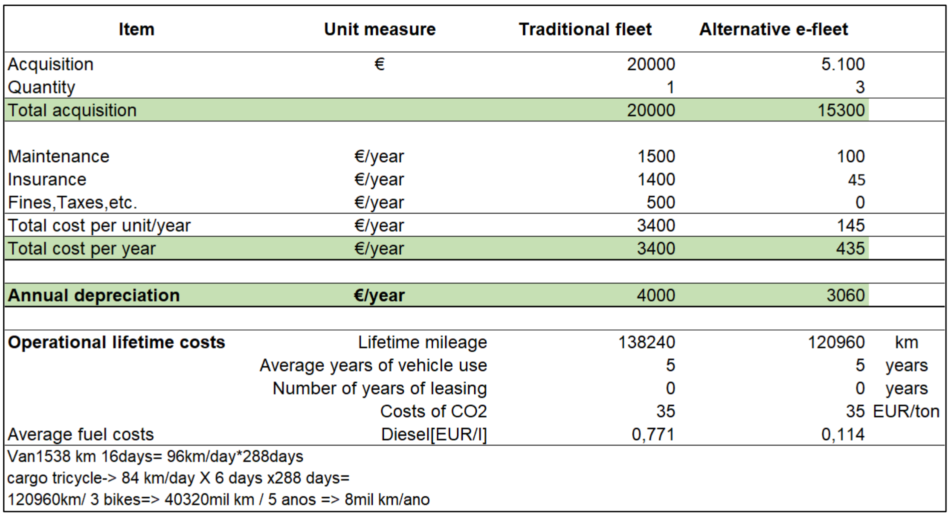
Regarding insurance costs, characteristic values can be found in Section 3.3. Hence, the insurance cost of an electrically assisted cargo-tricycle was considered to be 45€/year and a mini-van's average insurance cost was estimated in 1400€/year. Also, the company has a fleet of 10 diesel vans, 2 of which are owned and 8 leased.

In order to get the most realistc savings, it is important to enter with another cost: taxation. As seen in Section 3.3, each vehicle's taxation is different and dependent on the age, cubic capacity, whether it is utility or vehicle of ride, number of axles. The number of days of annual use depends on the type of service. The cargo cycles is not obligatory of any payment of fees and the like.

In the Table 14 the parameter of life mileage depends on several factors that were not addressed in this dissertation. Based on this, it was considered the useful life of 5 years (138,240 km) for the fossil-fuelled fleet and with respect to electric cargo tricycle were considered 120,960km (about 5 years for a vehicle with 8,000km/year). In the case study, we used data specific to the conventional vehicle used in this company. As for the average years of use of the vehicle, in a similar way to that already considered above, it was considered a life span of six years. According to the National Petroleum Agency (ANP, 2017), the average price of diesel is 0.771€.

Operating lifetime costs depend on practical aspects such as lifetime mileage, but also depends on aspects such as fuel cost and conversion factors, which are much more difficult to quantify and prove them. The electricity costs 0.114€/kWh, an average energy consumption of 0.01727kWh/km, a cost of CO2 emissions of 35€/ton and 0.30kgCO2/100km emission.

Table 14 – Vehicles purcharse costs for the two alternatives (source: author)

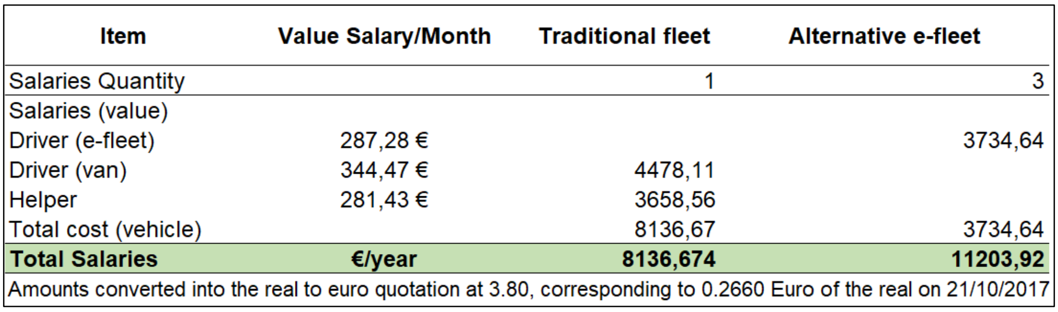


Item	Unit measure	Traditional fleet	Alternative e-fleet	
Acquisition	€	20000	5.100	
Quantity		1	3	
Total acquisition		20000	15300	
Maintenance	€/year	1500	100	
Insurance	€/year	1400	45	
Fines,Taxes,etc.	€/year	500	0	
Total cost per unit/year	€/year	3400	145	
Total cost per year	€/year	3400	435	
Annual depreciation	**€/year**	4000	3060	
Operational lifetime costs	Lifetime mileage	138240	120960	km
	Average years of vehicle use	5	5	years
	Number of years of leasing	0	0	years
	Costs of CO2	35	35	EUR/ton
Average fuel costs	Diesel[EUR/l]	0,771	0,114	
Van1538 km 16days= 96km/day*288days cargo tricycle-> 84 km/day X 6 days x288 days= 120960km/ 3 bikes=> 40320mil km / 5 anos => 8mil km/ano				

B_Line has considered replacing the fossil-fueled fleet with electric tricycle cargo as a marketing investment to develop new business opportunities. This exchange, in the beginning involves the purchase of 3 new electric vehicles, the hiring of more employees, the van works only the driver and the helper while in the tricycle position there will have to be another 3 new employees, implying in the increase of the salary costs, as shown in

Table 15; B-Line considered this as a marketing investment, able to take care of the environment and increase, at the same time, the number of employees.

Table 15 – Salary costs for the two alternatives (source: author)



Item	Value Salary/Month	Traditional fleet	Alternative e-fleet
Salaries Quantity		1	3
Salaries (value)			
Driver (e-fleet)	287,28 €		3734,64
Driver (van)	344,47 €	4478,11	
Helper	281,43 €	3658,56	
Total cost (vehicle)		8136,67	3734,64
Total Salaries	**€/year**	**8136,674**	**11203,92**
Amounts converted into the real to euro quotation at 3.80, corresponding to 0.2660 Euro of the real on 21/10/2017			

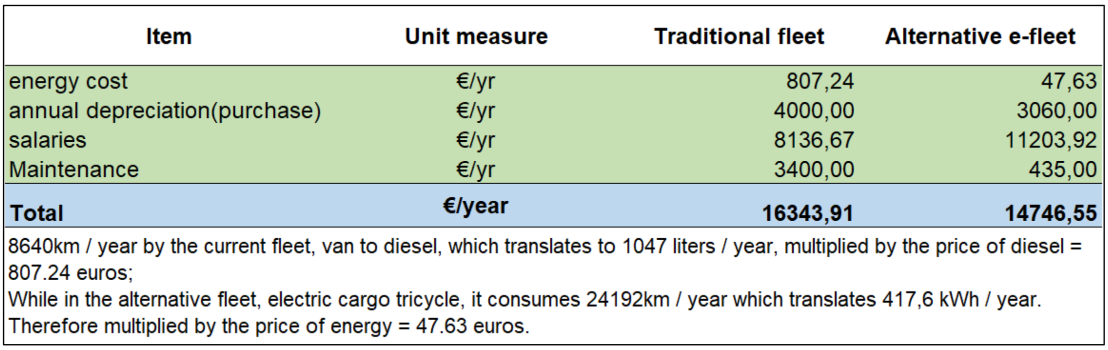
The factors proposed by Itten *et al.* (2014) were used as inputs in this dissertation: 0.1997 kgCO2/kWh for electricity, 0.266 kgCO2/l for diesel. Fuel-related parameters were proposed in our estimations (based on the previous reference) and, to evaluate their accuracy, were recalculated based on other sources. According to Carvalho (2011), each litrer of fuel is responsible for the emission of 3.20 kg of CO2. The volumetric weight of diesel is 0.8495 kg/l, which results in the same factors as indicated above. These parameters supported the understanding of how much CO2 is emitted for each liter of fossil fuel burned and for each kilowatt-hour of electricity generated, thus allowing the calculation of the external costs associated with each kilometer traveled using the vehicles studied, both conventional and electric.

The calculation of these external costs implies consideration of the average consumption and, energy consumption and the cost of CO2 [€/ton]. This cost can vary between 30 and 40 euros per ton of CO2 (European Commission, 2015), so the average was used in this dissertation (Table 3). The amount of pollutants in each fossil fuel also needed to be defined. In that extension, standard values from the same source were also adopted (Table 3): one kilometer traveled using a diesel vehicle is associated with an emission of 0.0035 grams of particles and 0.771 grams of NOx; the last contribution concerns the external costs of pollutants. According to the simulation, particulate matter emissions cost between 0.087 €/g and 0.174 €/g. Taking this into account, the average value of 0.1305 €/g was applied and the same happened with the costs of NOx of 0.0066 €/g and NMHC of 0.0015 €/g.

The savings are significant in terms of CO2 emissions and costs (

Table 16).

Table 16 – Costs for the two alternatives

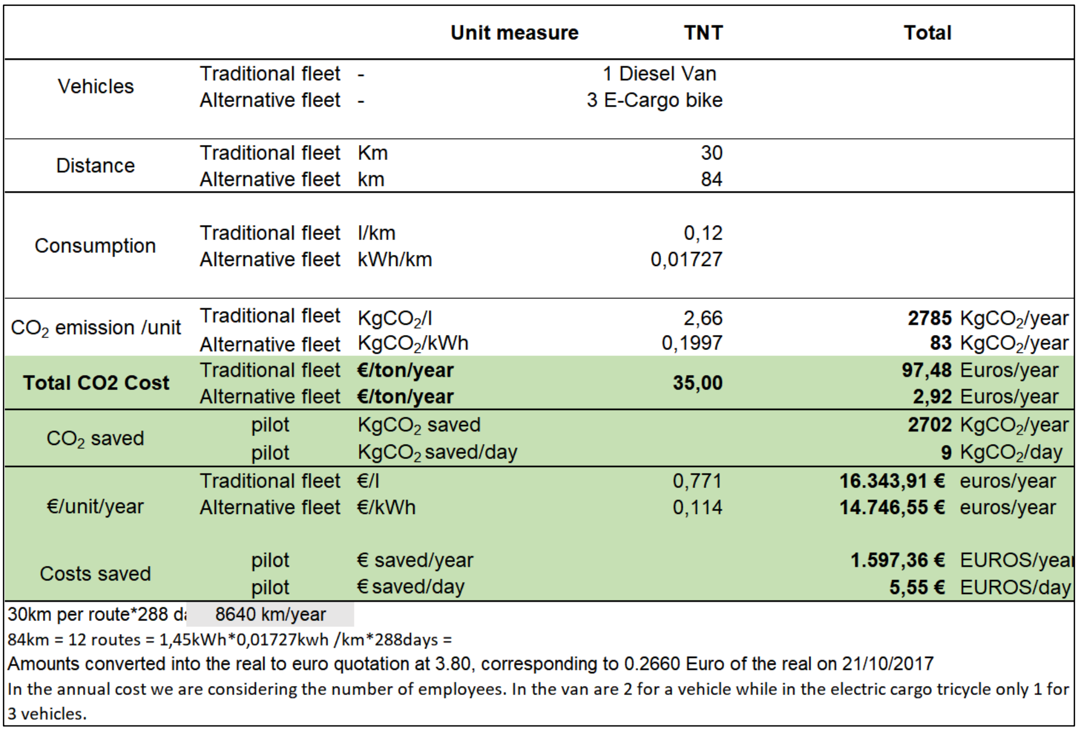


Item	Unit measure	Traditional fleet	Alternative e-fleet
energy cost	€/yr	807,24	47,63
annual depreciation(purchase)	€/yr	4000,00	3060,00
salaries	€/yr	8136,67	11203,92
Maintenance	€/yr	3400,00	435,00
Total	**€/year**	**16343,91**	**14746,55**

8640km / year by the current fleet, van to diesel, which translates to 1047 liters / year, multiplied by the price of diesel = 807.24 euros;
While in the alternative fleet, electric cargo tricycle, it consumes 24192km / year which translates 417,6 kWh / year. Therefore multiplied by the price of energy = 47.63 euros.

Table 17 presents an estimation of environmental and economic effects due to the introduction of e-vehicles, comparing the actual scenario of route 123 with the proposed alternative scenario for the distribution in the same route (using e-tricycles instead of vans). Estimations indicate that this alternative is environmentally much more friendly (97.0% less CO2), and yet seems to reduce actual costs (9.8% less).

Table 17 – Estimation of environmental and economic summary of comparation: actual scenario vs. proposed alternative scenario



		Unit measure	TNT	Total
Vehicles	Traditional fleet	-	1 Diesel Van	
	Alternative fleet	-	3 E-Cargo bike	
Distance	Traditional fleet	Km	30	
	Alternative fleet	km	84	
Consumption	Traditional fleet	l/km	0,12	
	Alternative fleet	kWh/km	0,01727	
CO_2 emission /unit	Traditional fleet	$KgCO_2/l$	2,66	**2785** $KgCO_2$/year
	Alternative fleet	$KgCO_2/kWh$	0,1997	**83** $KgCO_2$/year
Total CO2 Cost	Traditional fleet	**€/ton/year**	**35,00**	**97,48** Euros/year
	Alternative fleet	**€/ton/year**		**2,92** Euros/year
CO_2 saved	pilot	$KgCO_2$ saved		**2702** $KgCO_2$/year
	pilot	$KgCO_2$ saved/day		**9** $KgCO_2$/day
€/unit/year	Traditional fleet	€/l	0,771	**16.343,91 €** euros/year
	Alternative fleet	€/kWh	0,114	**14.746,55 €** euros/year
Costs saved	pilot	€ saved/year		**1.597,36 €** EUROS/yeaı
	pilot	€ saved/day		**5,55 €** EUROS/day

30km per route*288 dı 8640 km/year
84km = 12 routes = 1,45kWh*0,01727kwh /km*288days =
Amounts converted into the real to euro quotation at 3.80, corresponding to 0.2660 Euro of the real on 21/10/2017
In the annual cost we are considering the number of employees. In the van are 2 for a vehicle while in the electric cargo tricycle only 1 for 3 vehicles.

5.4 Proposed alternative strategy for all routes

This strategy consists of: (i) replacing the UCC at Canindé by a transhipment terminal (located at Square Sé); (ii) the transhipment terminal is feeded by a diesel truck that operates from the DC of Vila dos Remédios; and (iii) replacing diesel vans by electric cargo tricycles to distribute goods to clients (setting up new routes from the new transhipment terminal). The location of terminal at Square Sé was selected because it is the local with avaible capacity (in terms of area), near the area of clients.

Table 18 presents a summary of some key aspects that describe the scope of operations for this new distribution strategy.

Table 18 - Key aspects that describe the scope of operations for the new strategy

Characteristc or Parameter	**Electric Tricycle Fleet**	**Van fuelled diesel**
Average number of daily deliveries	240	240
Total daily load (kg)	500 kg	5000 kg
Working hours (h)	8 hours	8 hours
Total distance traveled per day	450 km	197 km
Customer service time(min)	5 minutes	8 minutes
e-Tricycle / Van load (min)	15 minutes	45 minutes
Delivery days per year	288 days	288 days
number of vehicles	12	7
6 days/week, 12 months per year 72 routes		

5.4.1 Fundamentation of the strategy

The alternative distribution system uses a combination of electric cargo tricycles with the installation of a transhipment terminal. The literature suggests that this type system is more agile and more sustainable that more traditional distributions systems based on fossil fuelled fleet. Electric cargo tricycles have no limitations to access the restricted area as they are a different vehicle class. In addition, they are agile and do not pollute the air. On the other hand, the transhipment terminal is a new facility that can increase the participation of more transport operators. The transhipment terminal offers shelter and security for the transsshipment, which also facilitates the work for the company that manages the delivery of the last mile of the terminal. The new process for pilot testing consists of the use of a support terminal that can accommodate more transport operators in the initiative and promote the use of this alternative in the area. One of the main differences with previous approaches is that different transport operators who transfer their products in the terminal could share the same vehicle in the last mile delivery. Another major difference is that the transfer always occurs in the terminal, providing advantages for the transport and terminal operator. This is not the case in this study, since only one operator is considered, the TNT company.

To successfully implement this project, the first key step is building partnerships among all stakeholders involved in urban freight transport, including public and private stakeholders. For example, according to the literature review (Section 3.4), in the case studies of Barcelona and Valencia, city councils were directly involved, since it is the public body responsible for the development and implementation of strategic lines related to urban mobility and transport infrastructures. From a commercial point of view, the transport operator specialized in parcels and express postings, that performs the delivery of goods in the urban consolidation center to be distributed to the final recipient in the city center. The electric cargo tricycles are used for distribution of the last mile of collection and delivery of goods (textiles, confectionery, auto parts, B2B and B2C) and an outsourced company must be contracted for the management of the transhipment terminal. In addition, it is important to include the public authority that manages and manages public and private parks in order to support initiatives that provide space for the base of the transhipment terminal. Finally, the project requires the involvement of the city center retail trade association to take market requirements into account.

5.4.2 Description of the strategy

In this alternative strategy, the last mile distribution is operated by implementing a transhipment center tat feeds e-tricycles routes, covering the central district of the city of São Paulo, specifically the districts of the Center (Sé and República), Santa Cecilia, Brás, Cambuci, Pari -Belém and Bom Retiro. Referring to zip codes, the terminal transhipment is designed to be dynamic and flexible to accommodate future services and changes. Primarily, if it is designed for parcel and similar consignment services (eg clothing). The size and weight of the packages are limited by the total capacity of the tricycles.

It is suggested to open a public tender, so that a company specializing in last-mile deliveries, manage the transhipment terminal. Figure 24 shows the route of the Vila dos Remédios - Praça da Sé in the new strategy and Figure 25 shows the map with the new distribution routes of the central area of the city of São Paulo.

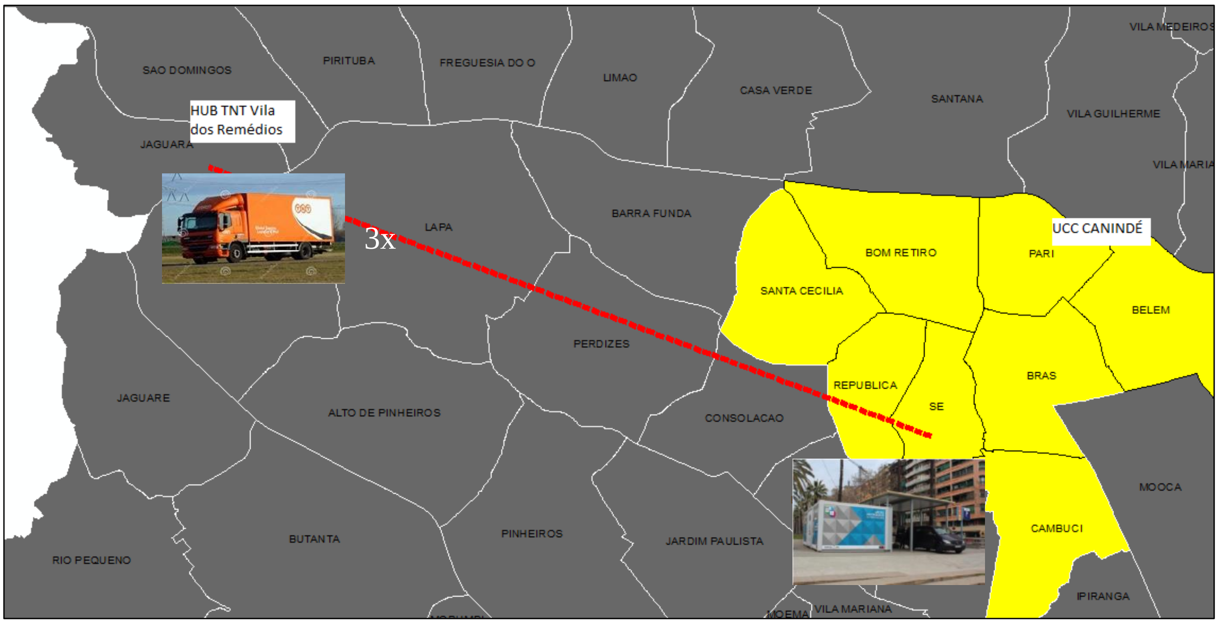


Figure 24 - Vila dos Remédios x Sé Square

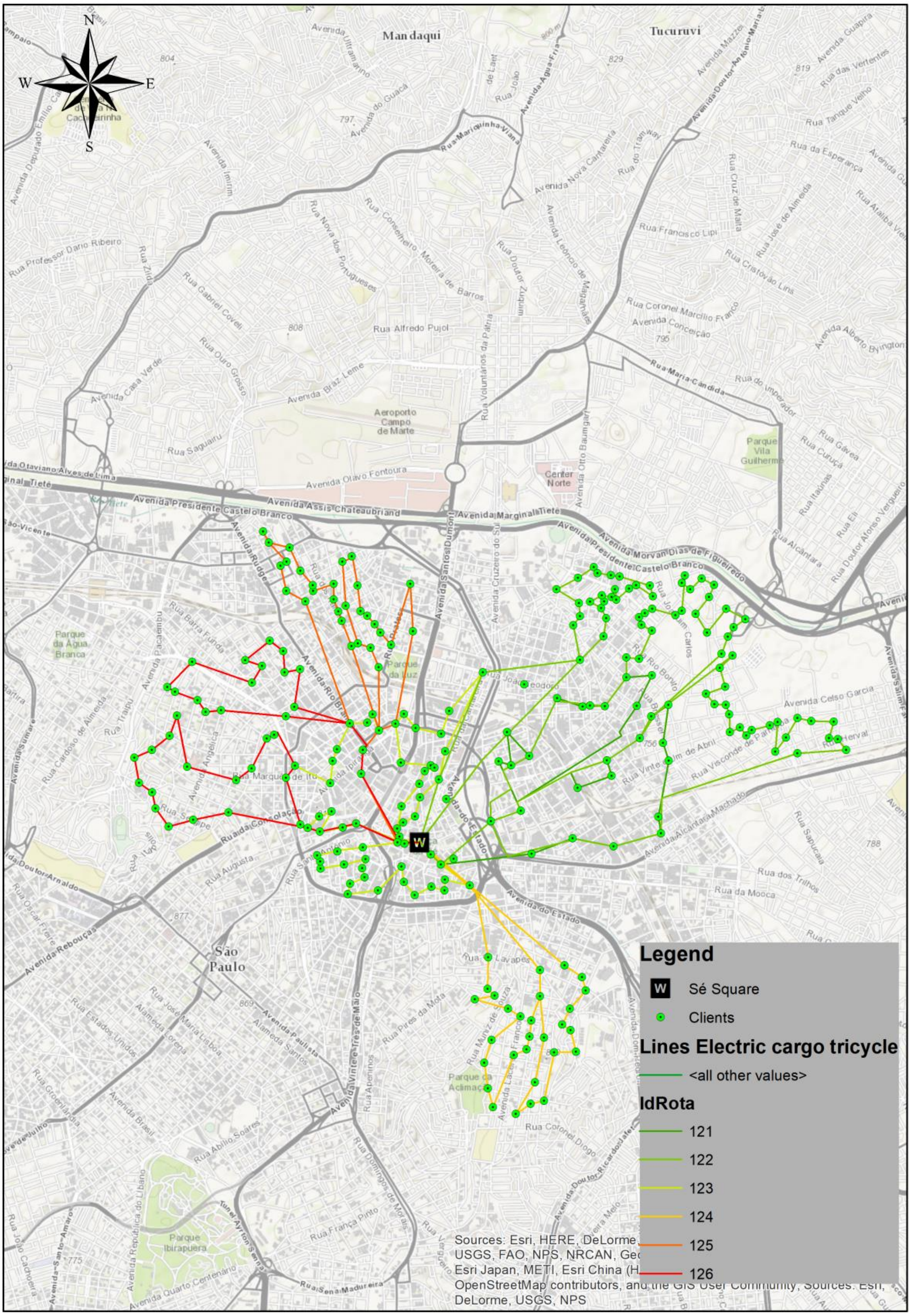


Figure 25 – Routes of the electric cargo tricycles

A study carried out by Navarro et al.,(2016), of a project financed by the European Union was installed in the cities of Barcelona and Valencia Transhipment Terminal.The transhipment terminal can be composed of two different modules, the closed one and a porch. The covered module occupies about 33m2 and a balcony of about 40m2. Inside the module, there are three different spaces. There is a small office where freight drivers can process information. Inside there is a dressing room for drivers and some shelves for temporary storage of orders if required, and also a meeting room that can have multiple uses if needed. The container is used overnight parking for tricycles. The transhipment terminal may be located in a public car park managed by a private company that manages some public parking space in the city center of São Paulo. This company would support the initiative by allowing some of the activities to take place in its facilities: night-time parking for tricycles and recharge, sanitary facilities for workers and storage of batteries of tricycles and other materials.

It should be noted that this is an alternative of a project tested in Barcelona and Valencia, and can be implemented in São Paulo.

The electric cargo tricycles carry parcels in a closed container located at the rear with a load capacity of 1.5 m3 and dimensions of 2.78 m in length, 1.03 m in width and 1.95 m in height. This vehicle can carry a maximum load of 280 kg, although the average transport weight is 180 kg (approximately 40 parcels).

The Figure 27 and Figure 27 presents show the terminal transhipment and the electric cargo tricycles in the city of Barcelona. A similar solution can be implemented in the case of TNT.

Figure 26 - Illustative photo of the last mile distribution system folowed in Barcelona pilot system (1)

This location of the transhipment terminal, at the edge of the access belt of the urban centre of São Paulo, helps to reduce the number of vehicles that enter in the city centre of São Paulo to deliver goods. Electric tricycles are used to deliver goods to reduce the traffic and congestion in this area whilst minimising negative environmental effects such as noise and pollution resulting from urban freight distribution.

Figure 27 - Illustative photo of the last mile distribution system folowed in Barcelona pilot system (2)

5.4.3 Assumptions

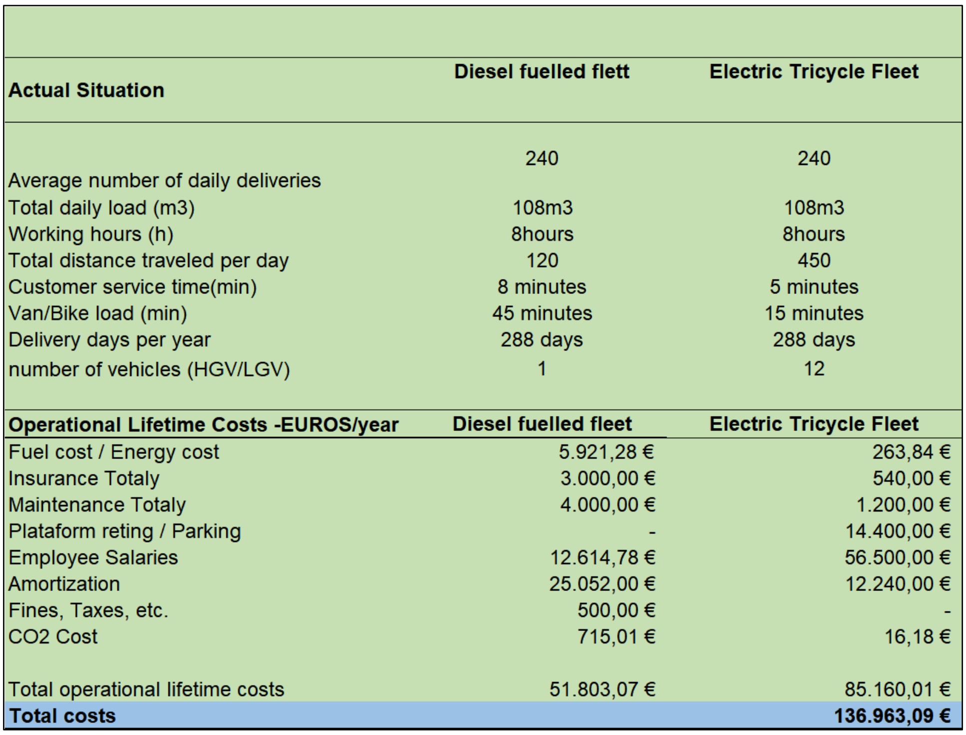
Electric vehicle input: The average energy consumption of 0.01727kWh/km, energy cost is 0.0020€/kWh/km and the maximum load capacity is 1.5 m^3 and an average load between 300 and 500 kg (considering the average weight of the Brazilian driver of 80kg + the weight of the tricycle 150kg + the weight of the 270kg load). In order to combine the same service level of the diesel Vans and find the total number of routes required, we must divide the total volume capacity of the vans by the capacity of the E-CB, corresponding to the creation of seventy-two (72) new routes due the restriction of volumetric capacity of the E-CB's.

To maintain an equal level of service, and carring out the 72 routes, with a total of 450 km daily, it requires the acquisition of 12 E-CB’s with a cost of 61,200 €, a maintenance cost of 1,200 €/year, an insurance of 540 €/year and depreciation 12,240 €/year. This operation will require the hiring of 12 drivers with a cost of 43,903 €/year. We also have the rent of the parking spot with an annual cost of 14 400€/year, there is also the need to insure the operation with the cost of 540 €/year, 288 days of work per year, 8 hours per day (six days a week, twelve months per year).

This operation will require the hiring of 2 drivers for high goods vehicle with a cost of 8,956 €/year, 1 helper with a cost of 3,658 €.

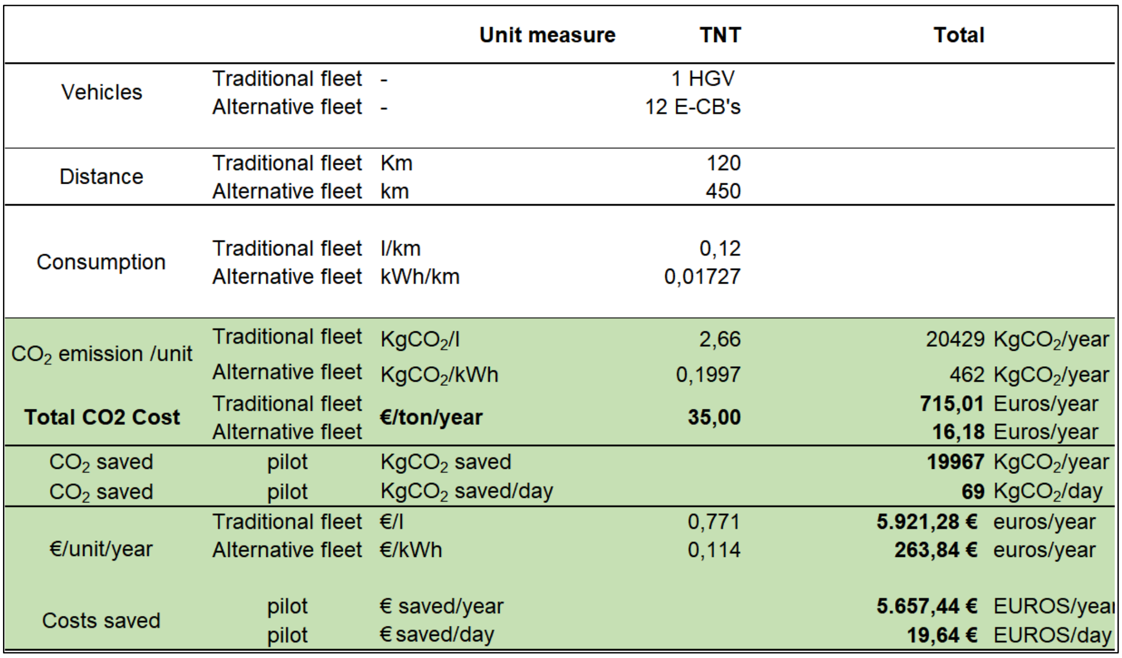
Operation’s inputs: For this operation, we considered 2 heavy vehicles (HGV) of 46m^3, making 3 trips per day from DC Vila dos Remédios - Praça da Sé, traveling a distance of 120 km per day, consuming a total of 26.67 l/km with a cost of 20.56 €/day, totaling 5,921 €/year. Table 19 and Table 20 show the results of the estimated costs and estimated savings costs and emissions for the new strategy, respectively.

Table 19 - Estimated costs for the new strategy with transhipment and electric cargo tricycles



Actual Situation	**Diesel fuelled flett**	**Electric Tricycle Fleet**
Average number of daily deliveries	240	240
Total daily load (m3)	108m3	108m3
Working hours (h)	8hours	8hours
Total distance traveled per day	120	450
Customer service time(min)	8 minutes	5 minutes
Van/Bike load (min)	45 minutes	15 minutes
Delivery days per year	288 days	288 days
number of vehicles (HGV/LGV)	1	12
Operational Lifetime Costs -EUROS/year	**Diesel fuelled fleet**	**Electric Tricycle Fleet**
Fuel cost / Energy cost	5.921,28 €	263,84 €
Insurance Totaly	3.000,00 €	540,00 €
Maintenance Totaly	4.000,00 €	1.200,00 €
Plataform reting / Parking	-	14.400,00 €
Employee Salaries	12.614,78 €	56.500,00 €
Amortization	25.052,00 €	12.240,00 €
Fines, Taxes, etc.	500,00 €	-
CO2 Cost	715,01 €	16,18 €
Total operational lifetime costs	51.803,07 €	85.160,01 €
Total costs		**136.963,09 €**

Table 20 - Estimated savings (costs and emissions) for the new strategy with transhipment and electric cargo tricycles

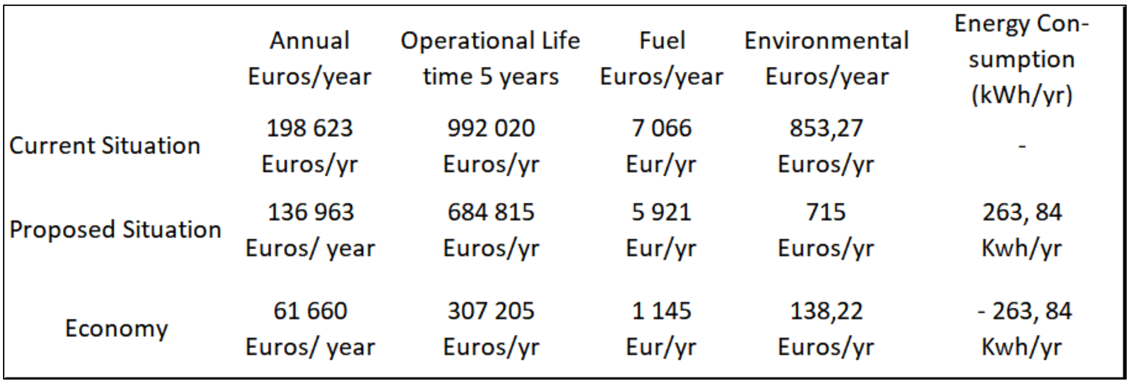


		Unit measure	**TNT**	**Total**
Vehicles	Traditional fleet	-	1 HGV	
	Alternative fleet	-	12 E-CB's	
Distance	Traditional fleet	Km	120	
	Alternative fleet	km	450	
Consumption	Traditional fleet	l/km	0,12	
	Alternative fleet	kWh/km	0,01727	
CO$_2$ emission /unit	Traditional fleet	KgCO$_2$/l	2,66	20429 KgCO$_2$/year
	Alternative fleet	KgCO$_2$/kWh	0,1997	462 KgCO$_2$/year
Total CO2 Cost	Traditional fleet	**€/ton/year**	**35,00**	**715,01** Euros/year
	Alternative fleet			**16,18** Euros/year
CO$_2$ saved	pilot	KgCO$_2$ saved		**19967** KgCO$_2$/year
CO$_2$ saved	pilot	KgCO$_2$ saved/day		**69** KgCO$_2$/day
€/unit/year	Traditional fleet	€/l	0,771	**5.921,28 €** euros/year
	Alternative fleet	€/kWh	0,114	**263,84 €** euros/year
Costs saved	pilot	€ saved/year		**5.657,44 €** EUROS/yea
	pilot	€ saved/day		**19,64 €** EUROS/day

In this particular case, the replacement of a conventional diesel fleet by an alternative fleet of electric cargo tricycles will allow a saving of 31% in terms of annual costs. Regarding the fuel and electric-assisted costs, it was verified that there is a lower consumption than the current scenario of 7,066 €/year and in the proposed situation a cost of 5,921 €/year adding diesel and kWh, thus generating a saving of 1,145 €/year, 16.2% per year. In addition, with respect to the environmental impact, the results show that replacing diesel vans by electric cargo tricycles along with adequately new distribution strategies can represent savings of up to around approximately 20 tonnes of CO2eq emissions per year around of 97% generating savings of 16% in terms of emissions costs. Regarding labor, in the current situation we have a cost of 68,751€/year, while in the alternative scenario it is expected a cost of 56,5007€/year, generating an economy of 36% (note that salaries of cyclists are lower than the salaries of drivers, a fact that contributes for this saving). Finally, with respect to the warehouse renting, it was verified that in the current situation there is a cost of 48,000 €/year, while in the alternative scenario the parking cost of the platform is 14,000 €/year, thus allowing an economy of 70% per year.

Table 21 sumarizes the main savings regarding the substitution of conventional vehicles by an electrically assisted cargo tricyle (based on a total distance of 450 km/day).

Table 21 - Cost savings summary of the new distribution strategy for TNT.



	Annual Euros/year	Operational Life time 5 years	Fuel Euros/year	Environmental Euros/year	Energy Con-sumption (kWh/yr)
Current Situation	198 623 Euros/yr	992 020 Euros/yr	7 066 Eur/yr	853,27 Euros/yr	-
Proposed Situation	136 963 Euros/ year	684 815 Euros/yr	5 921 Eur/yr	715 Euros/yr	263, 84 Kwh/yr
Economy	61 660 Euros/ year	307 205 Euros/yr	1 145 Eur/yr	138,22 Euros/yr	- 263, 84 Kwh/yr

5.5 Summary and discussion of results

Concerning the alternative strategy for the case of route 123, in order to accomplish the same level of service of the vans, the electric cargo tricycle must return to the warehouse more times. It was necessary to create 12 routes, totaling a distance of 84 km with a set of short routes (6 - 7km). Note that electric cargo tricycles have limited weight and volume capacity (500 kg), compared with diesel van (5000 kg). However, the results show a high reduction of emissions of greenhouse gases, replacing the diesel vans with electric tricycles. Using cargo tricycles assisted electrically in São Paulo, CO2eq emissions decreased by at least 97% and decreased by at least 9.8% estimated in the present case study. These emission reductions are similar to other research efforts. Browne *et al.* (2011) evaluated the use of an urban distribution center and electric vehicles in London and reached the same conclusion. CO2eq emissions were reduced by 54%. Fishman and Cherry (2016, p83) summarised "*the emissions of e-bikes are inconsequential and likely better than the set of alternative modes, even in large numbers and if the power sector is dominated by coal (eg China)*".

Regarding the alternative strategy for the case of the entire distribution system of TNT in São Paulo, the proposal is based on a case study comparing Barcelona and Valencia in Spain with several operators. A total number of 12 electric cargo tricycles are needed. On average, a total of 450 km has to be travelled in the scenario from a transhipment point in the central region of São Paulo to 6 new routing zones, totaling 72 new routes, each route serving 3.33 customers, totaling 240 customers (the same number of the actual scenario). Results show an economy of about 13 km per tricycle compared to vans. The savings in the delivery area are due to car restrictions in the area, which tricycles do not have. So the driver of the van is bound to deviate from the restrictions, while the tricycles can drive more directly. CO2eq emissions are reduced by at least 97%. The values are significant, showing clear potential in reducing impacts to citizens.

In general, we consider that the alternative distribution strategy and technological option will have a significant positive impact in society, contributing to a better economy and environment. From observations in the field during the data colletion phase of this study, the perception is that there is a high level of acceptance of this type of solutions.

6. CONCLUSIONS AND SUGGESTIONS FOR FURTHER WORK

This research arises from the need to understand if a new technological, more environmentally friendly alternative has the potential of benefiting companies that deliver goods and services in an urban environment. This dissertation analised the possibility of replacing conventional diesel fleets by electric cargo tricycles. The main conclusion is that the investigation question of this reseach was confirmed, i.e. the alternative distribution solution will allow to reduce costs, emissions of gases and energy consumption. The hypotheses tested were clearly accepted, confirming their premises.

The comparison of the performance of the use of the electric cargo tricycles with the diesel fleet is feasible in economic and environmental terms in the transport of loads in urban areas has been proved. The alternative fleet presented is capable of maximizing the use of resources and the harmonious operation of the cargo transportation system in the urban area, reducing its environmental impacts without damaging economic activities, improving the level of eco-efficiency and generating positive contributions to the perception of society.

This study included various types of costs (purchase, wages, maintenance, insurance, fuel and energy costs, CO2 cost), operational parameters (transported weight and volume, daily distance) and vehicle specifications (consumption, load capacity, mileage of life). To assess actual costs and operating conditions, it were conducted field observation and applied non-structured interviews to main stakeholders involved: company managers, drivers and helpers, and customers. Costs and savings of alternative distribution strategies were estimated in current monetary terms and in different perspetives (annual, total, operational, environmental, and life costs), tacking in account the different vehicle technologies, namely diesel vans and electric cargo tricycles.

Field observations that managers, employees, and customers recognize only environmental benefits. This lack of awareness is something that this work tries to solve, by showing the company that there is also potential economical benefits if it it implements new distribution strategies based on the use of electric cargo tricycles. It should be noted that the costs and savings presented in our analyses are only indicative, mainly because secondary aspects (costs and benefits) were not taken in account in this study, such as the influence of driver behaviour in maintenance costs and energy consumption, or the influence of delays due to traffic congestion and additional delays and distances that may needed when loking for a parking space close to clients (these problems are frequent at some hours in some zones of São Paulo).

In future developments, it will be relevant to investigate some other factors that may affect the relative performance (including operational effect, and social and economical impacts) of alternative technologies and distribution strategies: ex. the number and severity of road accidents, the effective space that can be saved by replacing consolidation centres (warehouses) and trucks by transhipment terminals and electric cargo tricycles (including space for cities) consolidation centers and more.

In this dissertation, only one logistic profile was directed (CEP). It would be important to assess the suitability of electric cargo tricycles for other profiles (e.g., Retail, Horeca, Construction, Waste), in order to generalize results and show to urban distribution operators that these vehicles are indeed part of the solution to urban logistics challenges, and can be widely used in most of the cases with potential benefits. In general, it is also important to show to society and public authorities and decisors that cargo tricycles have the potential to effectively replace polluting vehicles (adequating distribution strategies), and represent a viable and environmentally friendly transportation option in all the parameters involved for a sustainable and harmonious urban mobility.

Lastly, it is good to emphasize that transport problems have long been respectful of only engineers, managers, planners, etc., but of human and social character. It needs to be seen in an interdisciplinary way, from the perspective of different looks, to think and to act. It's definitely a behavioral issue.

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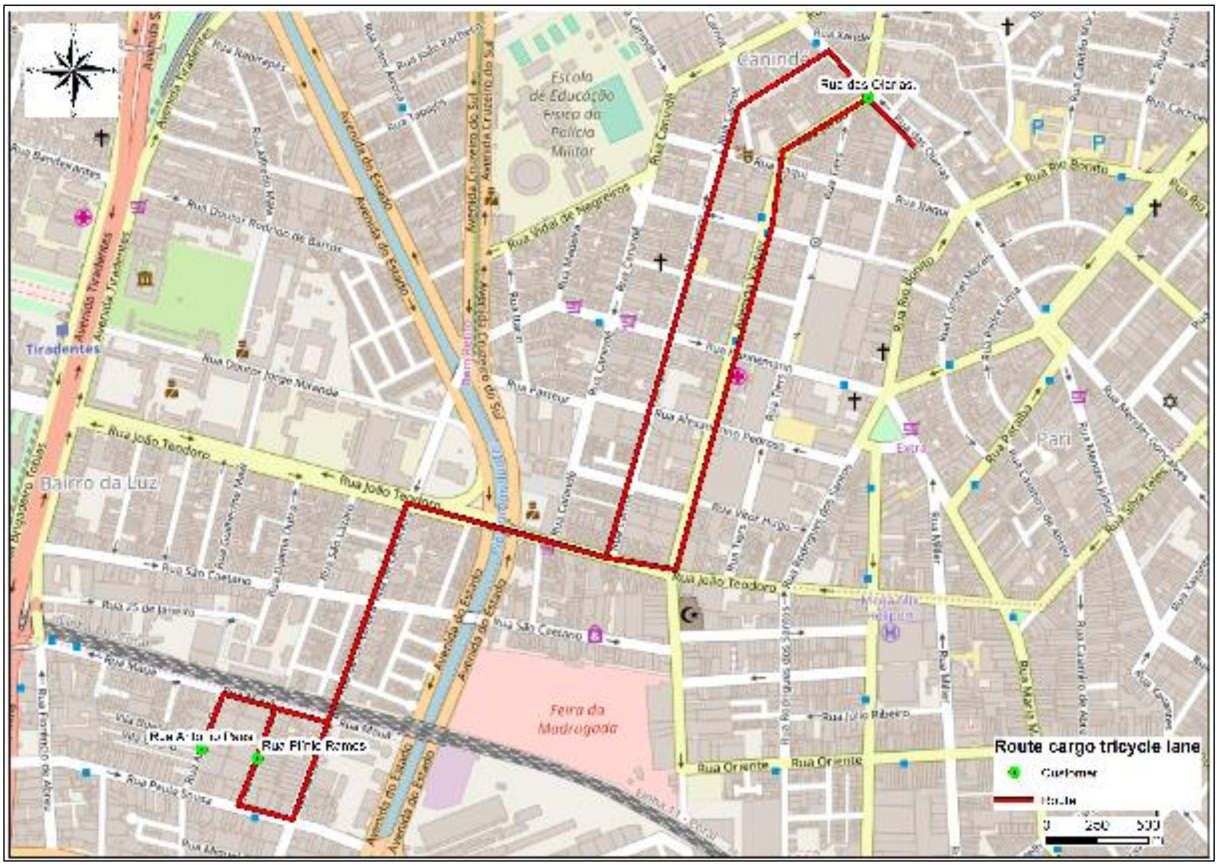
APPENDIX 1 – COLLECTED DATA FROM FIELD OBSERVATION (ROUTE 123)

Pesquisador	Paulo		
Van Sprinter D311			
Rota	123 - Centro		
Número de clientes	14		
Equipe	1 motorista + 1 ajudante		
Cenário	Van à diesel		
	Início	Fim	Km ou mi
Horário de saída do UCC	08:50		
Tempo gasto do UCC até o 1ºcliente	08:50	09:00	00:10
Distância do UCC até o 1ºcliente			2,50
Tempo parado ponto 1	00:13		
Tempo do ponto de parada1 para o ponto de parada 2	09:13	09:16	00:03
Distância do ponto de parada 1 para o ponto de parada 2			0,30
Tempo parado no ponto 2	00:04		
Tempo do ponto de parada2 para o ponto de parada 3	09:20	09:25	00:05
Distância do ponto de parada 2 para o ponto de parada 3			0,75
Tempo parado no ponto 3	00:14		
Tempo do ponto de parada 3 para o ponto de parada 4	09:39	09:44	00:05
Distância do ponto de parada 3 para o ponto de parada 4			0,65
Tempo parado no ponto 4	01:04		
Tempo do ponto de parada 4 para o ponto de parada 5	10:48	11:00	00:12
Distância do ponto de parada 4 para o ponto de parada 5			0,90
Tempo parado no ponto 5	00:03		
Tempo do ponto de parada 5 para o ponto de parada 6	11:03	11:10	00:07
Distância do ponto de parada 5 para o ponto de parada 6			2,10
Tempo parado no ponto 6	00:08		
Tempo do ponto de parada 6 para o ponto de parada 7	11:18	11:27	00:09
Distância percorrida da parada 6 para a parada 7			1,60
Tempo parado no ponto 7	00:20		
Tempo do ponto de parada 7 para o ponto de parada 8	11:47	11:55	00:08
Distância percorrida da parada 7 para a parada 8			3,50
Tempo parado no ponto 8	00:27		
Pausa para o almoço	01:00		
Tempo do ponto de parada 8 para o ponto de parada 9	14:00	14:23	00:23
Distância percorrida da parada 8 para a parada 9			3,30
Tempo parado no ponto 9	00:11		
Tempo do ponto de parada 9 para o ponto de parada 10	14:34	14:50	00:16
Distância percorrida da parada 9 para a parada 10			2,10
Tempo parado no ponto 10	00:30		
Tempo do ponto de parada 10 para o ponto de parada 11	15:20	15:35	00:15
Distância percorrida da parada 10 para a parada11			3,00
Tempo parado no ponto 11	00:25		
Tempo do ponto de parada 11 para o ponto de parada 12	16:00	16:10	00:10
Distância percorrida da parada 11 para a parada 12			1,90
Tempo parado no ponto 12	00:05		
Tempo do ponto de parada 12 para o ponto de parada 13	16:15	16:19	00:04
Distância percorrida da parada 12 para a parada 13			0,65
Tempo parado no ponto 13	00:04		
Tempo do ponto de parada 13 para o ponto de parada 14	16:24	16:30	00:06
Distância percorrida da parada 13 para a parada 14			1,80
Tempo parado no ponto 14	00:06		
Distância até o UCC			4,50
Tempo até o UCC	00:20		
Horário de chegada no UCC	16:56		
Distância total percorrida	29,55	Km	
Tempo total da rota	07:27		
Número total de clientes atendidos	14 notas		
OBS: da para 7 para a parada 8 o carro ficou cerca de 40 minutos esperando vaga para estacionar			

APPENDIX 2 – DESCRIPTION OF E-CARGO TRICYCLES ROUTES

Route 1



Warehouse 2,6km -> Customer1 (Plínio Ramos) 0,4km -> Customer 2 (Antonio Paes) ->2,5km – Warehouse

Total Distance – 5,5km

Total ascent: 42metres

Total descent: 423 metres

Maximum gradiente ascending: 3% at 0,4km

Maximum gradiente descending: 4% at 3,4km

Total cycle time to complete the route:

1) Time to charge the tricycle in the warehouse: 30minutes;

2) Circulation time on the route

Average speed tricycle: 4m/s => 15 km/h;

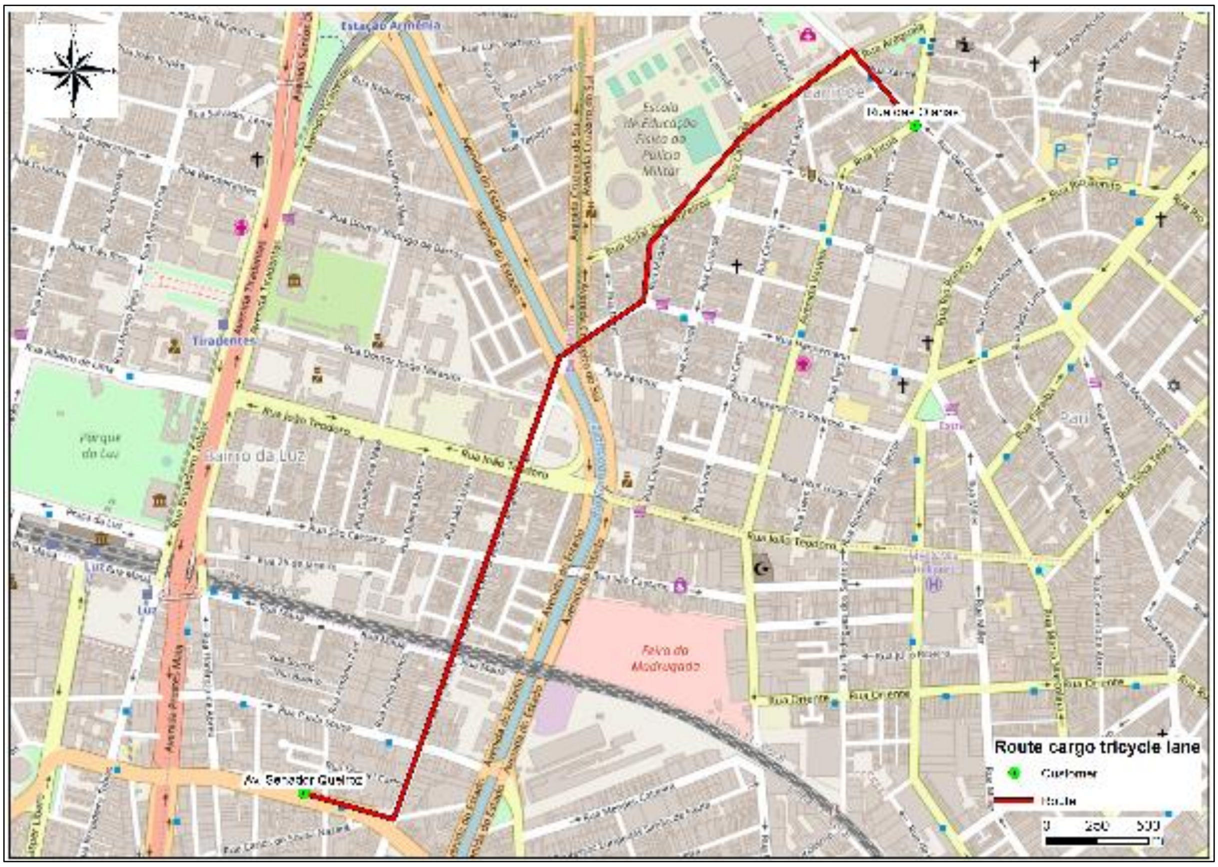
$$T = \frac{Distance}{Speed}\ x\ 60' = \frac{5,5}{15} x\ 60$$ = 22 minutes

3)Average time de unloading customer=> 8min.

2 clientes = 16 minutes

Total cycle time => ∑ (1+2+3) => 30+22+16 = 68minutes = 1h08min.

Route 2



Warehouse 2,8km -> Customer Senador Queiroz 3,1km–> Warehouse

Total Distance – 6,5km

Total ascent: 66metres

Total descent: 66 metres

Maximum gradiente ascending: 9% at 3km

Maximum gradiente descending: 7% at 4km

Total cycle time to complete the route:

1) Time to charge the tricycle in the warehouse: 30minutes;

2) Circulation time on the route

Average speed tricycle: 4m/s => 15 km/h;

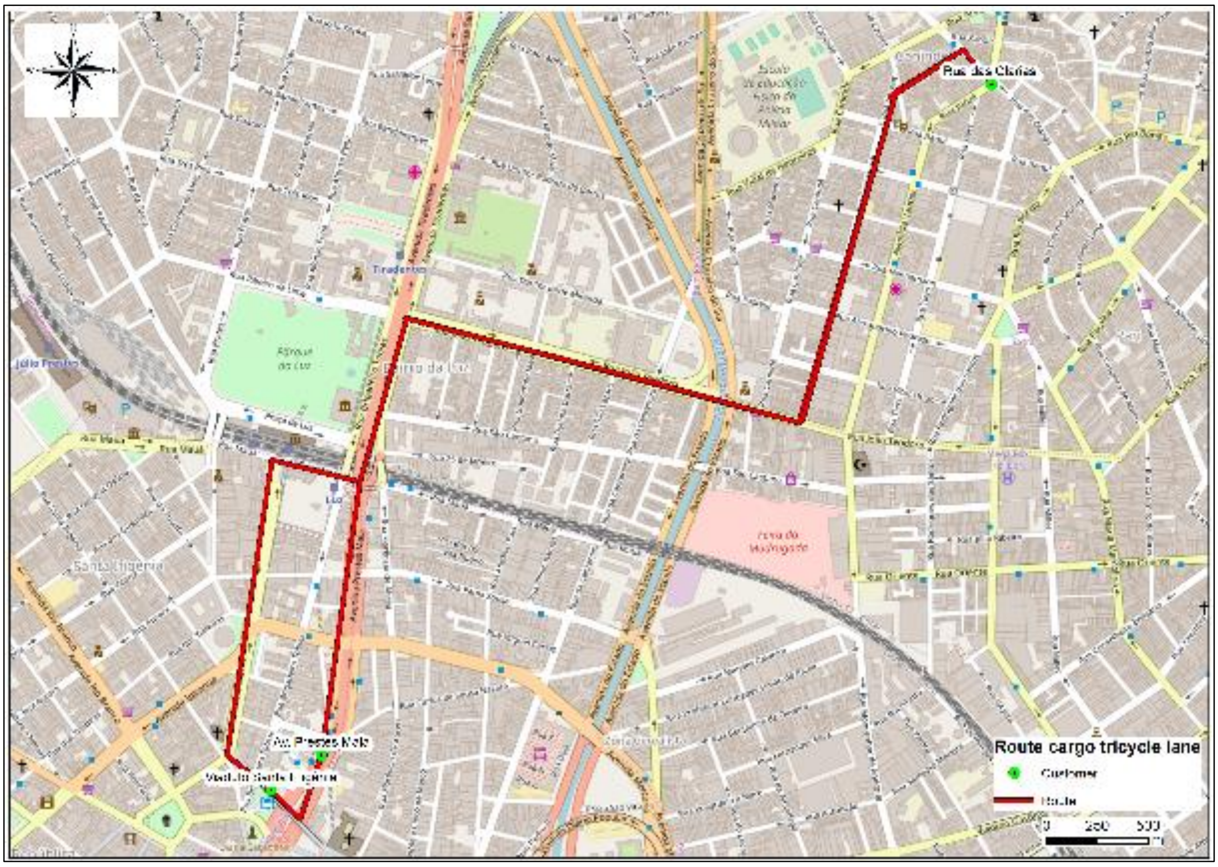
$$T = \frac{Distance}{Speed}\ x\ 60' = \frac{6{,}5}{15} x\ 60$$ = 26 minutes

3)Average time de unloading customer=> 8min.

1 customer = 8 minutes

Total cycle time => ∑ (1+2+3) => 30+26+8 = 64minutes = 1h04min.

Route 3



Warehouse 3,7km -> Customer1Viaduto Sta.Efigênia 0,9km-> Customer2 Av.Prestes Maia -> 3,1km–> Warehouse

Total distance traveled – 7,7km

Total ascent: 81metres

Total descent: 81 metres

Maximum gradiente ascending: 4% at 2,5km

Maximum gradiente descending: 7% at 5,2km

Total cycle time to complete the route:

1) Time to charge the tricycle in the warehouse: 30minutes;

2) Circulation time on the route

Average speed tricycle: 4m/s => 15 km/h;

$T = \frac{Distance}{Speed}\ x\ 60' = \frac{7,7}{15} x\ 60$ = 31 minutes

3)Average time de unloading customer=> 8min.

2 cutomers = 16 minutes

Total cycle time => ∑ (1+2+3) => 30+31+16 = 77minutes = 1h17min

Route 4

Warehouse 5,2km -> Customer1Martins Fontes Street -> 5,4km–> Warehouse

Total distance traveled – 10,6km

Total ascent: 149metres

Total descent: 149 metres

Maximum gradiente ascending: 10% at 4,6km

Maximum gradiente descending: 10% at 4,5km

Total cycle time to complete the route:

1) Time to charge the tricycle in the warehouse: 30minutes;

2) Circulation time on the route

Average speed tricycle: 4m/s => 15 km/h;

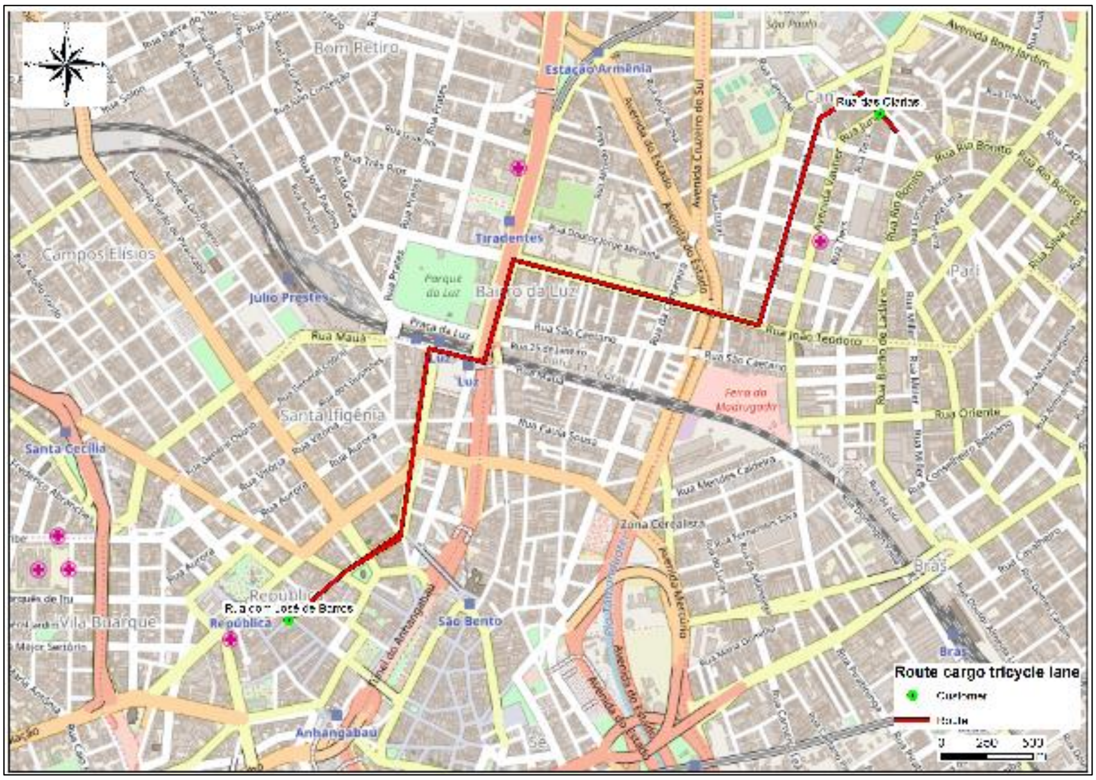
$T = \frac{Distance}{Speed}\ x\ 60' = \frac{10,6}{15} x\ 60$ = 43 minutes

3)Average time de unloading customer=> 8min.

1 costumer = 8 minutes

Total cycle time => ∑ (1+2+3) => 30+43+8 = 81minutes = 1h21min

Route 5



Warehouse 4,5km -> Customer1Dom José de Barros Street -> 4,3km–> Warehouse

Total distance traveled – 8,8km

Total ascent: 96metres

Total descent: 96 metres

Maximum gradiente ascending: 6% at 4km

Maximum gradiente descending: 7% at 3,8km

Total cycle time to complete the route:

1) Time to charge the tricycle in the warehouse: 30minutes;

2) Circulation time on the route

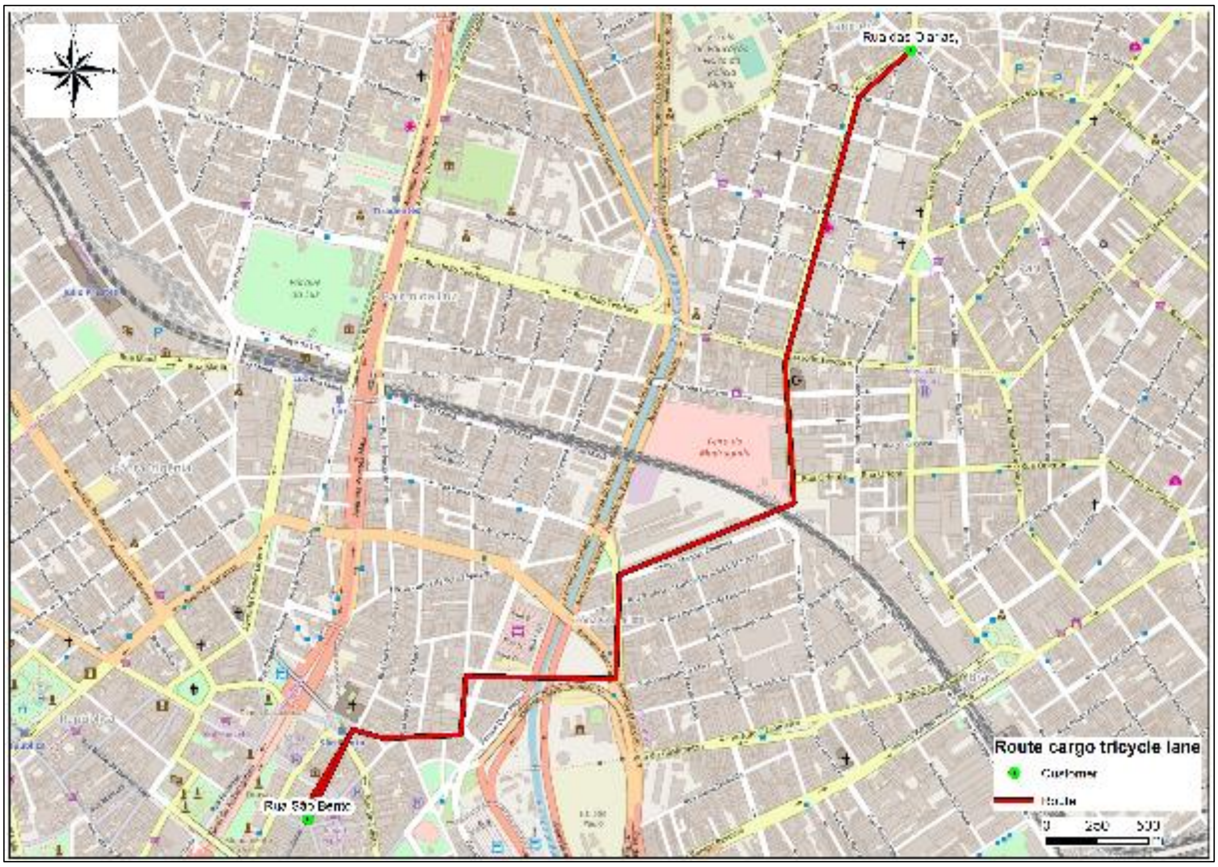
Average speed tricycle: 4m/s => 15 km/h;

$$T = \frac{Distance}{Speed}\ x\ 60' = \frac{8,8}{15} x\ 60 \text{ = 35 minutes}$$

3)Average time de unloading customer=> 8min.1 costumer = 8 minutes

Total cycle time => ∑ (1+2+3) => 30+35+8 = 73minutes = 1h13min

Route 6



Warehouse 3,7km -> Customer1São Bento Street -> 4,5> Warehouse

Total distance traveled – 8,2km

Total ascent: 109metres

Total descent: 109 metres

Maximum gradiente ascending:12% at 3,4km

Maximum gradiente descending: 9% at 4,3km

Total cycle time to complete the route:

1) Time to charge the tricycle in the warehouse: 30minutes;

2) Circulation time on the route

Average speed tricycle: 4m/s => 15 km/h;

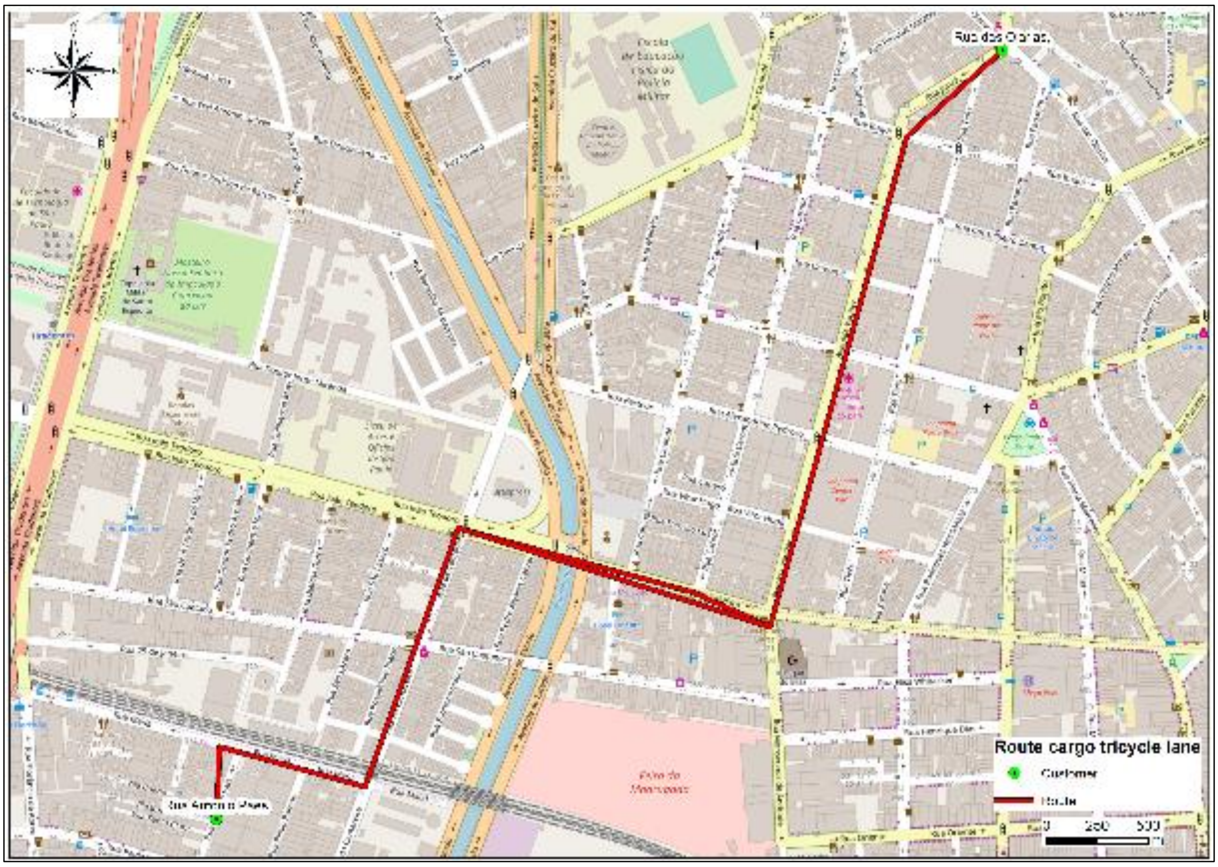
$T = \frac{Distance}{Speed}\ x\ 60' = \frac{8,2}{15} x\ 60$ = 33 minutes

3)Average time de unloading customer=> 8min.

1 costumer = 8 minutes

Total cycle time => ∑ (1+2+3) => 30+33+8 = 71minutes = 1h11min

Route 7



Warehouse 2,4km -> Customer1Antonio Paes Street -> 2,5> Warehouse

Total distance traveled – 4,9km

Total ascent: 36metres

Total descent: 36 metres

Maximum gradiente ascending: 3% at 0,4km

Maximum gradiente descending: 4% at 2,8km

Total cycle time to complete the route:

1) Time to charge the tricycle in the warehouse: 30minutes;

2) Circulation time on the route

Average speed tricycle: 4m/s => 15 km/h;

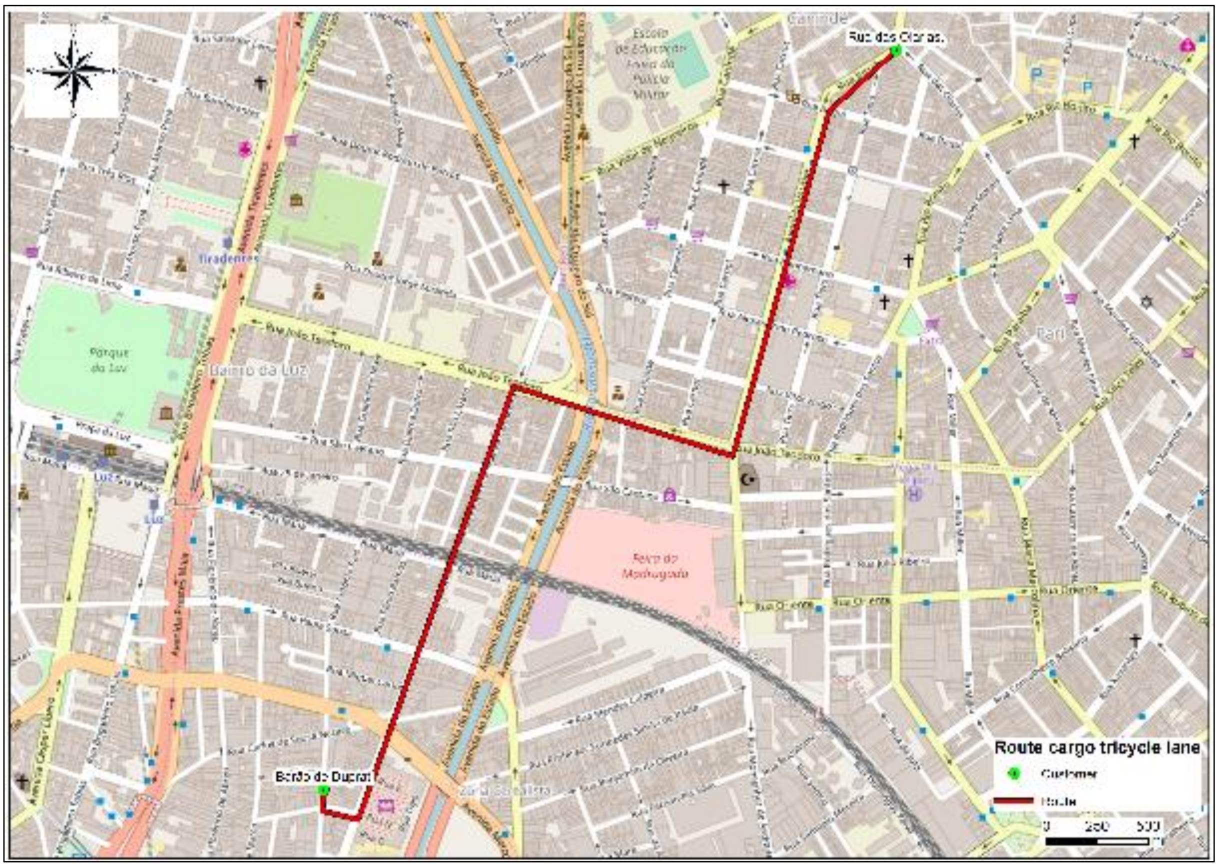
$$T = \frac{Distance}{Speed}\ x\ 60' = \frac{4{,}9}{15} x\ 60 = 20 \text{ minutes}$$

3)Average time de unloading customer=> 8min.

1 costumer = 8 minutes

Total cycle time => ∑ (1+2+3) => 30+20+8 = 58minutes = 58min

Route 8



Warehouse 2,8km -> Customer1Barão de Duprat Street -> 3,4 km> Warehouse

Total distance traveled – 6,2km

Total ascent: 46metres

Total descent: 46 metres

Maximum gradiente ascending: 3% at 0,4km

Maximum gradiente descending: 4% at 3km

Total cycle time to complete the route:

1) Time to charge the tricycle in the warehouse: 30minutes;

2) Circulation time on the route

Average speed tricycle: 4m/s => 15 km/h;

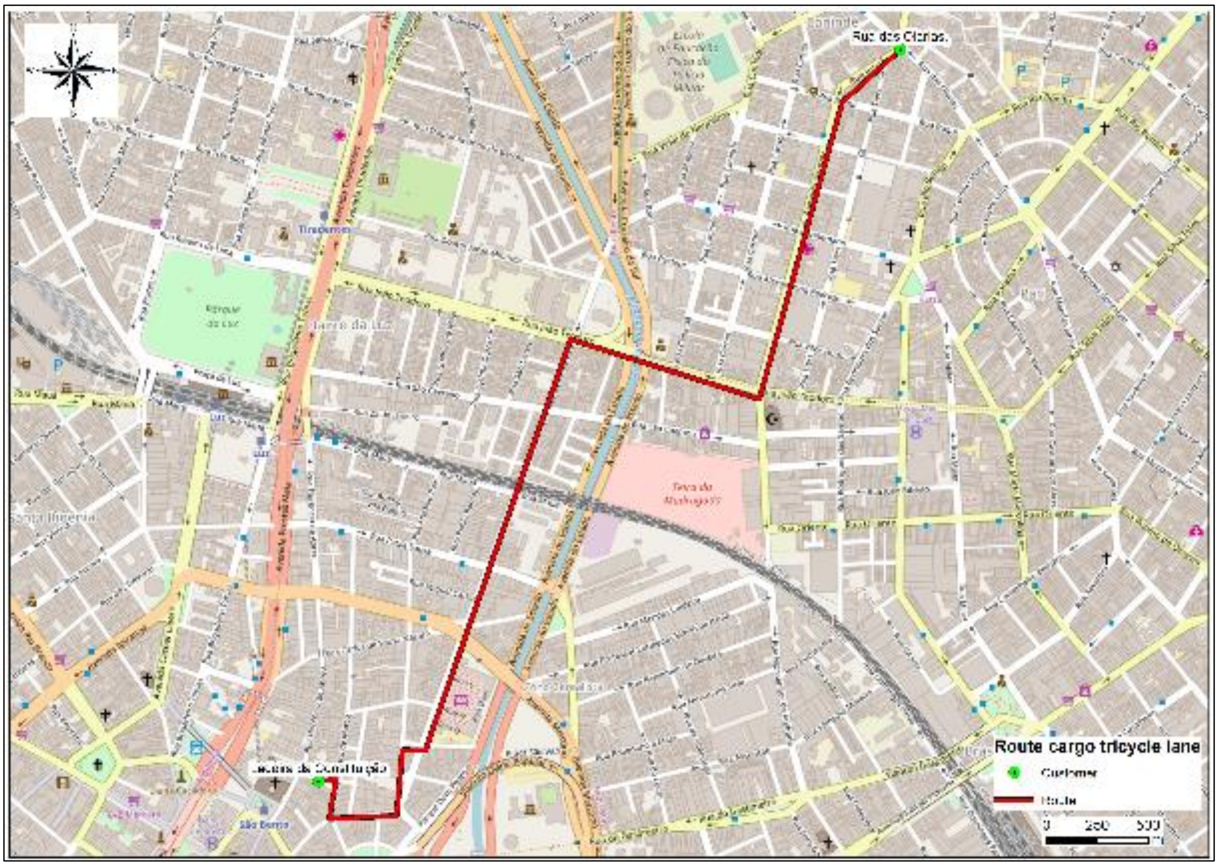
$T = \frac{Distance}{Speed}\ x\ 60' = \frac{6,2}{15} x\ 60$ = 25 minutes

3)Average time de unloading customer=> 8min.

1 costumer = 8 minutes

Total cycle time => ∑ (1+2+3) => 30+25+8 = 63minutes = 1h 03min

Route 9



Warehouse 3,3km -> Customer1Ladeira da Constituição Street -> 3,6 km> Warehouse

Total distance traveled – 6,9km

Total ascent: 63metres

Total descent: 63 metres

Maximum gradiente ascending: 4% at 2,7km

Maximum gradiente descending: 12% at 3,6km

Total cycle time to complete the route:

1) Time to charge the tricycle in the warehouse: 30minutes;

2) Circulation time on the route

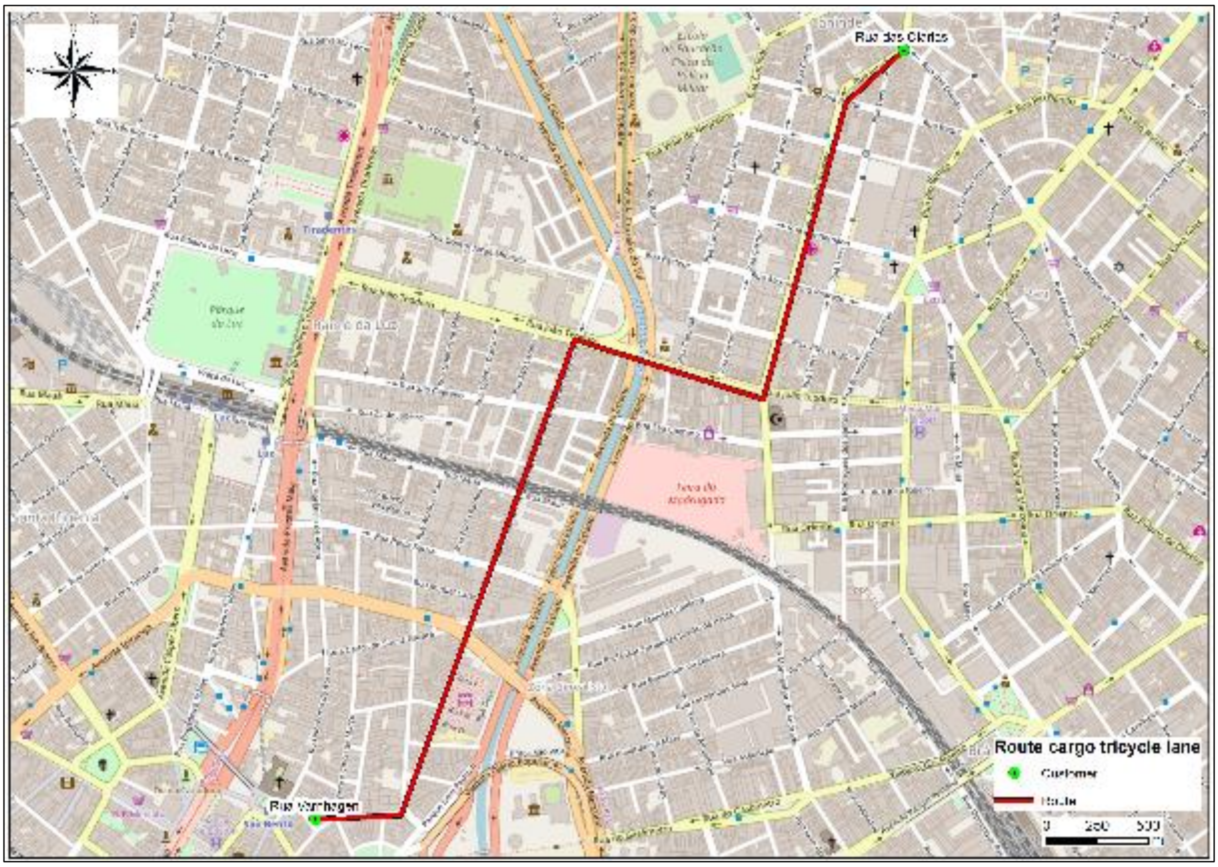
Average speed tricycle: 4m/s => 15 km/h;

$T = \frac{Distance}{Speed}\ x\ 60' = \frac{6{,}9}{15} x\ 60$ = 28 minutes

3)Average time de unloading customer=> 8min.1 costumer = 8 minutes

Total cycle time => ∑ (1+2+3) => 30+28+8 = 66minutes = 1h 06min

Route 10



Warehouse 3,3km -> Customer1Varnhagen Street -> 3,5 km> Warehouse

Total distance traveled – 6,8km

Total ascent: 70metres

Total descent: 70 metres

Maximum gradiente ascending: 14% at 3,2km

Maximum gradiente descending: 14% at 3,3km

Total cycle time to complete the route:

1) Time to charge the tricycle in the warehouse: 30minutes;

2) Circulation time on the route

Average speed tricycle: 4m/s => 15 km/h;

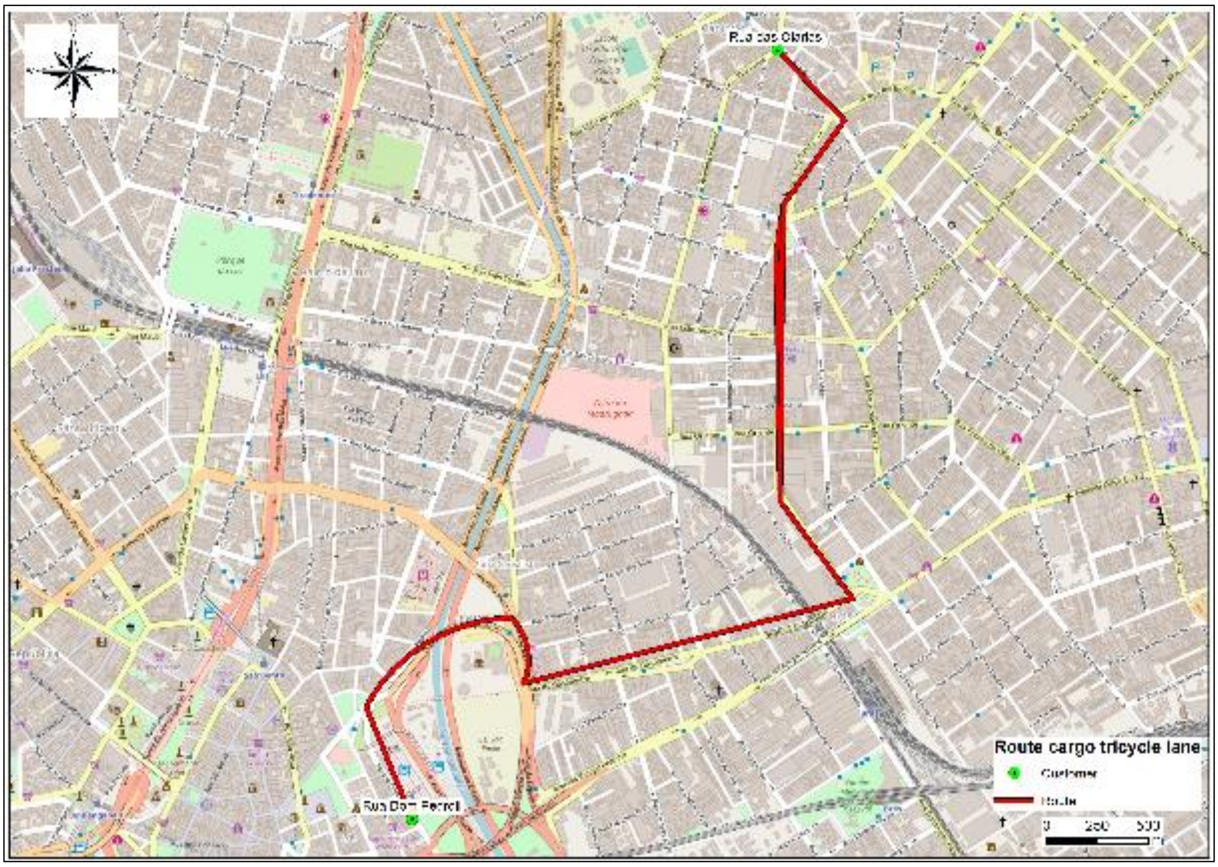
$$T = \frac{Distance}{Speed}\ x\ 60' = \frac{6,8}{15} x\ 60 = 27 \text{ minutes}$$

3)Average time de unloading customer=> 8min.

1 costumer = 8 minutes

Total cycle time => ∑ (1+2+3) => 30+27+8 = 65minutes = 1h 05min

Route 11



Warehouse 2,9km -> Customer1 Dom Pedro Park -> 3,4 km> Warehouse

Total distance traveled – 6,3km

Total ascent: 58metres

Total descent: 58 metres

Maximum gradiente ascending: 5% at 2,8km

Maximum gradiente descending: 7% at 3,5km

Total cycle time to complete the route:

1) Time to charge the tricycle in the warehouse: 30minutes;

2) Circulation time on the route

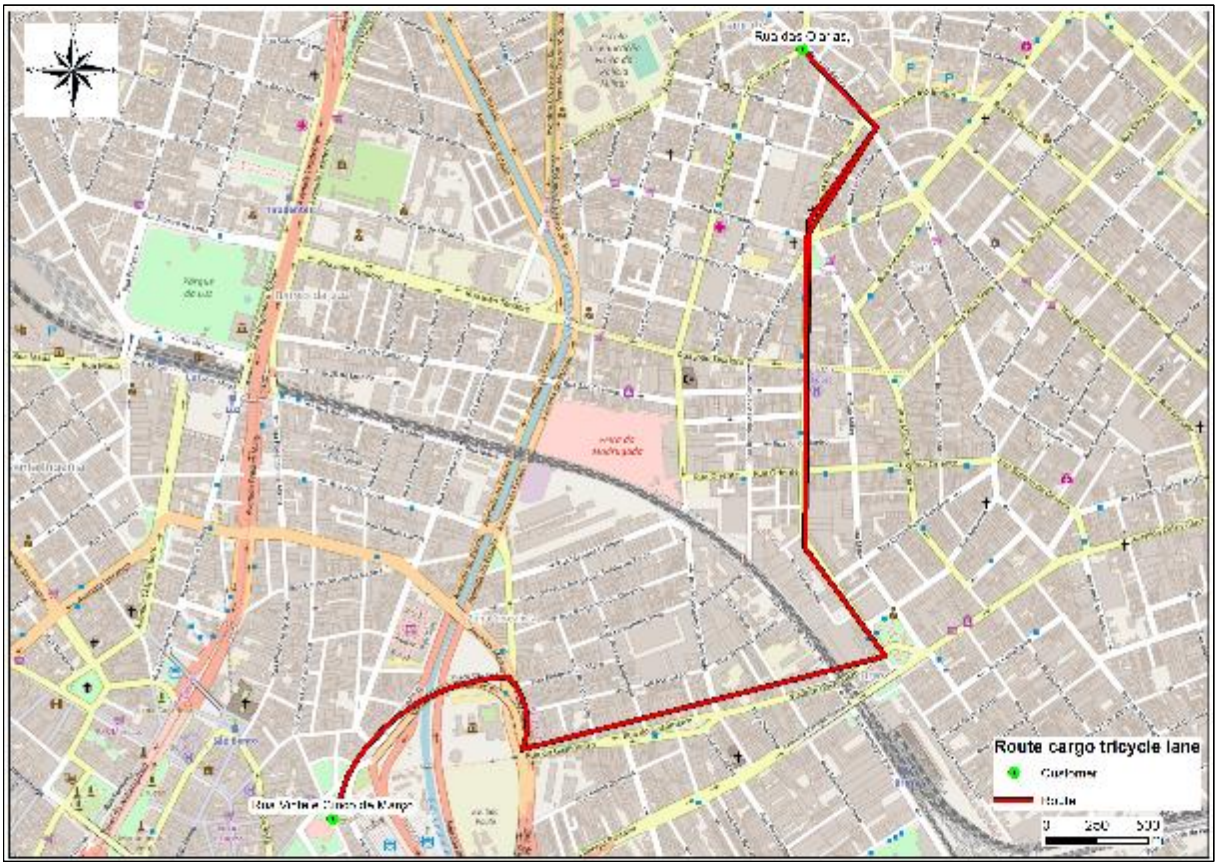
Average speed tricycle: 4m/s => 15 km/h;

$$T = \frac{Distance}{Speed}\ x\ 60' = \frac{6{,}3}{15} x\ 60 = 25 \text{ minutes}$$

3) Average time de unloading customer=> 8min.1 costumer = 8 minutes

Total cycle time => ∑ (1+2+3) => 30+25+8 = 63minutes = 1h 03min

Route 12



Warehouse 3,0km -> Customer1 Vinte e cinco de março Street -> 3,6 km> Warehouse

Total distance traveled – 6,6km

Total ascent: 54metres

Total descent: 54 metres

Maximum gradiente ascending: 4% at 3,1km

Maximum gradiente descending: 12% at 3,5km

Total cycle time to complete the route:

1) Time to charge the tricycle in the warehouse: 30minutes;

2) Circulation time on the route

Average speed tricycle: 4m/s => 15 km/h;

$$T = \frac{Distance}{Speed}\ x\ 60' = \frac{6{,}6}{15} x\ 60$$ = 27 minutes

3) Average time to unload on the customer=> 8min.

1 costumer = 8 minutes

Total cycle time => ∑ (1+2+3) => 30+27+8 = 65minutes = 1h 05min

How many routes can be served by an e-cargo tricycle per day?

Hours available per day = 8 hours (taking 1 hour of lunch)

Working hours worked

Considering a gap (safety margin) of 25%, ie useful time of 8h x 60 minutes x 0.75% => 360 min per day.

Total time on routes = 812 minutes = 13h 30min

Total average time on routes = 68 minutes = 1h 08 minutes

Number of routes= $\frac{\text{time worked hrs/day}}{Average\ time\ per\ route} = \frac{360}{68}$ => 5,3 rotes per day

Number of e-cargo tricycles:

Considering 5 daily routes, will be required: $\frac{12}{5}$ => 2,4 E-cargo tricycle ~ 3 vehicles

APPENDIX 3 – CASE STUDY 2:

How many electric cargo tricycles are needed for all 72 routes?

11,74 => 12 Electric cargo tricycles

Zone 121 – Brás – 7,8 routes

Total distance traveled – 36,73 kms

Average distance per route – 4,7km

Total cycle time to complete the route:

1) Time to loading the tricycle in the warehouse: 15 minutes;

2) Circulation time on the route

Average speed tricycle: 4m/s => 15 km/h;

$T = \frac{Distance}{Speed}\ x\ 60' = \frac{36{,}73}{15} x\ 60$ = 146,92 minutes

3) Average time to unload on the customer=> 5min.
1 costumer = 5 minutes

Total cycle time => ∑ (1+2+3) => (15*7,8)+146,92+(5*26) = 393,92minutes = 6 hours 34 min.

How many e-cargo tricycle are needed to do the 7,8 routes per day?

Hours available per day = 8 hours (taking 1 hour of lunch)

Working hours worked

Considering a gap (safety margin) of 25%, ie useful time of 8h x 60 minutes x 0.75% => 360 min per day.

Total time on routes = 393,92 minutes = 6 Hours 34 Min.

Total average time on routes = 50 minutes

Number of routes= $\frac{\text{time worked hrs/day}}{Average\ time\ per\ route} = \frac{360}{50{,}5}$ => 7,12 routes per day

7,12The total number of E-CB's will be equal to the number of routes of zone (7,8) divided by the number of routes per day per E-CB's.

Number of e-cargo tricycles:

Considering 7,8 daily routes, will be required: $\frac{7,8}{7,12}$ => 1,09 E-cargo tricycle

Calculate the average daily distance that each electric charge tricycle runs through.

Average daily distance= $\frac{Distance}{number\ E-CB}$ = $\frac{36,73}{1,09}$ = 33,57kms

As each E-CB 'has a range of 50km, then a charged battery is enough for a day's work

Zone 122 – Pari-Belém – 19,5 routes

Total distance traveled – 179,79 kms

Average distance per route – 9220 km

Total cycle time to complete the route:

1) Time to loading the tricycle in the warehouse: 15 minutes;

2) Circulation time on the route

Average speed tricycle: 4m/s => 15 km/h;

$T = \frac{Distance}{Speed}\ x\ 60' = \frac{179,79}{15} x\ 60$ = 719 minutes

3) Average time to unload on the customer=> 5min.

1 costumer = 5 minutes

Total cycle time => ∑ (1+2+3) => (15*19,5)+719+(5*65) = 1336,5minutes = 22 Hour and17 min.

How many e-cargo tricycle are needed to do the 19,5 routes per day?

Hours available per day = 8 hours (taking 1 hour of lunch)

Working hours worked

Considering a gap (safety margin) of 25%, ie useful time of 8h x 60 minutes x 0.75% => 360 min per day.

Total time on routes = 1336,5 minutes = 22 Hour 17 minutes

Total average time on routes = 68,54 minutes = 1 Hour 9 minutes

Number of routes= $\frac{\text{time worked hrs/day}}{Average\ time\ per\ route} = \frac{360}{68{,}54}$ => 5,25 routes per day

1 E-CB's can make 5,25 routes per day.

The total number of E-CB's will be equal to the number of routes of zone (19,5) divided by the number of routes per day per E-CB's.

Number of e-cargo tricycles:

Considering 19,5 daily routes, will be required: $\frac{19{,}5}{5{,}25}$ => 3.71 E-cargo tricycle

Calculate the average daily distance that each electric charge tricycle runs through.

Average daily distance= $\frac{Distance}{number\ E\text{–}CB} = \frac{179{,}79}{3{,}71}$= 48,422kms

As each E-CB 'has a range of 50km, then a charged battery is enough for a day's work

Zone 123 – Centre – 18,6 routes

Total distance traveled – 57 kms

Average distance per route – 3 km

Total cycle time to complete the route:

1) Time to loading the tricycle in the warehouse: 15 minutes;

2) Circulation time on the route

Average speed tricycle: 4m/s => 15 km/h;

$T = \frac{Distance}{Speed}\ x\ 60' = \frac{57}{15} x\ 60$ = 228 minutes

3)Average time to unload on the customer=> 5min.

1 costumer = 5 minutes

Total cycle time => ∑ (1+2+3) => (15*18,6)+228+(5*62) = 817 minutes = 13 hours 36min.

How many e-cargo tricycle are needed to do the 18,6 routes per day?

Hours available per day = 8 hours (taking 1 hour of lunch)

Working hours worked

Considering a gap (safety margin) of 25%, ie useful time of 8h x 60 minutes x 0.75% => 360 min per day.

Total time on routes = 817 minutes = 13 hours 36 min

Total average time on routes = 43,92 minutes

Number of routes= $\frac{\text{time worked hrs/day}}{Average\ time\ per\ route} = \frac{360}{43{,}92}$ => 8,19 routes per day

1 E-CB's can make 8,19 routes per day.

The total number of E-CB's will be equal to the number of routes of zone (18,6) divided by the number of routes per day per E-CB's.

Number of e-cargo tricycles:

Considering 18,6 daily routes, will be required: $\frac{18{,}6}{8{,}19}$ => 2.27 E-cargo tricycle

Calculate the average daily distance that each electric charge tricycle runs through.

Average daily distance= $\frac{Distance}{number\ E-CB} = \frac{57}{2{,}27}$ = 25,11 kms

As each E-CB 'has a range of 50km, then a charged battery is enough for a day's work

Zone 124 – Cambuci – 8,7 routes

Total distance traveled – 54,5 kms

Average distance per route – 6,2 km

Total cycle time to complete the route:

1) Time to loading the tricycle in the warehouse: 15 minutes;

2) Circulation time on the route

Average speed tricycle: 4m/s => 15 km/h;

$T = \frac{Distance}{Speed}\ x\ 60' = \frac{54,5}{15} x\ 60$ = 218 minutes

3) Average time to unload on the customer=> 5min.

1 costumer = 5 minutes

Total cycle time => $\sum$ (1+2+3) => (15*8,7)+228+(5*29) = 493,5 minutes = 8 hours 14min.

How many e-cargo tricycle are needed to do the 8,7 routes per day?

Hours available per day = 8 hours (taking 1 hour of lunch)

Working hours worked

Considering a gap (safety margin) of 25%, ie useful time of 8h x 60 minutes x 0.75% => 360 min per day.

Total time on routes = 493,5 minutes = 8 hours 14 min

Total average time on routes = 56,73 minutes

Number of routes= $\frac{\text{time worked hrs/day}}{Average\ time\ per\ route} = \frac{360}{56,73}$ => 6,35 routes per day

1 E-CB's can make 6,35 routes per day.

The total number of E-CB's will be equal to the number of routes of zone (8,7) divided by the number of routes per day per E-CB's.

Number of e-cargo tricycles:

Considering 8,7 daily routes, will be required: $\frac{8,7}{6,35}$ => 1,37 E-cargo tricycle

Calculate the average daily distance that each electric charge tricycle runs through.

Average daily distance= $\frac{Distance}{number\ E-CB}$ = $\frac{54,5}{1,37}$ = 39,76 kms

As each E-CB 'has a range of 50km, then a charged battery is enough for a day's work

Zone 125 – Bom retiro – 8,7 routes

Total distance traveled – 63,4 kms

Average distance per route – 7,3 km

Total cycle time to complete the route:

1) Time to loading the tricycle in the warehouse: 15 minutes;

2) Circulation time on the route

Average speed tricycle: 4m/s => 15 km/h;

$T = \frac{Distance}{Speed}\ x\ 60' = \frac{63,4}{15} x\ 60$ = 253,6 minutes

3) Average time to unload on the customer=> 8min.

1 costumer = 8 minutes

Total cycle time => ∑ (1+2+3) => (15*8,7)+253,6+(5*29) = 529,10 minutes = 8 hours 48min.

How many e-cargo tricycle are needed to do the 8,7 routes per day?

Hours available per day = 8 hours (taking 1 hour of lunch)

Working hours worked

Considering a gap (safety margin) of 25%, ie useful time of 8h x 60 minutes x 0.75% => 360 min per day.

Total time on routes = 529,10 minutes = 8 hours 48 min

Total average time on routes = 60,81 minutes

Number of routes= $\frac{\text{time worked hrs/day}}{Average\ time\ per\ route} = \frac{360}{60{,}81}$ => 5,92 routes per day

1 E-CB's can make 5,92 routes per day.

The total number of E-CB's will be equal to the number of routes of zone (8,7) divided by the number of routes per day per E-CB's.

Number of e-cargo tricycles:

Considering 8,7 daily routes, will be required: $\frac{8{,}7}{5{,}92}$ => 1,46E-cargo tricycle

Calculate the average daily distance that each electric charge tricycle runs through.

Average daily distance= $\frac{Distance}{number\ E-CB}$ = $\frac{63{,}4}{1{,}46}$ = 43,42 kms

As each E-CB 'has a range of 50km, then a charged battery is enough for a day's work

Zone 126 – Santa Cecília – 8,7 routes

Total distance traveled – 59,3 kms

Average distance per route – 6,8 km

Total cycle time to complete the route:

1) Time to loading the tricycle in the warehouse: 15 minutes;

2) Circulation time on the route

Average speed tricycle: 4m/s => 15 km/h;

$T = \frac{Distance}{Speed}\ x\ 60' = \frac{59{,}3}{15} x\ 60$ = 237,2 minutes

3) Average time to unload on the customer=> 5min.

1 costumer = 5 minutes

Total cycle time => ∑ (1+2+3) => (15*8,7)+237,2+(5*29) = 512,7 minutes = 8 hours 33 min.

How many e-cargo tricycle are needed to do the 8,7 routes per day?

Hours available per day = 8 hours (taking 1 hour of lunch)

Working hours worked

Considering a gap (safety margin) of 25%, ie useful time of 8h x 60 minutes x 0.75% => 360 min per day.

Total time on routes = 512,7 minutes = 8 hours 33 min.

Total average time on routes = 58,93 minutes

Number of routes= $\frac{\text{time worked hrs/day}}{Average\ time\ per\ route} = \frac{360}{58{,}93}$ => 6,10 routes per day

1 E-CB's can make 6,10 routes per day.

The total number of E-CB's will be equal to the number of routes of zone (8,7) divided by the number of routes per day per E-CB's.

Number of e-cargo tricycles:

Considering 8,7 daily routes, will be required: $\frac{8{,}7}{6{,}10}$ => 1,42 E-cargo tricycle

Calculate the average daily distance that each electric charge tricycle runs through.

Average daily distance= $\frac{Distance}{number\ E\text{−}CB} = \frac{59{,}3}{1{,}42}$ = 41,76 kms

As each E-CB 'has a range of 50km, then a charged battery is enough for a day's work

Fuelled fleet of fossil

Zone 121 – Brás – 1 route

Total distance traveled – 8,9 kms

Average distance per route – 13,6km

Total cycle time to complete the route:

1) Time to loading the diesel van in the warehouse: 45 minutes;

2) Circulation time on the route

Average speed tricycle: 4m/s => 15 km/h;

$T = \frac{Distance}{Speed}\ x\ 60' = \frac{17}{15} x\ 60$ = 68 minutes

3) Average time to unload on the customer=> 8min.
1 costumer = 8 minutes

Total cycle time => ∑ (1+2+3) => (45*1)+68+(8*26) = 321minutes = 5 hours 35min

How many van's are needed to do the 1route per day?

Hours available per day = 8 hours (taking 1 hour of lunch)

Working hours worked

Considering a gap (safety margin) of 25%, ie useful time of 8h x 60 minutes x 0.75% => 360 min per day.

Total time on routes = 321 minutes = 6 hours 55 min.

Total average time on routes = 321 minutes

Number of routes= $\frac{\text{time worked hrs/day}}{Average\ time\ per\ route} = \frac{360}{321}$ => 1,12 routes per day

1 Diesel van can make 1,12 routes per day.

The total number of diesel van will be equal to the number of routes of zone (1) divided by the number of routes per day per diesel van.

Number of diesel van:

Considering 1 daily routes, will be required: $\frac{1}{1{,}12}$ => 0,89 =>1 diesel van

Zone 122 – Pari-Belém – 1,62 = 2 routes

Total distance traveled – 106 kms

Average distance per route – 27,2 km

Total cycle time to complete the route:

1) Time to loading the diesel van in the warehouse: 45 minutes;

2) Circulation time on the route

Average speed tricycle: 4m/s => 15 km/h;

$T = \frac{Distance}{Speed}\ x\ 60' = \frac{106}{15} x\ 60$ = 424 minutes

3) Average time to unload on the customer=> 8min.

1 costumer = 8 minutes

Total cycle time => ∑ (1+2+3) => (45*2)+424+(8*65) = 1034minutes = 17 hours 23min

How many van’s are needed to do the 2route per day?

Hours available per day = 8 hours (taking 1 hour of lunch)

Working hours worked

Considering a gap (safety margin) of 25%, ie useful time of 8h x 60 minutes x 0.75% => 360 min per day.

Total time on routes = 1034 minutes = 17 hours 23 min.

Total average time on routes = 517 minutes

Number of routes= $\frac{\text{time worked hrs/day}}{Average\ time\ per\ route} = \frac{360}{517}$ => 0,69 routes per day

1 Diesel van can make 0,69 routes per day.

The total number of diesel van will be equal to the number of routes of zone (2) divided by the number of routes per day per diesel van.

Number of diesel van:

Considering 2 daily routes, will be required: $\frac{2}{0,69}$ => 2,89 => 3 diesel van

Zone 123 – Centre – 1,55 = 2 routes

Total distance traveled – 96 kms

Average distance per route – 25,5 km

Total cycle time to complete the route:

1) Time to loading the diesel van in the warehouse: 45 minutes;

2) Circulation time on the route

Average speed tricycle: 4m/s => 15 km/h;

$T = \frac{Distance}{Speed}\ x\ 60' = \frac{96}{15} x\ 60$ = 384 minutes

3) Average time to unload on the customer=> 8min.

1 costumer = 8 minutes

Total cycle time => ∑ (1+2+3) => (45*2)+384+(8*65) = 994minutes = 16 hours 56min

How many van's are needed to do the 2route per day?

Hours available per day = 8 hours (taking 1 hour of lunch)

Working hours worked

Considering a gap (safety margin) of 25%, ie useful time of 8h x 60 minutes x 0.75% => 360 min per day.

Total time on routes = 994 minutes = 16 hours 56 min.

Total average time on routes = 497 minutes

Number of routes= $\frac{\text{time worked hrs/day}}{Average\ time\ per\ route} = \frac{360}{497}$ => 0,72 routes per day

1 Diesel van can make 0,72 routes per day.

The total number of diesel van will be equal to the number of routes of zone (2) divided by the number of routes per day per diesel van.

Number of diesel van:

Considering 2 daily routes, will be required: $\frac{2}{0{,}72}$ => 2,77=>3 diesel van

Zone 124 – Cambuci – 1 route

Total distance traveled – 21 kms

Average distance per route – 18,8 km

Total cycle time to complete the route:

1) Time to loading the diesel van in the warehouse: 45 minutes;

2) Circulation time on the route

Average speed tricycle: 4m/s => 15 km/h;

$T = \frac{Distance}{Speed}\ x\ 60' = \frac{21}{15} x\ 60$ = 84 minutes

3) Average time to unload on the customer=> 8min.

1 costumer = 8 minutes

Total cycle time => ∑ (1+2+3) => (45*1)+84+(8*29) = 361minutes = 6 hours

How many van’s are needed to do the 1route per day?

Hours available per day = 8 hours (taking 1 hour of lunch)

Working hours worked

Considering a gap (safety margin) of 25%, ie useful time of 8h x 60 minutes x 0.75% => 360 min per day.

Total time on routes = 361 minutes = 6 hours.

Total average time on routes = 361 minutes

Number of routes= $\frac{\text{time worked hrs/day}}{Average\ time\ per\ route} = \frac{360}{361}$ => 1 routes per day

1 Diesel van can make 1 routes per day.

The total number of diesel van will be equal to the number of routes of zone (1) divided by the number of routes per day per diesel van.

Number of diesel van:

Considering 1 daily routes, will be required: $\frac{1}{1}$ => 1 diesel van

Zone 125 – Bom Retiro – 1 route

Total distance traveled – 21 kms

Average distance per route – 15,2 km

Total cycle time to complete the route:

1) Time to loading the diesel van in the warehouse: 45 minutes;

2) Circulation time on the route

Average speed tricycle: 4m/s => 15 km/h;

$T = \frac{Distance}{Speed}\ x\ 60' = \frac{21}{15} x\ 60$ = 84 minutes

3) Average time to unload on the customer=> 8min.

1 costumer = 8 minutes

Total cycle time => ∑ (1+2+3) => (45*1)+84+(8*29) = 361minutes = 6 hours

How many van's are needed to do the 1route per day?

Hours available per day = 8 hours (taking 1 hour of lunch)

Working hours worked

Considering a gap (safety margin) of 25%, ie useful time of 8h x 60 minutes x 0.75% => 360 min per day.

Total time on routes = 361 minutes = 6 hours.

Total average time on routes = 361 minutes

Number of routes= $\frac{\text{time worked hrs/day}}{Average\ time\ per\ route} = \frac{360}{361}$ => 1 routes per day

1 Diesel van can make 1 routes per day.

The total number of diesel van will be equal to the number of routes of zone (1) divided by the number of routes per day per diesel van.

Number of diesel van:

Considering 1 daily routes, will be required: $\frac{1}{1}$ => 1 diesel van

Zone 126 – Santa Cecília – 1 route

Total distance traveled – 21 kms

Average distance per route – 16,6 km

Total cycle time to complete the route:

1) Time to loading the diesel van in the warehouse: 45 minutes;

2) Circulation time on the route

Average speed tricycle: 4m/s => 15 km/h;

$T = \frac{Distance}{Speed}\ x\ 60' = \frac{21}{15} x\ 60$ = 84 minutes

3) Average time to unload on the customer=> 8min.

1 costumer = 8 minutes

Total cycle time => ∑ (1+2+3) => (45*1)+84+(8*29) = 361minutes = 6 hours

How many van's are needed to do the 1route per day?

Hours available per day = 8 hours (taking 1 hour of lunch)

Working hours worked

Considering a gap (safety margin) of 25%, ie useful time of 8h x 60 minutes x 0.75% => 360 min per day.

Total time on routes = 361 minutes = 6 hours.

Total average time on routes = 361 minutes

Number of routes= $\frac{\text{time worked hrs/day}}{Average\ time\ per\ route} = \frac{360}{361}$ => 1 routes per day

1 Diesel van can make 1 routes per day.

The total number of diesel van will be equal to the number of routes of zone (1) divided by the number of routes per day per diesel van.

Number of diesel van:

Considering 1 daily routes, will be required: $\frac{1}{1}$ => 1 diesel van