TÉCNICO LISBOA

A Study on the Adequacy of Electric Two-wheelers to Transport Goods in Urban Environments

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Thesis for the Degree of Master of Science in

Civil Engineering

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October 2015

Acknowledgments

Firstly I would like to thank my mentors, Dr. Vasco Domingos Moreira Lopes Miranda dos Reis and Dr. Filipe Manuel Mercier Vilaça e Moura for all the support they gave me so I could succeed in this dissertation. Then, I thank:

- Joana André Matias Ribeiro, at the time researcher at IST, the help and contacts she gave me so I could have the data and tools to work;
- Pedro Ventura, owner of *Camisola Amarela* and Luís Campos and all the team of *Moço de Recados*, who gave me the data and all the information I needed in order to compute their savings. I also thank Catarina Moreno the data regarding the restaurant O Marujo;
- And Steven Koster, from Puurlan in Netherland, by responding the survey so enthusiastically.

Porque esta dissertação é apenas o final de uma longa maratona, não posso deixar de agradecer a todos aqueles que fizeram parte dela e me ajudaram a chegar à meta:

- Ao meu irmão, André Filipe Arnêdo Reis, pela companhia, gargalhadas e coragem que me deu sempre;
- Ao Ricardo Miguel Rodrigues Pereira por toda a ajuda, todo o apoio e toda a companhia que me tem dado incansavelmente, por me ter dado coragem quando eu não a tinha e por estar sempre ao meu lado… por tudo!;
- Aos meus pais pelo apoio e por lutarem ao meu lado;
- À Tita e à minha prima Rita pela alegria contagiante e apoio incessante;
- Aos meus avós que nunca deixaram de estar presentes;
- À Ana Rita Álvaro Albuquerque Martins e ao Rui Miguel Alves Lopes pela amizade e apoio.

Muito obrigada a todos!

Abstract

Urban logistics is the last and less efficient part of the logistic chain. A fraction of the solution is the one aspect that permits, simultaneously, a reduction in pollution, noise and congestion and an increase in the quality of life and companies' profit without jeopardizing the operation: the technological transfer from fossil fuelled vehicles to the electric technology, in particular, electric two--wheelers.

These vehicle's dissemination for the transport of goods in urban areas has been postponed by factors such as the lack of studies proving their benefits. This dissertation aims to contribute to this body of knowledge. For that matter, three Portuguese case studies were selected between different segments of urban logistics. Recorded data by the case studies were analysed in a costs simulator, allowing to compute economic and environmental savings.

In a summarized way, the results show that electric two-wheelers can represent savings up to 2 171€/yr (81.2%) in annual economic terms, 2 092kg CO_2/yr (94.1%) in carbon dioxide emissions and 6 880kWh/yr (86.5%) in energy consumption, in the studied services. Based on a distributed survey to the pilots, it was possible to understand that there is, indeed, low awareness on this technology's economic benefits, shortcoming solved in part in this work. It was also found that the vehicle's usage has greater impact in savings than costs itself. This technology diffusion is still constrained by constant developments, high purchase costs and low autonomies. In the future, this work repetition for remaining LP and uses should be performed.

Key-words

Electric two-wheelers, Freight transport, Urban logistics, Economic Benefits, Environmental Benefits

Resumo

A logística urbana é a última e menos eficiente parte da cadeia logística. Uma fração da solução reside no aspeto que permite reduzir a poluição, ruido e o congestionamento e aumentar a qualidade de vida e o lucro das empresas transportadoras sem por em causa a operação: a transferência tecnológica dos combustíveis fósseis para a tecnologia elétrica, em particular os veículos elétricos de duas rodas.

A disseminação do uso destes veículos para transporte de mercadorias em ambiente urbano tem sido atrasado por fatores como a falta de estudos que comprovem os seus benefícios. É essa falha que este trabalho pretende colmatar. Para tal, foram selecionados três casos de estudo portugueses em diferentes segmentos da logística urbana. Dados recolhidos pelos três pilotos foram inseridos num simulador de custos, permitindo calcular poupanças económicas e ambientais.

Os resultados mostram que veículos elétricos de duas rodas podem representar poupanças de até 2 171€/ano (81.2%) em termos económicos, 2 092kg CO_2/ano (94.1%) em emissões de dióxido de carbono e 6 880kWh/ano (86.5%) em consumo de energia nos serviços aqui testados. De acordo com questionários realizados junto dos pilotos, percebeu-se que existe, de facto, pouco conhecimento dos benefícios económicos desta tecnologia, falha que fica, em grande parte, resolvida neste trabalho. Constatou-se que a difusão desta tecnologia está ainda limitada por evoluções constantes, preços de aquisição elevados e fracas autonomias. No futuro, aconselha-se a repetição deste trabalho para outros LP e usos.

Palavras Chave

Veículos Elétricos de Duas Rodas, Transporte de Mercadorias, Logística Urbana, Benefícios Económicos, Benefícios Ambientais

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Abbreviation and Symbols List

Latin Alphabet

B2B: Business-to-business business-to-client

B2C: Business-to-client

BSP: Bicycle Specific Power

CA: *Camisola Amarela*

CL: City of London

CH_4: Methane

CO: Carbon Monoxide

CO_2: Carbon Dioxide

CS: Courier Service

EACB: Electrically Assisted Cargo-bike

E-Bike: Electric Bicycles (including cargo-bikes) and Electric Motorcycles

ePTW: Electrically Powered Two-wheelers

eTW: Electric Two-wheelers

GHG: Greenhouse Gas

GPS: Global Positioning System

HDS: Home Delivery Service

ISV: *Imposto Sobre Veículos*

IUC: *Imposto Único de Circulação*

IVA: *Imposto sobre o Valor Acrescentado*

kVA: Kilo Volt Ampere

LMS: Last mile Service

LEV: Light Electric Vehicles

LP: Logistic Profile

MR: *Moço dos Recados*

MSP: Motorcycle Specific Power

NMVOC: Non-Methane Hydrocarbons

N_2O: Nitrous Oxide

NO_x: Nitrogen Oxides

OD: Origin-Destination

OPEX: operational costs

PM: Particulate Matter

SGPU: *Sistema integrado de Gestão de Pneus Usados*

SO_2: Sulphur Dioxide

TTW: Tank-to-Wheel

UmCC: Urban micro-Consolidation Centre

VOC: Volatile Organic Compounds

VSP: Vehicle Specific Power

WTW: Well-to-Wheel

WTT: Well-to-Tank

Greek Alphabet

Δ: Numerical variation

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1. Introduction

This first chapter presents the background of this dissertation and the main contribution of this work (Section 1.1). Then, in Section 1.2, it is possible to understand the underlying aim while, in Section 1.3, the reader is clarified about what was implemented in order to meet those objectives. In the same section, the structure of this dissertation is presented.

1.1. Dissertation's Context

Logistics is proved to be an essential affiliate to cities in a way that it is the only mechanism able to provide people the goods to satisfy their growing and global demand, assuring the quality of life they seek. If this demand is satisfied in a way capable of minimizing the negative impacts of human activity, a better quality of life will, indeed, be perceived, attracting more people to cities, and therefore, more companies. With such an increase in population, visitors and people working in cities, there is a growing need for mobility, which eventually leads to a higher rate of vehicles' ownership. The higher the number of vehicles running in urban roads, the higher the pollution, the CO_2 emissions and the congestion, if no technological changes occur. In addition, higher motorization rates mean more time lost stuck in traffic – and therefor lower national productivity with the inherent implications on national economy –, noise, infrastructure investment and higher utilization rate of public space to park cars. All this affect in a negative way the perceived quality of life. For those and other matters, efforts are being taken in order to change to a sustainable development and urban logistics has a role in this progress.

In the last decade many have been the warnings about Greenhouse gases emissions, global warming, extreme weather events, natural catastrophes, oil scarcity, public health deterioration, economic crisis, scarcity of public space, degradation of quality of life and so on and a common cause of these events is the increasing motorization rates. A different scenario can only be achieved with a wide awareness of population and a global mentality change. Also, a policy update is core to introduce important behaviour modifications in population' mobility pattern. However, that behaviour modification can only occur if proper mobility alternatives are available and the technology development has a great importance in offering these solutions. Those political change and technology innovation have to follow a consistent and sustainable path. With this in mind, the European Commission defined a set of directives for all the European Community. In a short term, the 20-20-20 objective must be achieved: to reduce 20% of Greenhouse gases emissions, comparing with the 1990 levels, to increase 20% in energetic efficiency and to increase 20% in renewal energy sources' implementation, all this by 2020. More recently, mandatory values to achieve by 2030 and 2050 were defined and transmitted in the 2011 White Paper on Transport (European Commission 2011, pp.4, 5): "to reduce emissions by 80 to 95% below 1990 levels by 2050", specifically, to reduce CO_2 emissions by 60% (20%) below 1990 (2008) levels by 2050 (2030). In the same document, it is mentioned "new technologies for vehicles and traffic management will be key to lower transport emissions" (pp.5).

There are many ways to achieve those numbers but for that to really happen, all those options have to be implemented and work in coordination. For instance, a change in policy does not change the present scenario by itself if people and technology are not being updated, changing the way people think can only present results if the tools for the change to be implemented are provided by the authorities. For people to change their mind, it is indispensable time, as much information as possible and, potentiality, an acknowledgement of the benefits that change means and the impact the change has in the all system. It is also imperative that they perceive the practical consequences and context in which the change exists. A technological change will only be valuable if people acknowledge the implications behind that change. One such technological approach is the use of electric vehicles in urban logistics, electric two-wheelers in particular.

Comparing with fossil fuelled vehicles – specifically with vans as prime road users –, electric two-wheelers have intrinsic benefits, some of them are just known such as their better accessibility as these vehicles have access to car restricted areas such as pedestrians roads, they are less noisy, do not cause nor suffer from congestion because their smaller dimensions allows them an easy overcome of cars, vans and trucks and electric two-wheelers are easier to park than four – and six – wheelers, but few are proved and quantified. The development of the electric technology is still scarce especially in what concerns urban logistics, its benefits and suitability and there are aspects, accordingly with specialists and users, claiming for improvement such as autonomy and battery's duration. No one has, until now, proved people and urban companies that transporting freight with electric two-wheelers is not just possible but it is also easy, cheap and non-pollutant.

1.2. Objective

Generically, this work's aim is to quantify the benefits of electric two-wheelers to transport goods in urban environment. But because the time to develop this work was limited, it was essential to constrain its scope. Due to its own nature, companies usually take decisions based on economic data and now, more than ever, environmental context is gaining weight on companies' strategy. Thus, the background of this work was confined to those areas. Ultimately, this dissertation aims to quantify eTW's economic and environmental benefits to answer the question "Do eTW represent economic and environmental benefits in urban logistics? How big are the savings?". In the end, this dissertation culminated in these benefits quantification using real world companies.

By quantify these advantages, the most important objective is to show companies that electric two-wheelers can reduce costs and also their impact in the environment. It is important not to forget that this work focused on three different companies and contexts but many more similar contributions will be needed in order to universalise those benefits. Another aspect to take in mind is that, besides these economic and environmental benefits, an electric fleet of two-wheelers is silent, boosts accessibility and therefor reduces lead time and improves productivity.

1.3. Methodology, Method and Structure

Figure 1 represents, in a schematic way, this dissertation's structure. In order to gather the benefits usually referred to electric two-wheelers, an extensive literature review was performed. This first step also provided information about this vehicles' characteristics, mostly in what concerns with expenses (both purchase and annual costs). In addition, direct consultations with motorcycles' and mini-vans' dealers, repair shops and insurance companies were performed in order to determine purchase, maintenance, insurance and taxation costs of the different technologies. This collection, alongside with some important considerations about urban logistics, its challenges and the role electric two-wheelers have in those challenges resolution are presented in "Chapter State of the Art". 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.

The next phase involved a methodology capable of computing the savings that a technological shift can represent in a company. The procedure description can be found in "Chapter 3 Methodology". Firstly, three case studies were identified and a research on each one was performed in order to understand their business market, the areas in which they operate and the agent needs. These case studies were part of a European project, during which on-road data were collected. That collection process and the registered data – distances, carried weights and volumes, remaining battery level and more – were defined in section "3.2.2 Collected Data". During this period surveys were distributed in these and other companies in order to understand company owners', riders' and clients' experience with electric two-wheelers to transport goods, so the economic benefits could be quantified.

After the trial period end, the registered on-road data was compiled and indicative values were calculated (minimums, maximums and averages) so they could be used in the costs simulator. This simulator was developed in the Pro-E-Bike scope by a Portuguese partner: Occam. Before using this tool, there was the need to define the inputs. The parameters that do not depend on the case study, such as conversion factors, were defined and explained in Section "3.2.3 Quantification of Both the Economic and Environmental Benefits" alongside with the calculation proceedings. The remaining parameters were only defined in the correspondent section. The inputs are mostly related with each technology's consumptions, both energetic and economic.

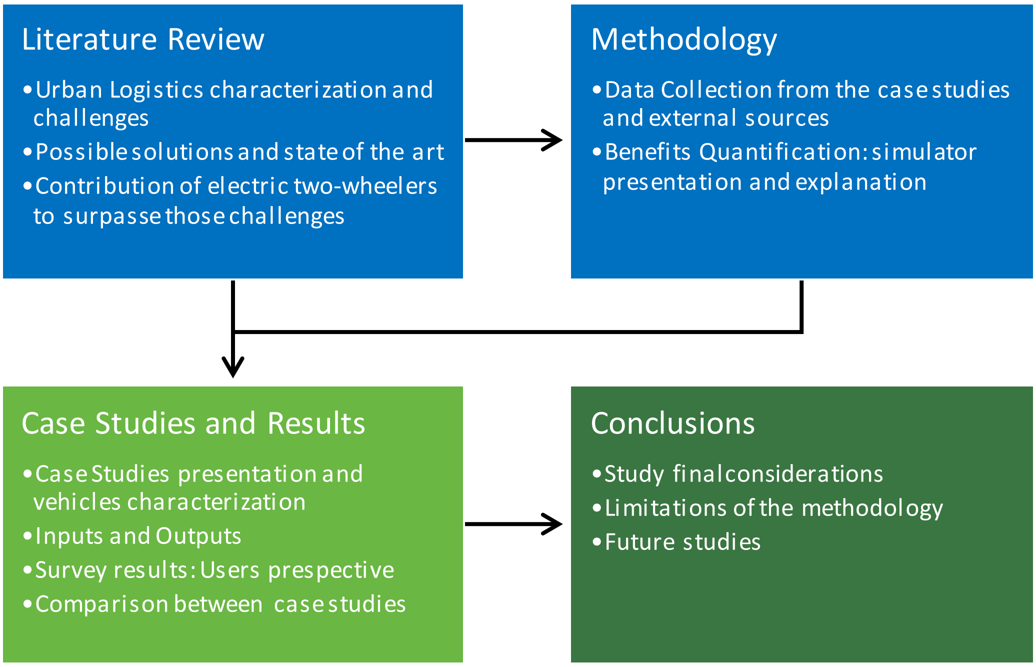

Figure 1 – Dissertation structure

For each case study, defined in "Chapter 4 Case Studies and Results", the electric vehicle used during the trial period was characterized in the corresponding section (4.1, 4.2 and 4.3) and, based on the responses on the rider inquiry, the fossil fuelled vehicle that suits the most that service was also defined (the best-selling model in the previous year was considered whenever there was no real alternative vehicle). Then, those data were introduced in the simulator as explained in sections 4.1.2, 4.2.2 and 4.3.2 and the results are presented and explained in the same section. Those results were then quantified based on company owner's and riders' responses of the surveys in the next section on each case. This balance between results and survey responses was crucial to understand whether those benefits are real or not. Regardless this analysis in each case study, a descriptive analysis to all the surveys was also performed (aside from the responses in the case studies, another client, two company owners and two riders responded), allowing to understand real users experience and their opinion on which features of electric two-wheelers need improvements in order to make them an urban logistics solution.

Finally, the "Chapter 5 Conclusions" reviews the results and makes final considerations and suggestions for future studies.

2. State of the Art

This chapter is structured in a way that allows a rational and organized understanding of this work's scope: it starts with a description of what is urban logistics, what is its role in today's society and the different profiles in which it can be found. Afterwards, the reader finds the problems related to these services, followed by the explanation of a possible solution: electric two-wheelers. In the end of the chapter, a final section summaries the contribution of these vehicles to urban logistics' improvement.

2.1. Literature

Despite all the positive technological and organizational developments in the last decades, the transport sector is still a massive contributor of gases emissions. This sector is responsible for 19.7% of GHG emissions in the EU with 71.9% of those being generated in the road (European Commission 2014).This portion gets even higher within the urban environment due to the congestion and constant stop and go. The manifold roles of the transport sector for pollution is well described by Borken-kleefeld & Ntziachristos (2012).

In this Literature section, it is explained the context of the Urban Logistics, its main difficulties and then it is presented the role of electric two wheelers in solving those problems.

2.1.1. Logistic Process and Profiles

According to APICS - Association for Operations Management (2011, p.28), "logistics is the art and science of obtaining, producing and distributing materials and products in the proper place and with the proper quantities". Urban logistics is embedded in the last segment of the distribution section of logistics, when the product moves within the final urban area to reach the final consumer. In order to be functional, the supply chain have to have some specific characteristics and, according to that same author, it has to be responsive (to meet all the diversity in customer needs), agile (to change its products, process duration, delivery services and volumes involved in order to provide a variety of options that meet clients' satisfaction) and it has to be efficient (to verify the previous characteristics at the lower costs).

The supply chain – in which logistics is inserted – combines the role of six types of agents. Each one of them has a goal and each one of them aims to a better service. In some situations, either to increase competition or in a more complex production process, the same entity can be more than one agent. The six players, which relations are represented in Figure 2, can be described as follow, accordingly with Caiado (2004):

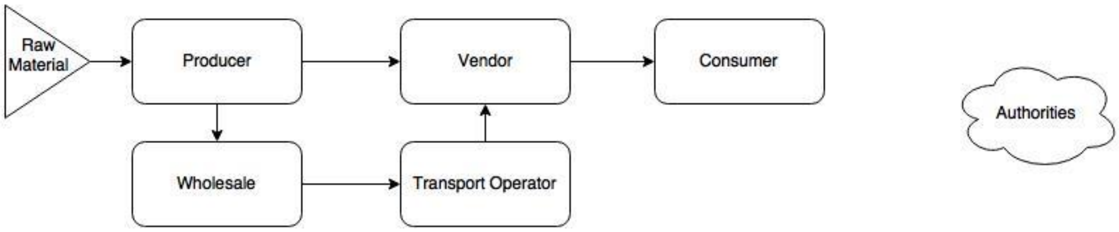

Figure 2 – Agents' relations and proposes (own source)

In Figure 2, the triangle represents the system's input, the arrows represent the goods flow, the rectangles with curved corners represent the "inside" agents in the process and the cloud shape represents the "outside" agent as the agent that will never possess the good but that will monitor the all process and relations between the "inside" agents.

The producer, transforms the raw material in final or semi-final product. He also can be both a receptor (of the raw material from the origin to the production place) and a retailing company (when he send the final or semi-final product to the next agent).

The wholesale, who buys the products directly from the producer and then sells them to the retailer. He buys in large amounts and sells in few. Because of this differential, he has to have a large stock capacity in warehouses disposed as near as he can to his clients, in order to the response to be fast.

Logistics operator or transport operator is the one responsible for the transport itself. There are four main possibilities for freight transportation: using vehicles belonging to the store, delegating the service to a courier company, to an express mail operator or to another transport operator. Express mail operators and couriers services are the fastest, most flexible and reliable types but they have weight and volume limits which constrains their application's scope. The bigger the geographic scale, the more are their advantages.

The retailer brings the desired product to the final consumer and deals with small selling volumes. The retailer can exist in one of four formats: small and independent stores, clusters of small and identical stores, neighbourhood supermarkets and hypermarkets, depending on the selling volume. Independently on the size of the store, the tendency is to shorten store inventory and subscribe for just-in-time deliveries (Rodrigue 1998). With more frequent and customized deliveries, the demand for express and courier services also rise forcing to a more organized system.

The consumer is the one placing the order. He is the agent that buys more times but in less quantity. Consumers are becoming more exigent both in terms of how long it takes from placing the order until its actually delivery and in terms of diversity, increasingly requesting foreign products. This trend has been growing mostly due to the advent of e-commerce (the possibility to buy online), which, as a consequence, has been expanding reverse logistics (the process by which the parcel is sent by the client to its primary origin). All these new developments are forcing the remaining agents to increase their productivity and to become more client-oriented.

The authorities, either in a municipality or in a national level, are responsible for regulating the overall operation in their city/region/country, on the one hand in terms of the citizens and their livelihood, and, on the other hand, in terms of developing the city economically, in quality standards, enhance its attractiveness and value. Freight transactions create employment, activity, revenues, wealth and, when performing the best practices, recognition to the city.

In urban logistics, the most active entities are the retailer, the consumer, the transport operator (within the urban areas) and the authorities. All these agents have in common three main concerns: efficiency of freight urban transportation, reduction of traffic congestion and mitigation of the environmental impacts of their role in the service (Macário 2011). The main problem is that each one of them aims for these objectives in a different way: while some of them pay more attention to the time the delivery takes and the correspondent punctuality, other seek higher load factors and other worry the most about the people. This means that there is a conflict of interests and, consequently, it is impossible to guarantee all those alternatives at once and some of them have to be left out.

Freight in cities can be derived from three main sources: production (of goods themselves but also of services with the consequent production of documents, for instance), consumption (of material goods, perishable goods and even letters) or waste (garbage, overproduction), which are all direct consequences of today's lifestyle. People need goods in order to maintain and improve their quality of life and goods can be produced both within (services and small producers like handcraft) and outside (industrial producers) the city. But it becomes more difficult to guarantee this quality of life when urban population increases rapidly. It is expected that, by 2025, more than three quarters of Europe's population will be living in cities and that by 2050 that number will grow to 84% (MDS Transmodal and CTL 2012). This growth rate has been inducing not only to increases in the amount of trades both between urban areas and between those and rural ones but it also has been increasing the need for mobility as cities grow along with their population, which ultimately corresponds to higher motorization rates and less available space. This occurs mainly in cities where population growth is exponential and there is not enough time to plan a proper urban expansion. In those cases the mobility is sacrificed to the detriment of the residential construction, because that is a much more profitable business with smaller payback times. A direct consequence is a climbing in emissions' levels, both greenhouse gases (GHG) and other air pollutants. These GHG emissions are responsible for the rising of Earth's temperature with the related consequences such as extreme weather events and the extinction of many ways of life. In addition, air pollutants are responsible for the degradation of air quality and cause respiratory diseases among other health issues. All this leads, inevitably, to a worst quality of life, so a call for innovation is crucial to solve urban logistics' challenges.

Urban logistics begins where the city starts: usually this is when the product arrives to the retailer's or to the client's hands and both the entities can take several forms such as a clothing store and an individual that receives a letter in his home, or a restaurant with home delivery and a company waiting for its documents to arrive via courier. Hence, a common element that links two agents is the service they provide or is provided to them. There are four main services at the clients' disposal (Rodrigue 1998):

Independent Retailing: this type of service relates to small single owner stores and similar. These activities define the commercial and social environment of a neighbourhood and usually are stores, neighbourhood supermarkets, street markets and stalls. Because each store is unique and belongs to a different owner, there can be a vehicle for each store but it also can happened to have the same vehicle (not always a heavy one) providing to more than one commercial establishment whenever they are similar. Only in this case, their impact in congestion and remaining negative consequences of urban logistics is lower. However, areas where there is many small stores, load and unload operations most probably generate conflicts.

Chain retailing: Stands for hypermarkets and shopping centres. This type of retailing is much more attractive for the consumer, since it aggregates many different types of stores in the same place. In the provision of these agglomerations, heavy vehicles are used. There is no problem regarding the loading and unloading operations because usually those manoeuvres are performed in specific areas but the problem is the circulation of this vehicles in highly consolidated areas.

Food Deliveries: This service is dedicated to perishable goods such as meat, fresh fish and vegetables. This service is mostly used by bars, restaurants and similar. Because of the products specificities, there can be the need to use special vehicles such as refrigerated or isothermal. Many of these goods also have handling specifications. Usually, the dimension of the provider's vehicle is not very large but in residential areas – where much of these stores are located – this can generate conflicts.

Parcel and Home Deliveries: These can be classified as Business to Business (B2B) or Business to Consumer (B2C), accordingly with the destination. Home deliveries are characterized by small and light parcels with only few of them per client – which jeopardizes efficiency because there is the need to travel longer distances for the same load –, so this service is the one with higher propensity to be executed using lighter vehicles such as bicycles, tricycles, cargo-bikes, electric vehicles in general and electric two-wheelers in particular. The same author explains that there are two different types of actors: the private and the common courier. On the one hand, companies with their own fleet, using private couriers, only carry their goods in it. In the other hand, common couriers can be contracted whether by individual and by other companies. This "flexibility" allows common couriers to better organize their activity and improve their efficiency by using the same vehicle, in the same trip to make more than one deliver. In what concerns with the product and modal choice independently, there are three main models (Lia et al. 2014):

- Small parcels (office material, letters, documents, small packages) delivered by courier companies and contracted by people and/or firms that are not willing to pay much and are not much concerned with delays;
- Urgent parcels with high variability in volume and weight (E-commerce, laboratory samples, equipment). As priority increases also do the need to know with certainty the time

window delivery and to track product's position. With higher exigency comes higher willingness to pay higher prices;

- High priority parcels (urgent documents, food delivery) with much higher expectations and much higher prices and exigencies. This is the market segment that will be addressed in this dissertation.

Every service in urban logistics have the same six objectives: economy, efficiency, safety, environmental, infrastructure and urban structure (Macário et al. 2011). A single solution capable of respond to each one of the previous objectives is extremely complex to find so the approach followed by a certain service, should allow a comparison between the different business concepts and models, so that particular service can be characterized.

Urban logistics is about freight flows between parties in a certain area. Therefore, in order to characterize an urban logistics' service, a full description of these three elements (freight flow, parties and area features) is crucial. This full description can be found in the service's logistic profile (LP). It is essential to ensure an efficient communication between the intervenient parts of a logistic process (KOIKE et al. 2005) and the LP is the easiest way to find solutions in order to improve service's performance. Macário (2011) suggests the definition of LP as represented in Figure 3. The author mentions those three main aspects as unique and indispensable to entirely define a logistic service, allow an easier understanding and define the most suited intervention. Agents' needs stands for the requirements of the parties in the service. It can be the client's urgency in receiving the parcel or the stipulated amount of deliveries per route in order to satisfy efficiency. The features related with product characteristics are the easiness of handling and the special conditions that need to be fulfilled so the product does not get jeopardized (like chemical or perishable goods). These specificities describe the way the product must be managed during the delivery process. In order to verify those time requests such as urgency, it is essential that the messenger knows the city area in which he operates, so he can avoid the most congested roads in the most congested times. It is important that he knows the accessibility level and everything that can makes the difference between arriving on time and being late (commercial density, homogeneity, accessibility). Accordingly to the type of services in the study area, there are five main types of LP and their characteristics are summarized in Table 1. Those highlighted in grey are the most relevant features for each profile.

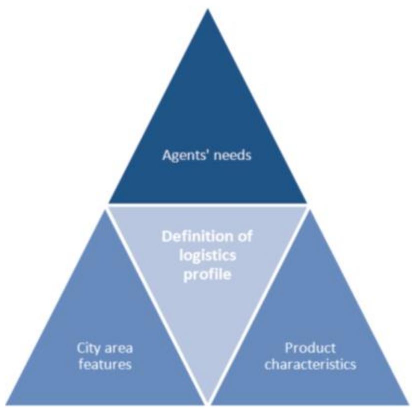

Figure 3 – Logistic Profile definition (Macário 2011)

Table 1 – Five types of logistic profiles (Macário 2011)

		Profile A Cluster of shops specialized in one specific type of service/product: ex. A neighbourhood that is known for furniture stores, craft or art pieces, technological pole.	**Profile B** Hotels, restaurants, small grocery stores, neighbourhood markets	**Profile C** Business center (courier, small deliveries, B2C)	**Profile D** Large commercial (retail, shopping centers, distribution warehouses)	**Profile E** Residential areas with local trade
City Area Features	1.1 Commercial density	High	Low/Medium/High	High	High	Low/Medium
	1.2 Homogeneity	High	Low/Medium/High	Low	Low	Low/Medium
	1.3 Logistics Accessibility	Good/Reasonable	Bad/Reasonable/Good	Reasonable/Good	Good	Reasonable/Bad
	1.4 Restrictions Applied	Yes/No	Yes/No	Yes	No	Yes
Product Characteristics	2.1 Easiness of Handling	Easy/Reasonable/Difficult	Easy/Reasonable/Difficult	Easy	Easy/Reasonable/Difficult	Easy/Reasonable/Difficult
	2.2 Special Conditions	No special needs/Special needs	Special needs	No special needs	Might have special needs	Might have special needs
	2.2.1 Fragility	No special needs	Fragile	No special needs	No special needs	No special needs
	2.2.2 Perishability	Not perishable	Perishable	Not perishable	Not perishable	Not perishable
Agents' Needs	3.1 Urgency of deliveries	Irrelevant/Relevant/Urgent	Urgent	Relevant/Urgent	Relevant	Irrelevant/Relevant/Urgent
	3.2 Frequency of deliveries	Low/Medium/High	High	High	Medium/High	Low/Medium
	3.3 Amounts to be Delivered	Few/Several/Many	Several	Few/Several	Many	Few/Several/Many
	3.4 Planned Deliveries	No defined routine/Defined routine	Defined Routine	No defined routine/ Defined routine	Defined routine	No defined routine

2.1.2. Conflicts and Difficulties

There are difficulties inherent to urban logistics, as already seen. Accordingly with Reis (2015), there are four main conflicts urban logistics entities face on a daily basis:

1. "Growing congestion of urban roads;
2. Growing interaction with pedestrians;
3. Increase of logistics costs;
4. Jeopardise of urban region's sustainable and economic development and populations' quality of life."

The same author also proposes sources for these conflicts from where some are worth to highlight: land use, lack of cooperation between agents, inadequate enforcement, technological limitations and utilization of old vehicles. However, they are dependent of each other. For instance, the difficulty to implement rules (inadequate enforcement) is because of the general disrespect in excessive consumption of transport services and traffic concentration and because of the incompatibility in land uses. Sometimes it can also be owed to lack of legislation (in Portugal, for instance, there is no legislation concerning loading, unloading and remaining logistic activities). Regarding land uses, the way its management is thought can dictate the accessibility and level of congestion of a certain area, which can define which vehicles are and are not better suited to perform that service.

Reis (2015) also presents some explanations about why those four facts constitute conflicts:

1. The contributions for the growing congestion in urban areas are several and concerning multiple entities. The increasing urban population and their need for mobility lead to a higher motorization rate mostly in cities were the public transportation is not properly managed, which inevitably leads to a high vehicles-per-parking-lot factor incentivising the illegal parking. Additionally, urban logistics represents up to 18% of urban traffic flows, freight vehicles are responsible for 20 to 25% of road space use and these vehicles' flows reduce road capacity by 30% due to pick-up and unload operations (MDS Transmodal and CTL 2012 cited by Lia et al. 2014; Macário 2011). Moreover, infrastructure are becoming saturated and municipalities are now facing the impossibility to improve its capacity because there is no more urban space. Apart from that, freight vehicles, due to their heavy loads and advanced age, move in lower speeds which constitutes an additional contributor to congestion. Vehicle's age can also constrains the vehicle operation because lately many cities have been imposing low emissions zones. In these areas, older vehicles (the most pollutant ones) are forbidden to enter.

2. Freight vehicles are starting to have a great negative interaction with pedestrians, mostly due to their visual intrusion, air and noise pollution and both accidents and incidents between these and both pedestrians and private cars.

3. The logistic costs have many components. It includes costs with the logistic infrastructure, fixed and variable costs with both human and material resources, etc. It also includes losses of productivity and time costs which are higher when there are traffic jams and vehicles are stopped in traffic. All these losses increase logistic costs which reverts to product/service cost.

4. Because driving in urban environment represents shorter trips, more stops and generally higher slopes than driving in highways for instance, the urban freight transport is the most pollutant freight transport of the chain. Apart from congestion inducing drivers to higher levels of stress, it also increases the exposure of all the road users to harmful (pollutants), increases GHG gases emissions and causes delay for both people and freight. On the one hand, the GHG (CO_2 (carbon dioxide, 82%), CH_4 (methane, 10%), N_2O (nitrous oxide, 5%) and fluorinated gases, 3%) are responsible for the degradation of the Earth environment as it intensifies the so-called greenhouse effect, which is essentially the capture of sun radiation keeping it inside our atmosphere increasing global temperature. This increase in global temperature has many known consequences but ultimately, it has been extinguishing many ways of life. On the other hand, pollutants emissions are the truly enemy for the human being (or at least the faster) and they are: volatile organic compounds (VOC) – which can be methane (CH_4) or non-methane hydrocarbons (NMVOC) –, Carbon Monoxide (CO), Particulate Matter (PM), nitrogen oxides (NO_x) and sulphur dioxide (SO_2) (Borken-kleefeld & Ntziachristos 2012; Hickman et al. 1999). These gases injury public health and they are responsible for illnesses like asthma, bronchitis, leukaemia and lung diseases (Banister 2008). With the aim to compare different transport modes in terms of its pollutants emissions, Table 2 resumes reference values of emission factors. These values differ according to factors like vehicle's age, total distance, distance per year, if it runs the most (and how much) in urban areas or in rural ones.

Table 2 – Driving emission factors, France (Borken-kleefeld & Ntziachristos 2012)

	Light Duty Truck (gasoline)	**Light Duty Truck (diesel)**	**Motorcycle (gasoline)**
NOx (g/MJ)	0.032	**0.309**	0.111
PM2.5 (mg/MJ)	0.255	**23.139**	3.237
CO (g/MJ)	1.173	0.138	**1.699**
NMVOC (g/MJ)	0.031	0.030	**0.219**

It is owed to these conflicts and three more causes that urban logistic is the less efficient part of the logistic chain: low load factors and vehicles running empty during long periods, many small parcels – each one of them for one different receiver – and long loading and unloading times (MDS Transmodal and CTL 2012).

Generically, there are three main measures types: policy, logistics and technology (Quak 2012). Of course, some of these measures are more complex to implement than others. For instance, land use policies are more difficult to manage once the city is built. But Reis (2015) also suggest five typified measures to prevent and minimize those conflicts:

A. Organisational measures

a. Cooperative logistic system which aims to a unified effort of all the transport agents to work together. On the one hand this allows a higher acceptability level and resources efficiency and a reduction of the overall costs but on the other hand each agent has its own perspective, they usually do not easily agree on working together since they are direct competitors and the incentives towards that attitude are small;

b. Public-Private partnership where both the infrastructure development and management are entirely implemented and there are operational agreements as well as joint initiatives for identifying problems and solutions;

c. Night deliveries. On the one hand this solution permits congestion and conflicts reduction, increase of efficiency and productivity (higher speeds and less time losses) and lower visual intrusion. But on the other hand, some collateral effects are also registered: noise at night, extra working time that not all the directly affected companies are willing to pay for and resistance in retailers to open the store at night to receive or discharge products;

B. Legal measures

a. Pricing of urban freight activities which permits both the internalisation of external costs and disincentives the excessive use of transport services encouraging companies to improve their efficiency. In London, dynamic taxation was imposed and the higher the demand the higher the cost to perform urban freight activities. Measures of this type incentives companies to cooperate in arranging time schedules for each one and the expected result is urban freight activities evenly distributed during all the day decreasing congestion and conflicts between road users;

b. Restraining access measures. By limiting the access of certain types or number of vehicles in a certain area or time of the day, both conflicts and gases emissions are predicted to decline. An example of this type of measure is the Low Emissions Zone in Lisbon where vehicles older than 2000 are forbidden to enter in the downtown part of the city and vehicles older than 1996 cannot circulate in an upper belt;

C. Land Use Measures

a. Urban space designed for accommodating freight activities

b. Allocation of space for freight activities

c. Regulation of urban freight activities. In Portugal there is only a legislation for all the road users – *Código da Estrada* (The Road Code) – where freight activities are just briefly mentioned and no specific legislation was already defined for this activities which cannot be so generically parameterized;

D. Technological measures

a. Traffic monitoring and management also called Intelligent Transport Systems;

b. Vehicles properly tailored for urban logistics in order to decrease inefficiencies and null (or almost) gases emissions. Accordingly with the type of service, different vehicle technologies can be applied successfully and in a way that total annual costs can decrease. Hence, a technology transference can mean not only a higher efficiency and a lower environmental impact but it can also mean higher profits. However, it is important to take into account that the best solution is very dependent on the service and the utilization the vehicle has/might have;

E. Infrastructural measures

a. Load zone provision (loading bays) reserves more space for logistic operations but, at the same time, consumes the so scarce urban space and potentiates illegal parking whenever the enforcement is not adequate;

b. Hub areas to be used by freight vehicles, however they are located far away from the city in order to decrease infrastructure purchase cost and that location is not convenient since the operation happens entirely within the city;

c. Use of reserved spaces such as special lanes and parking spaces. However, it boosts illegal parking and it interferes with other activities without a commitment;

d. Urban collection point ends the resources consumption of the door-to-door system, decreases transport costs (shorter distances), increases load factors and can be performed at night however it can be perceive as a less quality service because it obliges the client to dislocate himself to those collection points;

e. Urban distribution centres or logistic platforms (in the outskirts) permit on the one hand, a reduction on travelled distance and, therefore, in emissions and an increase in the load factors but on the other hand it implies a relevant investment, requires high collaboration between agents and constantly face organisational and contractual problems. In addiction it cuts the relationship with the client and for some retailers this solution do not add any value because they already use an efficient logistic system.

Due to the complexity and interaction between the urban logistics' difficulties and challenges above, it is extremely demanding to find a single solution that suits them all. The way out must be a cumulative solution with as many contributions as possible and using only the available resources.

To sum up, urban logistics is a very complex system and it is hard to find exact answers to its challenges because of the multiplicity of players and services involved, because it implies spending money from different authorities, because it deals with conflicts of interests and because some requirements are not compatible with the remaining.

2.2. Possible Solutions and State of Practice

A possible and already validated approach to achieve operation improvements relies on technological innovation, whether it is intelligent transport systems or electric vehicles, smaller and lighter ones, sharing systems and much more.

2.2.1. Electric Two-wheelers as Part of the Solution

Focusing on the environmental consequences of urban logistics, electric vehicles have the ability of not to contribute to gases emissions during their utilization. In addition, two-wheelers have the ability to surpass many of the negative aspects of performing deliveries in urban areas: smaller vehicles do not need as much parcels to reach a higher load factor, they do not occupy much space when parking and even in the road itself, contributing to decrease congestion. They have access to low accessibility areas like pedestrian streets and stairs. Hence, a solution fitting some major concerns in logistics services is electric two-wheelers, such as e-scooters, e-bikes, e-cargo-bikes and e-tricycles. One possible explanation of their still weak utilization may reside in their relatively recent existence (still suboptimal in many aspects) and in the diffusion of innovation. Because a certain technology is new, there is no perceived knowledge, no previous experience enough to widely spread the results. Also, in some cases, because of the novelty and high-tech applied, prices are too high to attract new investors (Rogers & Everett 1983) and updates are frequent, quickly invalidating the recently bought technology.

There are electric two-wheelers of several sizes, capacities, power, autonomy and suitable for all the purposes one can imagine. According to Jorna and Mallens (2013), electric vehicles of two-wheelers can be of two types, defined as "Bicycles equipped with an auxiliary motor that cannot be exclusively propelled by that motor. Only when the cyclist pedals, does the motor assist" (pedelecs) and "Bicycles equipped with an auxiliary motor that can be exclusively propelled by that motor. The cyclist is not necessarily required to pedal" (e-bikes). Nevertheless, there is a distinction worth to mention between electrically powered two-wheelers (ePTW such as e-bikes, e-cargo-bikes and e-tricycles) or electric two-wheelers (eTW such as e-scooters). While the former runs with and without electric assistance – the rider can switch the motor on and off whenever he wants with the possibility of continuing to move using human power – the least can only transport people and goods if the electric engine is turned on. The authors also distinguish "Pedelec is (…) a bike with e-motor assistance", "Cargo Pedelec (e-cargo-bike) is a cargo-bike with e-motor assistance. The purpose of such a bike is the transport of goods, the supply of services and most important it could be the substitution for a car" and "E-Scooter / E-Moped – Bikes with an e-motor system instead of a compression-ignition engine (…) the use is similar to a standard motorbike. Depending on the battery capacity, the cruising range is 30 to 60km with one full charge. E-Scooter and E-Mopeds require a license plate for the use on public roads." In the development of this dissertation, whenever there is the need to refer both types without description, the term electric two-wheelers – or eTW – is used. Some of the advantages usually associated with this vehicles are passive. For instance, while the electric assistance allows e-bikes to move faster than conventional models, an e-scooter is slower than fossil fuelled ones (Mendes et al. 2015) and while e-bikes and e-cargo-bikes are allowed to use bike lanes, e-scooters are not so their accessibility, in spite of being higher than cars' and vans', is lower than e-bikes'.

In what concerns eTW's environmental benefits, it is worth to highlight that these vehicles are not entirely non-emitter. It is true that, contrary to fossil fuelled vehicles, eTW do not emit end-of-pipe gases when the vehicle is turned on, nor when it moves, nor stopped. However, it is during the electricity production process that CO_2, SO_2 and NO_X emissions can occur, depending on the primary energy source, if it is renewable (e.g., wind, sun, waves), there is no emissions related with the vehicle's operation onceover. For that matter, the bigger the percentage of electricity generated from renewable sources, the bigger the importance of electric vehicles' dissemination. It is in these conditions, that a technology replacement from fossil fuelled to electric vehicles has a potential impact in the reduction of pollutant emission levels. Portugal is one of those cases since, in 2014, 73% of the total energy generated by the biggest national electricity producer derived from renewable sources, including large dams, cogeneration, solar and wind energy (EDP 2015). During the utilization stage eTW' emissions 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 technological improvement based on European directives. Also 75% of eTWs' components can be reused in another vehicle in the end of its useful life, the remaining 25% can be recycled (The Motorcycle Industry 2012). Furthermore, Borken-kleefeld (2012) enhances the contribution of electric vehicles in the decarbonisation plan but the author also alerts that a complete usage of them is only possible with the corresponding technologic improvements and policy regulation. 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. Table 3 resumes indicative values from different types of vehicles, from the internal combustion ones to the human powered modes (eTW are coloured with grey).

2.2.2. Electric Two-wheelers Suitability in Urban Logistics

According to Gruber et al. (2014), the average delivery weight for one of the most common clients of urban delivery companies – offices – is 5.65kg and the average bulk volume is 37.5L. These values correspond to only one client, but almost always one trip corresponds to at least two or three clients. Even in that situation, eTW would have the capacity to carry those parcels, as Table 3 suggests. Regarding all the market segments explained above, eTW have the ability to perform each one of those services as long as their capacity is suitable and their logistics model are adapted to each market niche.

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

Those same authors performed a study in two urban areas with 892 km^2 and $98km^2$ (Berlin and Mainz, respectively) with the aim to evaluate the suitability of e-cargo-bikes to perform courier services. Considering a circular area, those values correspond to a radius of 17km and 6km, so a round trip to the city border would correspond to 8.5km and 12km, which can easily be performed by an eTW, based on the information provided in the table. However, factors like weight, quality of the sensor system, the motor and controller software efficiency as well as the external temperature influence both the autonomy and the cruising range (distance from an origin and return to it at a cruising speed).

Furthermore, those same authors implemented a costs comparison between three types of vehicles (eTW and conventional ones). They separated the costs into three components: financial economic sustainability (business point of view), socio-economic sustainability (society point of view) and product life cycle and environmental sustainability (society point of view). A review of the first component can be found in Table 4.

Table 3 – Vehicle characterization (adapted from (Lia et al. 2014), (Gruber et al. 2014), (Jorna & Mallens 2013), (Browne et al. 2011), (Macário et al. 2011))

		Internal Combustion		Electric					Human power/Traditional		
		Vans (Diesel)	Motorcycle	E-Van	E-scooter	E-Bike	E-Tricycle	E-Cargo-bike	Bicycle	Tricycle	Cargo-bike
Capacity	L	6 500-7 900	100-200	3000	100-200	40-60	500-1 500	160-300	40-60	500-1 500	160-300
	kg[1]	710-1 490	180-250	515	180-250	100-120	170-300	170-210	100-120	170-300	170-210
Recharge time	h	0	0	All night (6-8h)	3-5	3-5	4-8	4-8	0	0	0
Average speed in traffic	Km/h	6-15	35	8	35	20	15	20	20	15	20
Autonomy	km	-	-	-	30-120	50-180	50-90	50-70	-	-	-
Driving (adverse conditions)		Easy	Easy	Easy	Easy	Easy	Easy	Demanding	Easy	Easy	Demanding
Emissions		High	High	Low	Low	Null	Low	Low	Null	Null	Null
Costs		Very High	Very High	-	Average	Average	High	High	Low	Low	Low
OPEX/ 10 000km	€/ year	7 050	-	-	-	3 915			1 480		

[1] Including rider (70kg)

Table 4 – Financial Economic Sustainability: Vehicles costs comparison (Jorna & Mallens 2013)

		Purchase Costs [€]	**Maintenance Costs [€/yr]**	**Insurance and other Costs[2] [€/yr]**
Pedelecs		1 500 to 2 000	Considering an e-bike: 200	Insurance: 55 Electricity: 12 to 48
e-cargo-bikes	Babboe	2 699		-
	Bullitt	4 300		
		3 900 (423Wh)		
e-scooter		2 500 - 6 000	-	-
Mini-van		12 000	500	Insurance: 300 Fuel: 240 to 960 + Road taxes: 200

The purchase cost of an electric vehicle depends on the power, capacity, brand and other characteristics, so the range of values is wide. Instead of buying an electric vehicle, there is the possibility of buying a conventional fossil-fuelled one and then add an electric kit. According to the Fold n'visit, a Portuguese bike rental store in Oporto, one can add an electric battery to a conventional bicycle with 700€ but *Camisola Amarela*, a bike courier company in Lisbon that adapted a 250W electric kit to a cargo-bike, paid 937€. To verify the adequacy of motorized vehicles' prices in Portugal, the 2014 best-selling equivalent vehicles (mini-vans and motorized scooters) were used as reference: a Renault Kangoo 75cv (Moura 2015) costs about 14 000€ and has a 5.4l/100km consumption (Renault Portugal 2015) and an Honda PCX 125 (ACAP 2014; Honda 2014) costs 3 050€ and has a consumption of 2.0l/100km. This is a 125cc scooter, which is the fuelled scooter equivalent to an electric one.

Bishop et al. (2011) found that electric scooters spend 2.9 or 6.1 times less energy per kilometre than a gasoline motorcycle or a car, respectively, and, according to Gruber, Kihm and Lenz (2014), an e-cargo-bike spends 0.15€/100km in electricity while cars spend 10.50€/100km in fuel (a saving of almost 99%). In order to confirm this information, the U.S. Department of Energy (2015) provides the conversion between ten types of fuels and its energy content. Thus, one gallon of gasoline corresponds to 112.114 to 116.090Btu[3], one gallon of diesel represents 128.488Btu and a kWh of electricity has 3.414Btu (so one gallon of gasoline has approximately 33.7kWh and a gallon of diesel has 37.7kWh). In addition, with the objective to compare maintenance cost from the different technologies, a direct consultation to four motorcycle's repair shops in Lisbon was performed exclusively for this dissertation and the results can be found in Table 5, together with more representative costs from four different technologies (all the costs in this table are charged in Portugal – country where the study companies in this work operate). Those maintenance costs concern a five-year-old vehicle with an annual distance of 15 000km to 20 000km in urban environment. Note the difference in the maintenance costs between an electric scooter and

[2] Highly variable from region to region, variable with number of years of coverage, with the vehicle's value and it is also dependent on how common bikes are in that particular country. This value was concerns to an e-bike of 2 500€ purchase price with a 5 years insurance coverage in Holland. This value is lower than the insurance cost of a conventional bicycle and is possibly higher than e-cargo-bikes and e-scooters as they are not usually parked in high-crime areas.
[3] Btu stands for British Thermal Unit

a conventional one. This gap can be explained by the need of motorized vehicles to change much more mechanical components (e.g., tubes, oils, spark plugs and more) than electric scooters.

Regarding insurance costs on Table 4, there are still few insurance companies providing cycle insurance and there are even less providing distinguished services between electric and conventional bicycles. This is mainly true in Portugal where only four insurance companies have cycle coverage ranging from 34.51 to 76.17€/yr (Dias 2015). Regarding scooters, in Portugal the obligatory insurance (Civil Responsibility or third party insurance) paid by riders with more than two years of riding (accordingly with Gruber and his partners (2014), 88% of the messengers are between 23 and 55 years old and in Portugal one can ride a scooter by the age of sixteen) ranges from 145 to more than 230€ if the vehicle is a 125cc scooter and from 48 to 220€ considering an electric scooter. This reference values represent the cheapest (*Fidelidade Mundial*) and the most expensive (OK) insurance companies in Portugal, respectively and were acquired through direct consultation in order to being used in this dissertation. Hence, the difference in insurance between the two technologies can be as higher as 97€/yr. On the other side, the obligatory insurance (also Civil Responsibility) for a five year old commercial mini-van equivalent to the referenced is 443.85€[4] in the most expensive insurance company (*Tranquilidade*) and 263.96€ in the cheapest (*Fidelidade Mundial*) considering the same – and only obligatory – insurance coverages.

Regarding commercial vehicles' taxes, in Portugal there are five types: *Imposto Sobre valor Acrescentado* (IVA) – Tax on added value –, *Imposto Sobre Veículo* (ISV) – Tax of vehicles –, *Imposto Único de Circulação* (IUC) – Tax of circulation –, *Sistema Integrado de Gestão de Pneus Usados* (SGPU) – Integrated System of Used Tires' Management – and more "eco" taxes. IVA is included in all the goods' purchase price. It increases 23% of the purchase cost whenever the good is not a basic need – such as vehicles. The ISV depends on the cubic capacity, the CO_2 emissions and the type of fuel (diesel or gasoline) and it is also paid in the purchase process (Assembleia da República 2014). The IUC is the only tax paid annually and it also depends on the cubic capacity, the vehicle's weight, the CO_2 emissions and the type of fuel – thus, electric vehicles do not pay this tax. IUC of the reference vehicles can be consulted in Table 5. SGPU tax covers all the vehicles because it charges the pollution due to the use of tires. This tax is paid in the purchase process and never again. All the tax values presented in Table 5 were provided by official dealers of each brand.

Table 5 – Summary of reference values from four different vehicle technologies

	Purchase[5] [€]	**Maintenance[6] [€/yr]**	**Insurance[7] [€/yr]**	**Taxes[4] [€/yr]**
e-Cargo-Bike	3 900	100	25	0
e-Scooter	6 500	350	48	0
Scooter 125 cc	3 050	485	145	5.49
Mini-van	14 000	1 000	354	32

[4] Considering a male driver with 15 years of driving experience and no insurance history
[5] Direct consultation to official dealers of each brand (own source)
[6] Direct consultation to motorcycles' repair shops (own source)
[7] Direct consultation to Portuguese insurance companies (own source)

Nevertheless, all the transportation modes, especially the motorized ones, have external costs associated. These are socio-economic costs and can be classified as environmental, time-savings or safety issues. Table 3 already illustrated that electric vehicles contribute to less (local) emissions than motorized vehicles and these savings in pollution and public health damage can be easily computed using a cost per kilogram of emitted gas which is then multiplied by the effective emissions of each mode. For that matter, within the European project Pro-E-Bike, (Occam 2015) developed a simulation tool in which it considered 35€/CO_2 tonne, 130 500€/particulate tonne and 6 600€/NOx tonne CO_2 tonne, and, respectively as emission costs. Another cost component associated with health is the noise cost. In Portugal, accordingly to Becker et al. (2012), cars' noise was estimated to have an external cost of 125 Million €/yr. Besides that, costs concerning time usage must also be considered. An analysis of this component allows to understand how faster a two-wheeler is compared with motorized vehicles and therefor how much time can be saved only by changing the mean of transportation. The main reasons are two-wheelers' capacity to overtake congestion, not to cause it or suffer from it (at least to the same extent as other motorized vehicles), and to access restricted areas to motorized transit. This allows a higher certainty in their delivery time window. Because "time is money" and this is especially true in a business environment, a conversion between these two units is interesting. Based on this, Ceuster et al. (2004) explained that this conversion is dependent on many variables such as type of company, service and goods, peak/off-peak hours, region and covered area, modes and many more parameters. So, the value itself should be defined by each company, to each service, to each type of goods and there is no universal, generic value one can use as a reference. In order to quantify the difference between the two technologies it was selected an origin/destination (OD) pair Alcântara-Saldanha (the port of Lisbon and other industrial areas are located in Alcântara and one of the major Central Business Area (CBA) of Lisbon is Saldanha). These two locations are 3.45km apart linearly, 8km by car and 5km by bicycle (measurements on Google Earth). Considering congestion, road slopes, stopped times due to traffic lights and other causes, the speed of 14km/h can be used as a reference for vans' speed (Dekoster & Schollaert 2000), corresponding to a travel time of 34 minutes. Regarding bicycles' duration and in order to obtain the most accurate result, time values from a bike courier company in Lisbon (*Camisola Amarela*) were used: an electrically assisted cargo-bike performs the same trip for the same OD pair in about 30 minutes – corresponding to a 10km/h speed which is coherent with the established in the latter document, however, other authors, like Lia et al. (2014), claim a higher speed for these vehicles –, which corresponds to, at least, a 4 minutes saving. Still, it is important to note that safety plays against eTW when compared to other modes: according to the European Commission (2014), bicycle drivers are much more exposed to road accidents than cars: 78.4 pedal cycle road fatalities per year between 2009 and 2012 versus 27.3 in small lorries in Europe. Soft modes have a higher safety cost than motorized vehicles. On the other hand, the role electric two-wheelers have to national economy must be taken into consideration. The less time a citizen looses stuck in traffic, is that much time he has to produce work, to shop, to leisure, and to develop national's economy. Also, the lower the amount of motorized vehicles, the smaller and less sophisticated infrastructures are needed, which ultimately results in lower road construction and maintenance costs and less occupied space. These reductions are core to achieve lower energy dependency rates and lower costs with public health. A shift for eTW result in promotion of two-wheelers' national factories and happier people and thus, higher national productivity.

The best way to build an analysis model is considering as many of these components as possible. In this extend, this is why a cost-benefit analysis is a very good methodology, however its results are dependent on the study's purpose, which can lead to subjective results.

Considering all the previous features, it becomes clearer which are electric two-wheelers' potential advantages in urban freight transportation. Plus, they are silent and because eTW 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 traditional 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.

It is also essential to attend to the learning process, the way users exploit eTWs' benefits, in order to achieve a more functional and efficient vehicle. For example, there is the charging process, one of the major issues associated with electric vehicles: while some operators might plug-in when the battery is completely off, another might do it when there are still some kilometres to run and, still, an operator can unplug it when the battery is 100% charged or he can do it earlier (Bishop et al. 2011). Only with the usage, drivers learn the best way to use and deal with their vehicle and, as consequence, the full and better use of these vehicles might happen not in the beginning of the usage but only a few weeks later.

2.2.3. State of the Art

With the aim of discover if these vehicles have potential to transport freight in urban areas, the European Commission has been creating and investing in projects and several authors have been studying their responses. As a result, several papers were published. Among them:

- An Italian case study from the Pro-E-Bike project in which the performance of Light Electric Vehicles (LEV) such as e-bicycles, e-cargo-bikes and e-scooters is being evaluated in three delivery services in terms of CO_2 emissions and energy savings. In order to evaluate the effectiveness in the different services, there will be (the project is still on-going) data collection combined with performance and economic indicators. Then, a comparison between costs and profits and between LEV and traditional vehicles' indicators will be performed (Lia et al. 2014).
- A case study in London of a major supplier of stationery involving the substitution of seven diesel vans to six e-tricycles and three e-vans and the utilization of an urban micro-consolidation centre (UmCC), from which the trial vehicles departure to deliver within the city centre. During the trial the company worked in the same conditions as before and answered a survey, both before and during the trial. The UmCC was supplied overnight by an 18-tonne goods vehicle. Because the electricity used to charge the batteries came from renewable sources, no emissions nor fossil fuel consumption was involved. The survey allowed to collect operational data (distances, number

of stops, time). These data were then examined after a descriptive statistical analysis and then a comparison took place. As result, the authors got that the vans (both diesel and electric) were the most suitable in terms of load capacity. The remaining significant results were a reduction in the overall distance travelled per parcel and a 0.07kg of CO_2 equivalent reduction per parcel during the experiment (Browne et al. 2011).

- Lenz and Riehle (2013) expect that a quarter of total city centre freight can be carried out by bicycle, so they analysed several projects in Europe, whether publicly funded or performed by companies themselves, already using cycle freight (bikes, e-bikes, (e)cargo-bikes, (e)tricycles). In the end, they were capable of formulate a list of pros and cons of this kind of vehicle that can be transferable for most cities in Europe. In order to achieve this the authors ran surveys to tradesmen and producers, and then a descriptive statistical analysis was performed. Part of those surveys pretended to assess operators' acceptance of electric cargo-bikes. The authors were able to realize that the majority of companies using cycle freight are small enterprises and that 42% of them only uses cargo-bikes and conventional bikes. In the majority of the cases, cargo-bikes were used because they were part of company's image. The surveys' answers made it clear that bicycles cannot replace the bigger vehicles, essentially due to their limited load capacity. Another observation is that only few companies recognize bicycles' aptitude to transport freight. This author remembers that there is no studies on the effects of cycle freight in city centre traffic.

- Gruber, Kihm and Lenz (2014) developed a survey focusing on a potential substitution of cars and bicycles by e-cargo-bikes in urban transport of freight and its acceptance by bicycle and car messengers, as the immediate competitors of e-cargo-bikes. Trip's and goods' data were collected and used both a descriptive statistics analysis and a binary logit model to assess courier messengers' opinion. Regarding the substitution potential, the authors got that the majority of the deliveries are in short distances, the load is not relatively heavy and there are only few parcels per shipment. In addition, e-cargo-bikes' speed is potentially higher than cars' and cycles'.

In what concerns with both car and bike couriers' acceptance of e-cargo-bikes, the authors found that bicycle's messengers are younger than car's which can be a clue to diffuse this practice and attract more people. More than 90% of the interviewees affirmed their interest in vehicle technology. Furthermore, more than half thinks that e-cargo-bikes have potential to be used in their urban surroundings and only a third believes that there is enough information about these vehicles.

- Hans J. Quak (2012), on the other hand, performed a compilation of logistics' best practices and courier initiatives for a sustainable urban freight transportation in the Netherlands during the EU project CityLog. Among an all set of solutions (based on the three possible directions: policy, technology and logistics), the author mentions electric vehicles as an engine solution and analyses their pros (subsides, most suitable for regional scale, no noise) and cons (limited battery capacity, high costs for batteries and charging times).

- In another perspective, Ibeas and his partners (2012) conducted a study with the aim of assess which type of data can be easily transferred between different environments. From this study resulted that between cities in which structure and size are much alike, it is not proper to generalize data from one city to another. Moreover, the authors built a model to analyse urban freight transport and logistics and evaluate policy measures. Between the results, the authors concluded that the quantities of goods attracted by zones and the origin/destination matrix of freight quantities' estimation is generalizable and transferable for both cities.

In a very different approach, Mendes and remaining team (2015) used the Vehicle Specific Power (VSP) methodology aiming to quantify the energy consumption in the TTW stage and the driving dynamics on six routes in Lisbon based on vehicles' mobility pattern. The author found that electric motorcycles have a higher travel time (+36%) and a lower energy consumption (-61% regarding Tank-to-Wheel (TTW) type and -30% Well-to-Wheel (WTW)) than the fuelled one but an e-bike has a lower travel time (-9.5%) than a conventional bicycle. Bishop and remaining team (2011), cited by the previous author, discovered that using an electric bicycle means 6.1 (2.9) times less energy, 3.8 (1.8) times less GHG emissions and 5.9 (2.7) times less operational costs than using a common car (conventional motorcycle). The same author also found a 65% improvement regarding efficiency on an electric powertrain compared with conventional one.

Table A 1 (in annex) summarizes these author's methodologies, results and conclusions.

2.3. Summary Conclusions

There is now evidence that eTW might be part of the solution to increase urban logistics efficiency. Although not the solution as an all, using eTW in coordination with political and logistic measures (urban consolidation centre or change in selected routes, for instance), it is possible to achieve a more efficient operation partly because of their accessibility potential, no congestion limitation and easier parking, less pollution (whether in terms of public health, noise levels or in terms of GHG emissions), less social impacts (smaller vehicles means more space for pedestrians) and more revenues for both logistical operators (an improved operation leads to higher profits) and public policy makers (that makes the city a better place to live and work increasing its attractiveness). Urban logistics is a very operational topic, this is why the majority of the authors use case studies and applied descriptive statistics analysis to their survey results in order to assess eTW operation. All of those case studies had a similar conclusion: eTW have a great potential in noise and emissions reduction and two-wheelers in general have a major capacity for congestion reduction and increasing accessibility but none of those studies evaluates the benefits these vehicles can have in a business context, environmentally but also economically. Table 6 displays the contribution of eTW to the detected problems associated with Urban Logistics.

Table 6 – Urban logistics' complications and eTWs' contribution

Problems Associated with Urban Logistics		Contribution of eTWs
Economic	Many agents	x
	Many services	x
	Lower direct costs for the owner	✓
	Lower external costs for the society	✓
Efficiency	Load/Capacity ratio	✓
	Many single parcel receivers	✓
Safety	Road accidents[8]	✓ / x
Environmental	Source of pollution	✓
	Source of CO_2	✓
	Congestion	✓
	Noise	✓
Infrastructure	HV's % road space use	✓
Urban Structure	Population increase	x
	Limited accessibility	✓
	Parking restrains	✓
	Land use	x

In Table 6, the mark symbol represents a positive contribution of electric two-wheelers to that urban logistics problem and the cross symbol represents the incapability for electric two-wheelers to positively contribute to that particular problem.

8 eTW can only solve the high number of accidents in roads when they achieve a dimension big enough to earn their own space in road and when cycle infrastructures become safe and sufficient

3. Methodology

The aim of this work is to understand how beneficial a technological transference from fossil fuelled vehicles to eTW is for a company and to quantify the benefits that are most likely to mean a fleet shift. Because an important element for companies is their profit and they mostly seek a sustainable development policy, the benefits addressed, measured and compared in this dissertation, were from the economic and environmental domains, for the case studies analysed here.

3.1. Methodological Approach

ETWs' advantages were already described in the previous chapter. However, some of them need quantification so they can be used as proper arguments. They are energy consumption, money, time, attractiveness[9] and emissions. Because this dissertation focus on the business context, the aim was to quantify those vehicles' advantages in business' budgets. As so, economic and environmental costs of these and fossil fuelled vehicles were estimated and then compared.

In order to find real savings, three case studies were considered and all the costs parameters that were possible to find in their operation were used in the respective case study. Reference values were only considered whenever real parameters' values were not available. Because the use of these vehicles in these case studies is recent, there were not real maintenance costs, so they were collected from two repair shops (there are still few repairers investing in this technology). Regarding conventional vehicles, the values introduced came from the literature review.

The remaining data are particular of a certain service and environment so operational data from the three case studies were collected like Federico Lia et al. (2014) did. In order to validate the approach and get a robust results' transferability, the selected case studies, all Portuguese, represent different services in different environmental contexts and different geographical areas using different types of ePTWs: *Camisola Amarela* (CA) is a courier company operating in Lisbon's central business area with an electrically assisted cargo-bike; *Moço de Recados* (MR, meaning "errand boy") performs almost all types of services in an e-scooter in Lisbon and Oeiras, from delivering parcels to walking someone else's dog; and the last company is *O Marujo* restaurant, a sea food restaurant in Matosinhos (near Oporto) performing home deliveries of food and also using an e-scooter. The technical data (such as distances, weights and volumes) of these case

[9] This subjective component was measured in this work using surveys to the three entities directly affected by these vehicles in the business perspective: owner, driver and clients.

studies were the remaining inputs. These were then introduced in a costs simulator (Occam 2015) and the data regarding both eTWs and fossil fuelled vehicles (a mini-van and a scooter) were extracted supporting vehicles' benchmark.

In order to assess those positive results, it was also important to evaluate the new technology's attractiveness for both owners, riders and clients. With this concern in mind, three different surveys were delivered to those three entities. The owner survey aimed to understand if that entity perceives these vehicles practical utility and what motivates him to use that vehicle. The rider survey aimed to discover rider's knowledge and experience with these vehicles, their potential to substitute fossil fuelled vehicles in urban logistics, the charging profile and practical features such as battery's autonomy and sensibility to slopes. Regarding the rider and owner surveys, answers from the three case studies and a Netherlands' food delivery company were collected. In what concerns to the clients' survey, the aim was to find if the speed limitation of these vehicles has consequences in the delivery performance and, therefore, client perception, clients' affinity with this technological transfer and the importance of these vehicles utilization for them. Regarding this survey, only the costumers of *Camisola Amarela* and the companies using *Moço de Recados* to perform services did not respond. The results were then submitted into a descriptive statistical analysis, methodology already applied by Lenz and Riehle (2013).

All the case studies are partners of a European project called Pro-E-Bike (Figure 4). This project "promotes clean and energy efficient vehicles, electric bikes and electric scooters" for goods and passenger transport in urban areas (PRO-E-BIKE 2013). In total, Pro-E-Bike works along with companies in 8 European countries, among them, Portugal.

Figure 4 – Pro-E-Bike's logo

3.2. Methods

In order to perform a comparison between electric and fossil fuelled vehicles and identify eTWs' suitability for different services it was crucial to ensure the same on-road conditions for both technologies and to measure how successful eTWs' implementation was for both activities.

3.2.1. Experimental Procedure

The search for eTWs' benefits started in the State of the Art Chapter. However, it is essential to prove some of them true. In order to do that, each case study's context and service was defined using the proved best tool in defining urban logistics services' major strong and weak points: logistic profiles.

During Pro-E-Bike's trial, each company ran the corresponding vehicle in usual conditions: *Camisola Amarela* used an electrically assisted cargo-bike to perform deliveries in the same conditions as the remaining cargo-bikes the company already had, *Moço de Recados* used his e-scooter in the same conditions as he used to run – and still does – his conventional one and the restaurant, because it is also the trial of home deliveries at all, the electric scooter is also their first vehicle. Data were collected during one and four months in *Moço de Recados*, in the restaurant and in CA, respectively. During these periods, each company recorded data in consecutive working days in a standard sheet from the Pro-E-Bike project. The results were, therefor, quite accurate and up to date. These data were enough to define how the study vehicles were used and in what conditions.

In order to compute both technologies' costs (both economic and environmental), a costs simulator was applied. It responded with CO_2 emissions – of fossil fuel burned and of electricity generation (estimative) –, fossil fuel costs and operational lifetime costs of the fossil fuel technology, CO_2 costs and pollutants costs. By computing these total operational lifetime costs – which excludes the acquisition cost – it becomes possible to compare how the different technologies behave in similar on-road conditions in environmental terms. Ultimately, the savings one can obtain by simply substitute a conventional fleet by an electric one in a complete or partial manner are presented. However, some of the outputs are only presented to the conventional vehicle and, therefore, additional calculations were performed.

Regarding pollutants (VOC, CO, PM SO_2 and NO_x), electric vehicles do not emit small particles in their tank-to-wheel stages, only in the well-to-tank stage (VOC, CO and PM not included) and in residual (still unquantified) volume. Although this methodology retrieves particulate, NO_x and NMHC emission levels for the conventional technology, the remaining gases and technology could not be addressed due to a lack of methodologies. Because these gases emissions are residual for the electric vehicles, "pollutants cost" were considered null in the results. It would be interesting a real quantification as a future study in order to complement the present analysis. Nevertheless, companies should acknowledge that their pollution are externalities that, ultimately, the society, as a whole, has to pay, namely (but not only) through the national health care systems.

Furthermore, in order to assess the benefits above, user experience data was collected through three surveys: one was delivered to the vehicle's rider in order to assess how easy and safe an electric two-wheeler feels, what is the charging scheme and his perception of suitability to the service; a second survey was delivered to the company's owner in order to evaluate his business experience and his motivations to use these vehicles; and the third survey's aim – addressed to clients – was to understand how much costumers care about the technology that is being used and the way they look at the recent "electric" company. This data was then analysed using descriptive statistical analysis with the aim to assess entities' willingness to use eTW on daily deliveries in urban context and the social impact of this alternative mode. The surveys were not only distributed to the pilots, they were also available online and three responses were collected, two of them outside Portugal.

3.2.2. Collected Data

The first stage of the research consisted in searching and reading papers and other relevant documents, mostly via Internet in browsers like Science Direct, Transportation Research Board and European Commission's portal. A search to electric two-wheelers', Renault's and Honda's dealers, repair shops and insurance companies were also executed using direct consultation. In order to achieve consistent values, the two conventional vehicles used as equivalents to eTW were a mini-van and a scooter 125cc and, whenever the company did not possess these vehicles, the best-selling models in the previous year were considered. Because there is no immediate conversion between electric and conventional scooters, it was necessary to consider an equivalent model in these cases. As so, the 2014 best-selling 125cc scooter (Honda PCX 125) was taken as reference. The equivalent was applied to the mini-van: the 2014 best-selling conventional mini-van, a Renault Kangoo Express 75cv was considered as the type of vehicle most commonly used in Urban Logistics. Regarding maintenance, it was stipulated a five year old vehicle performing 15 000km to 20 000km per year exclusively in urban context. In the end, a filter was applied and the eTW's benefits were collected.

Regarding data quantification part, within the Pro-E-Bike project each pilot had a standardized form, like the one in Table A 2 (annex), to fill on a daily basis in the end of the day. Each column represents a day and each line represents a variable to measure like number of deliveries performed by that vehicle in that day, quantity of parcels and trips, total duration and distance, remaining battery's level and duration of charging and could be easily measured both by simple counting, GPS track or even, in what concerns speed and distance, it could be read from the vehicle's panel, since e-scooters register these parameters for further consultation and analysis. Those data were collected on a daily basis and were meant to reproduce usual utilization conditions. The data collection described above was identical in the three case studies. The electrically assisted cargo-bike's trial in this company lasted four months. Whereas in the restaurant, the trial lasted for only one month and the home deliveries in this experimental period only occurred for loyal customers. Nevertheless, to obtain a pragmatic approach with the possibility of easy transference, a six day per week working period was considered in emission and costs calculations. In the third case study, *Moço de Recados*, trial's duration was also only one month with the mean of 2.6 services per day.

Regarding vehicle's costs, the purchase value of electric vehicles was based on pilots' real expenses. All the remaining eTW's costs were not available in all the case studies, so whenever the company had the real value, it was used but if there was not that possibility, reference values from the literature review were applied. The same happened concerning the fossil fuelled vehicles. Although MR had all the information about the conventional vehicle actually used in the comparison, none of the remaining case studies had that, so reference values from the literature were considered.

Additionally, during the trial a survey was delivered to restaurants' and *Moço dos Recados*' private clients. In the first case, because the clients were regular, the survey was delivered during their food deliveries and collected in the next request. In the second case, because the rider do not contact directly with the client most of the times, the survey went online so the most frequent private clients could respond whenever they have the time to do it. Unfortunately, due to confidentiality, it was not possible to collect answers from the remaining costumers of MR (40% of their clients) nor from *Camisola Amarela*'s clients, which are mainly companies. In the end of the experiment, another two surveys were run in the three companies. One provided riders' opinion about the vehicle and about the suitability of the vehicle to that particular service and the second one's purpose was to show the owner's business perspective of the vehicle's suitability. Surveys' composition can be consulted in Annex B. Because it was important to evaluate eTWs' performance in a more generalized way, those same surveys were distributed to more eTWs' users in the business context. In that inquiry, one more Pro-E-Bike pilot – Puurland from Netherland – participated and another company using eTW to deliver flowers. In those cases, the survey was diffused by mail and on social networks (Facebook and LinkedIn).

3.2.3. Quantification of Both the Economic and Environmental Benefits

In order to compute both costs, emissions and energy consumption, a costs simulator developed by a Portuguese partner in the Pro-E-Bike project – the consultant Occam – was used. This simulator's output is the savings one can get by simply substituting a fossil fuelled fleet by an electric one. It is possible to try the following hypothesis: substitute *d* diesel and *g* gasoline vehicles by an e-bike or e-cargo-bike or by an e-scooter. In addition, it is possible to try combinations of these vehicles and find out the combination with higher savings, however that is not the aim of this dissertation. This tool can be found on Pro-E-Bike's website in the publications sector.

Tool's layout can be found in Table 7 to Table 12 and the inputs are:

1. Number of fossil fuelled vehicles (*d* of diesel and *g* of gasoline) substituted;
2. Average consumption of those vehicles [l/100km];
3. Average distance [km/veh.day];
4. Average load [kg];
5. Average cargo volume [m^3];
6. Acquisition, maintenance, insurance and other costs per vehicle of the fossil fuelled fleet;
7. Acquisition, maintenance, insurance and other costs per vehicle of the electric fleet;
8. Number of electric vehicles;
9. Days of annual use;
10. Energy consumption [kWh/km], average electricity cost [€/kWh], maximum cargo capacity, both weight [kg] and volume [m^3] of the electric fleet and conversion factors from electric energy into CO_2 quantity [kg CO_2/kWh];

11. Lifetime mileage, average years of vehicle's use, number of years of leasing, cost of CO_2 [€/ton] and average fuel costs of the fuelled fleet, conversion factors from diesel and gasoline volume into CO_2 [kg CO_2/l] and particulate, NOx and NMHC emissions [g/km] due to fuel.

The number of both conventional vehicles (Table 7) and eTWs (Table 8) was considered to be one in all the cases since the objective of this simulation was not fleet design, but rather the comparison between technologies. The reference value for the average consumption of the fuelled vehicle was 5.4l/100km to the referenced mini-van and 2.0l/100km to the referenced scooter (see Section 2.2). However, *Moço de Recados* has a conventional scooter, which the company uses to do the same services and in the same conditions as the studied electric vehicle. For this reason, that vehicle was used as a comparison for that particular case, in order to find what would be the savings the company would achieve if they would have changed that vehicle for another electric vehicle equal to the one used during the trial. The average distance travelled per vehicle, the average load and cargo volume in one work day were computed for each case study through their Pro-E-Bike form. A single average was performed using all the recorded days during the trial period.

Table 7 – Simulator's Inputs: Fossil Fuelled Fleet (Occam 2015)

Fossil fuelled fleet											
Diesel	nº vehicles	1	Average con-sumption [l/100km]	5.4	Average dist [km/vehi.day]	-	Average Load [kg]	-	Average cargo volume [m^3]	-
Gasoline	nº vehicles	1	Average con-sumption [l/100km]	2.0	Average dist [km/vehi.day]	-	Average Load [kg]	-	Average cargo volume [m^3]	-

Table 8 – Simulator's Inputs: Electric Fleet (Occam 2015)

Electric fleet simulation
Alternatives to simulate
○ e-Bike/e-Cargobike
○ e-Scooter
◉ Both — How many vehicles do you want to replace with e-Bikes: ___ and e-Scooters: ___

In what concerns to average global costs (Table 9) of the fossil fuelled fleet, the purchase cost was 14 000€ for a Renault Kangoo Express of (Renault Portugal 2015) and 3 050€ for an Honda PCX 125 (Honda 2014), as already seen in Section 2.2. On the other hand, electric vehicle's purchase costs were the actual vehicles used by the pilots.

Because the maintenance cost of an electrically assisted cargo-bike is the same as a conventional one (only the battery needs to be changed in the end of its life) and CA uses these vehicles since 2013, the employed maintenance cost for an electrically assisted cargo-bike used in the simulation was the one reported by CA: 100€/yr. Accordingly with motorcycles' repair shops, fossil fuelled scooters' maintenance cost is higher than electrics' since the latter do not need to change spark plugs nor oils and the battery does not need maintenance during its life time (approximately

50 000km). According with the same source, whereas an electric scooter maintenance cost is about 350€/yr, the equivalent conventional vehicle's maintenance cost can go up to 525€/yr. In order to get more adequate results, e-scooter maintenance costs actually paid by the pilots could be used, however none of the vehicles was being used long enough, hampering the estimate of a consistent annual cost. The maintenance cost of a Renault Kangoo Express was given by the manufacturer and it costs 80€/yr. However, the maintenance cost given be the producer tends to be lower than the real cost, as a marketing campaign. Taking this into consideration, a direct consultation to two Lisbon specialized repair shops showed that this type of vehicle, in its first year can have a cost of 100€ but after five years – which is the reference age considered in this dissertation – a maintenance cost of 1 500€/yr can be achieved (the delivery companies studied in this work are all small sized and still entering this new market so the business volume are still low, thus they do not have economic capacity to invest in new vehicles and a five year old vehicle can be considered as reference). Hence, a cost of 1 000€/yr will be considered as proposed in the simulator.

Regarding insurance costs, characteristic values can be found in Section 2.2. Hence the insurance cost of an electric scooter was considered to be 48€/yr, the employed cost regarding a gasoline scooter was 145€/yr, the insurance of an electrically assisted cargo-bike was considered to be 25€/yr and a mini-van's average insurance cost was estimated in 353.91€/yr. Also, a bought, and not leased, fleet was considered.

In order to get the most realistic savings, it is important to enter with another cost: taxation. As seen in Section 2.2, each vehicle's taxation is different and dependent on the age, cubic capacity, CO_2 emissions and more, so the value it takes were defined in each case study. The number of days of annual use depends on the type of service.

Table 9 – Simulator's Inputs: Average Global Costs (Occam 2015)

Average Global Costs					
Fuelled Fleet		*Reference Value*			
Acquisition [EUR]	-	10 000-25 000	Leasing [EUR/yr]	0	3 000-25 000
Maintenance [EUR/yr]	-	750-1 500			
Insurance [EUR/yr]	-	500-1 000			
Other costs [EUR/yr]	-	(e.g. taxes)			
e-Bike/e-Cargo-bike					
Acquisition [EUR]	3 737	3 500-1 500			
Maintenance[EUR/yr]	100	100-150			
Insurance [EUR/yr]	25	50-100			
Other costs [EUR/yr]	0	(e.g. taxes, employees, etc.)			
e-Scooter					
Acquisition [EUR]	-	1 500-2 500			
Maintenance[EUR/yr]	-	100-150			
Insurance [EUR/yr]	48	80-100			
Other costs [EUR/yr]	0	(e.g. taxes, employees, etc.)			

The energy consumption of the electric fleet (Table 10) resulted from de ratio between the energy that is provided by the battery [kWh] (producer's specification) and the total travelled distance recorded in the form – it is, therefore, different in each case study. This energy consumption resulted from the average of each day's recording and represents the energy the battery consumes to allow the vehicle to travel one kilometre. The average electricity cost depends on the country. Because all the case studies analysed here are Portuguese, the corresponding tariff was used. In Portugal, the energy's unitary tariff for low tension between 2.3 and 20.7kVA[10] in a bi hourly rate[11] (less than 6.9kVA) in off-peak hours (is during night time that the majority and longer charging situations occur) is 0.0986€/kWh[12] (Entidade Reguladora dos Serviços Energéticos 2015). The maximum cargo and volume capacity are also producers' specifications and, obviously, depends on the case study and the vehicle used by each company. The right column of Table 10 to Table 12 contains the reference values for the European Union. However, the data used in this work reflects the real values for these case studies in Portugal.

Table 10 – Simulator's Inputs: Characteristics of the electric vehicle (Occam 2015)

Electric fleet			
Energy consumption [kWh/km]	e-bike/e-cargo-bike	-	0.0065
	e-scooter	-	0.0512
Average electricity cost [EUR/kWh]		0.0986	0.211
Maximum cargo capacity	e-Bike/e-Cargo-bike [kg]	-	100/250
	e-Scooter [kg]	-	100
	e-Bike/e-Cargo-bike [m^3]	-	0.5/1.5
	e-Scooter [m^3]	-	0.2

On Table 11, the lifetime mileage parameter depends on several factors that were not addressed in this dissertation. Based on that, the mean of the suggest mileage range in the simulator was considered (225 000 km of lifetime mileage) in the CA and restaurant case studies. In the case study of the company MR, specific data from the conventional vehicle used in that company was used. Regarding the average years of vehicle's use, in a similar way of what was already considered above, a 5 years lifetime was considered. Accordingly with the Portuguese Ministry of the Environment, Land Planning and Energy (2015), the average diesel and gasoline prices are 1.200€/l and 1.425€/l respectively.

Table 11 – Simulator's Inputs: Characteristics of the fossil fuelled fleet (Occam 2015)

Fossil fuelled fleet				
Operational lifetime costs	Lifetime mileage	225 000	200 000–250 000	km
	Average years of vehicle use	5	10	years
	Number of years of leasing	0	4	years
	Cost of CO_2	35	30-40	EUR/ton
Average fuel costs	Diesel [EUR/l]	1.2000	1.244	
	Gasoline [EUR/l]	1.4250	1.352	

Regarding the conversion factors (Table 12) from electric energy and from diesel and gasoline

[10] Measure of electric power

[11] This is the most common fare and it has enough power to all the case studies, even the restaurant which, due to the specific equipment such as refrigerators and ovens, has a higher energy need.

[12] Energy available to whom contracted the service

spent volume into CO_2 quantity [kg CO_2/kWh] and [kg CO_2/l], factors proposed by EDP - Energias de Portugal (2014) and European Clean and Energy Efficient Vehicles Directive (2015), respectively, were used as inputs in this dissertation: 0.1225 for electricity, 2.67 for Diesel and 2.49 for gasoline. The fuel related parameters were proposed in the simulator (based on the previous reference) and, in order to assess its accuracy, they were recalculated based on other sources. Accordingly with Sørensen and Kilde (2000), each kilogram of fuel is responsible for the emission of 3.15kg of CO_2. The volumetric weight of diesel and gasoline is 0.8495 and 0.79kg/l, respectively which results in the same factors as previously indicated. Those parameters supported the understanding of how much quantity of CO_2 is emitted for each litre of fossil fuel burned and for each kilowatt-hour of generated electricity, therefore allowing to compute the external costs associated with each kilometre travelled using the studied vehicles, both the conventional and the electric ones. The calculation of this external costs implicates the consideration of the average consumption (Table 7), the energy consumption (Table 10) seen above and the cost of CO_2 [€/ton]. This cost can vary between 30 and 40 euros per tonne of CO_2 (European Commission 2015) so the mean was used in this dissertation (Table 11). The amount of pollutants in each fossil fuel also needed to be defined. In that extend, default values from the same source were also adopted (Table 12): one kilometre travelled using a diesel vehicle is associated to an emission of $1.1x10^{-5}$ grams of particulate matter and 0.1225 grams of NO_X; if the vehicle runes with gasoline, the same distance corresponds to $1.68x10^{-5}$ grams of particulate matter, 0.0416 grams of NO_X and 0.052 grams of NMHC[13] emitted. The last input regards to pollutants' external costs. Accordingly with the simulator, particulate emissions cost between 0.087 and 0.174€/g. Taking this into consideration, the mean value (0.1305€/g) were applied and the same happened with NOx (0.0066€/g) and NMHC (0.0015€/g) costs.

Table 12 – Simulator's Inputs: Conversion factors from fuels to gas (Occam 2015)

Conversion factors				
	Diesel	2.6700	2.67	kg CO_2/l
	Gasoline	2.4900	2.49	kg CO_2/l
	Electricity	0.1225	0.47	kg CO_2/kWh
Particulate emissions		0.1305	0.087-0.174	EUR/g
	Diesel	$1.1000x10^{-5}$	0.000011	g/km
	Gasoline	$1.6800 x10^{-5}$	0.0000168	g/km
	Electricity	0	0	g/km
NO_x emissions		0.0066	0.0044-0.0088	EUR/g
	Diesel	0.1225	0.1225	g/km
	Gasoline	0.0416	0.0416	g/km
	Electricity	0	0	g/km
NMHC emissions		0.0015	0.001-0.002	EUR/g
	Diesel	0	0	g/km
	Gasoline	0.0520	0.052	g/km
	Electricity	0	0	g/km

[13] NMHC stands for Non-Methane Hydrocarbons

Since the simulator only retrieves operational lifetime costs for fossil fuelled vehicles and not for electric two-wheelers, an additional calculation was performed considering an electric vehicle lifetime mileage of 50 000km (this is an e-scooter battery's lifetime mileage[14] but because no other value was found, this was also considered to be true for an electrically assisted cargo-bike): the energy costs were computed by multiplying the electricity cost (0.0986€/kWh) with the average energy consumption (depending on the case study; kWh/km) and with the lifetime mileage (50 000km), the carbon dioxide cost was computed by multiplying the CO_2 cost (35€/ton CO_2) with the emissions (from the consultation of the respective simulation results; kg CO_2/100km) and with the lifetime mileage. The pollutants cost is null because this type of emission is not meaningful for eTW. The total operational lifetime cost is the sum of the previous costs.

Nevertheless, some important considerations must be clarified: all the calculations were made in constant monetary terms and whenever the costs are annual, the calculation only includes the sum of all the annual costs (fuel, maintenance and taxes). Only in the "average total costs per vehicle" the remaining costs (purchase) for a fossil fuelled vehicle with approximately a 10 years (225 000km) lifetime were considered. This "average total costs per vehicle" is only computed by the simulator for conventional vehicles, so the total costs of the electric models were computed afterwards for a 50 000km lifetime mileage (approximately 2.5 years for a vehicle performing 20 000km/yr) accordingly with the following expression:

$$Average\ annual\ costs\ per\ vehicle\ \left[\frac{€}{yr}\right] \times \frac{50\ 000\ [km]}{Annual\ distance\ \left[{km}/{yr}\right]} + Purchase\ cost[€]$$

However, it is important to be critic with the results of this expression, mainly in cases where the daily distance is low. In such cases, in order to achieve the lifetime mileage, it would take many years, which can lead to unrealistic outcomes. Also, whenever the daily distance was higher than the maximum advised by the simulator, this tool added an additional vehicle to the electric fleet until the daily distance became entirely covered considering that each vehicle only travels that advised distance. Thus, the final results corresponded to that more-than-one vehicle fleet. Because the decision to invest in more vehicles is not so linear and depend from case study to case study, the results presented were modified to include only one vehicle: the "costs per year of total electric fleet", both economic and environmental, were divided by the total number of electric vehicles. Those maximum advised distances correspond to the average battery's autonomy (see Table 3).

[14] Because the most expensive part of an electric two-wheeler is its battery, it is frequent to buy a new vehicle once the battery is dead (this information resulted from direct consultation with electric two-wheelers users). So, the vehicle's lifetime is often mistaken with the battery's lifetime.

4. Case Studies and Results

This Chapter presents the three case studies, defining them and presenting the respective results, both from the simulator and from the three surveys. Each one of the sections 4.1, 4.2 to 4.3 corresponds to one of the case studies. The first case to be analysed was *Camisola Amarela*, then the restaurant and the last was *Moço de Recados*. Section 4.4 presents a generic review of all the responses collected in each one of the three surveys and the conclusions that could be seized both in each entity and in a generic perspective.

4.1. Case Study 1: Urban Delivery Company

Camisola Amarela (CA) is a new concept of courier deliveries in Lisbon. The messengers cover all the city using only bicycles and cargo-bikes. The company begun as a single courier with a conventional bike in September 2009. Since then, the company has been growing exponentially in business' volume and in number of employees (Ventura 2009). During the Pro-E-Bike project, running from May 2015 to March 2016, CA used for the first time an electrically assisted cargo-bike (ePTW). The ePTW, in Figure 5, weights 28kg (e-cargo-bike plus the battery), has a bulk capacity of 0.14m^3 (70x40x50cm^3), a maximum weight capacity of 110kg without the rider – that was considered to weight 70kg –, 7 mechanic gears – accordingly with Larry vs Harry's (producer) Bullitt technical data (2015) –, a battery with a capacity of 250W and a charging time of about 5 to 6 hours. The vehicle was conventional initially but, in order to participate in the project, CA

Figure 5 – Electrically assisted cargo-bike used by *Camisola Amarela*

Figure 6 – Electric battery

bought the electric battery (Figure 6) and attached it to the vehicle with a total cost (purchase included) of 3 737€. It is core to highlight that this vehicle is not electric. It has electric assistance: the rider can choose when to turn on the electric assistance and when to turn it off without stopping the vehicle; it do not need electric power to start moving, the battery only assists the rider when he needs it. The battery's controller used in this e-cargo-bike has two operating modes: it switches on whenever the rider's effort passes a certain limit and it allows the rider to control the level of assistance he wants.

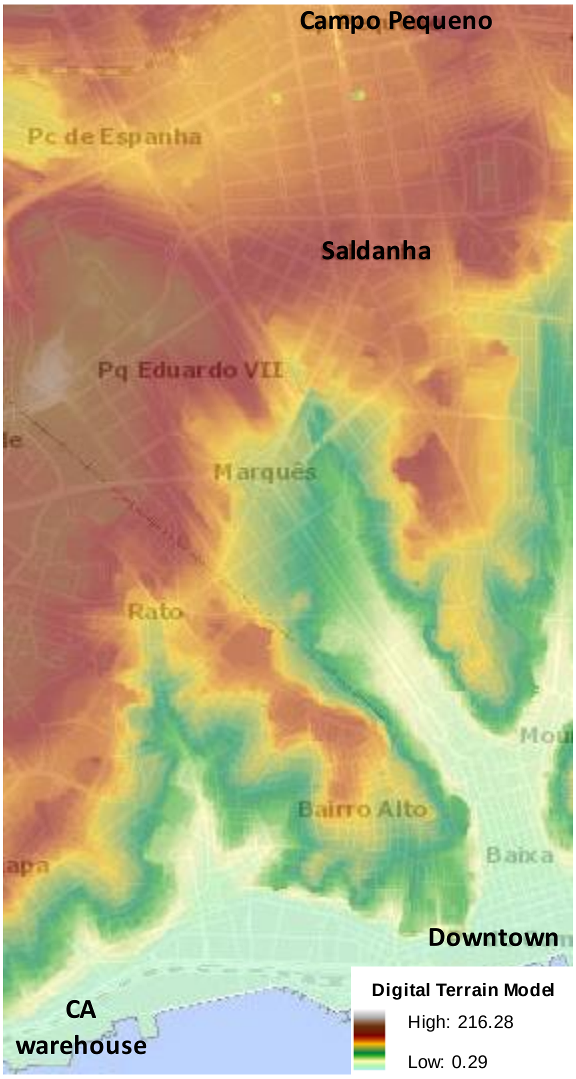

Figure 7 – Terrain digital model of Lisbon without scale (Adopted from (Lisbon Municipality 2015b))

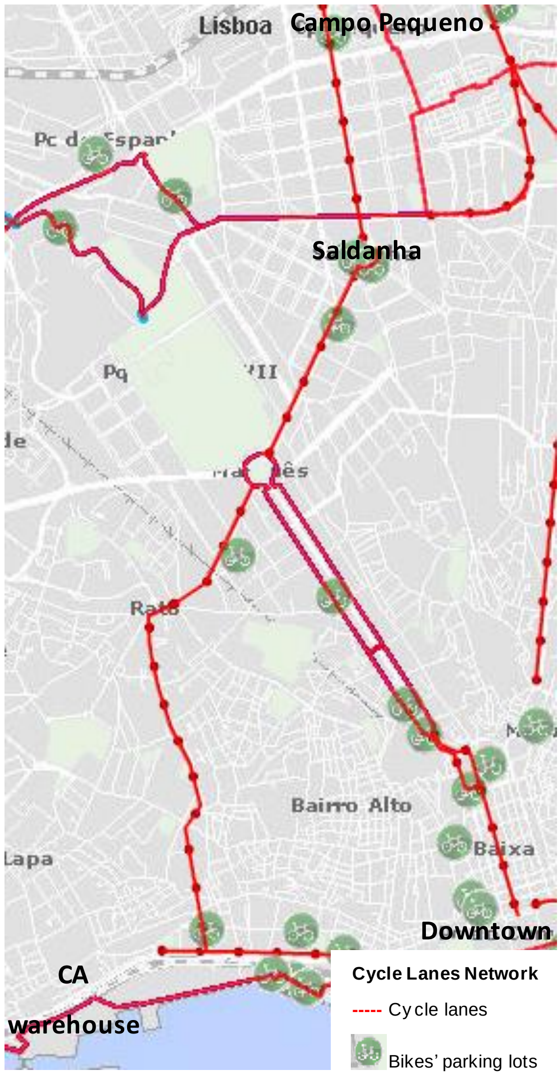

Figure 8 – Cycle lanes' network in Lisbon without scale (Adapted from (Lisbon Municipality 2015a))

Camisola Amarela mostly operates in the central business area of Lisbon (Saldanha and Campo Pequeno) in highly consolidated zones, relatively sloped roads and with high traffic levels. Their clients are companies and services that request express mail (documents or parcels) deliveries and that care about their image and their environmental impact. In Figure 7, it is possible to observe Lisbon's digital terrain model where red and white coloured areas correspond to the highest elevations and yellow and green areas correspond to the lowest. The same figure supports the conclusion that a route beginning at CA warehouse and ending in Saldanha, or even in Campo

Pequeno, corresponds to climbing higher than 200m. In addition, both the principal avenue between the major clients (Avenida da República) and, in part, the path between CA warehouse (in the downtown of Lisbon) and this two major costumers (Avenida da Liberdade) have bicycle lanes and bicycle parking lots as Figure 8 shows. This infrastructure availability obviously helps CA travelling and parking among high congested areas. A plus of travelling by bicycle in these areas is that most of those lanes are built across lower slopes avenues as the comparison between the two maps shows. In addition, in the downtown part of the trip and between downtown and nearly Saldanha, there is traffic restriction to vehicles produced before 2000 and, because it is the oldest part of Lisbon, streets are mostly narrow and sometimes one direction only, meaning that it is not easy to drive in this area by car. CA has also this in their favour.

4.1.1. Logistic Profile

The best way to characterize the CA's service is, as seen in Chapter 2, the logistic profile, as it describes both city area features, product characteristics and also agents' needs. For that matter, the logistic profile of CA was defined and can be consulted in Table 13. In a generic way, all the characteristics described there are representative of LP type C – courier deliveries in highly consolidated urban areas (see Table 1).

Table 13 – *Camisola Amarela*'s Logistic Profile

Camisola Amarela's Logistic Profile (C)

City Area Features	
Commercial Density	Medium
Homogeneity	Medium (a mixture of residential, services and offices)
Logistics Accessibility	Bad
Restriction Applied	Motorized vehicles older than 2000 forbidden to circulate
Product Characteristics	
Easiness of Handling	Easy (documents and small parcels)
Special Conditions	No special needs
Agents' Needs	
Urgency of Deliveries	Urgent
Frequency of Deliveries	High
Amounts to be Delivered	Few
Planned Deliveries	Defined routine

Because the central business areas where CA operates (Saldanha and Campo Pequeno) is mostly composed, by definition, by offices and services instead of commerce or residential buildings, the commercial density is not significant and the homogeneity can be classified as medium. Also, due to high consolidation and traffic levels, logistics accessibility is bad in those areas since there are limited parking lots to load and unload operations. As seen above, these difficulties do not apply to two-wheelers since they can whether use bike lanes, overcome cars easily and they can park in smaller spaces, even in the sidewalk. These advantages will become even more pronounced as soon as the requalification works end, especially in Saldanha. This plaza will soon be more bike and people friendly (see Figure 9 and Figure 10) due to the expansion of the sidewalks and the creation of a bike lane that will join the two already existent in that area of Lisbon. The better the infrastructure, the most suitable the city will be for people and bikes and the more evident will be the electric two-wheelers benefits. In addition, the requalification works will provide a bike corridor between the two business areas CA mostly serves, so this company will most certainly benefit from this works as their productivity will increase. This investment also means that the Lisbon municipality is seeking a more sustainable urban mobility for its population. Regarding the restrictions applied, it is mostly related to motorized vehicles older than 2000 (1996) being forbidden to circulate in the city downtown (centre). As seen previously, these city area features constitute mostly advantages to ride a two-wheeler and use it to perform express deliveries. Also, because the route is relatively sloped (see Figure 7), the electric assistance supports the climbing. Obviously, to perform this service, the rider has to be fit. It is worth to notice that, the empty vehicle weights 28kg by itself, the average male weights 70kg and the average transported weight per trip is 14kg, so the courier has to climb higher than 200m in slopes with the order of magnitude of 18% (Lisbon Municipality 2015b) with 112kg. Because the human effort is too intense, even with a good physical preparation, the electric support helps to assure that the parcels arrive in time to the final destination without the rider physical exhaustion.

Figure 9 – Praça Duque de Saldanha today (Google Maps)

Figure 10 – Praça Duque de Saldanha after the requalification plan (Soares 2015)

The type of products most common in CA's services are small parcels and envelopes containing documents. Thus, the parcels are mostly small (average of 0.005m^3/parcel) and light (average of 1.26kg/parcel with a maximum of 5.63kg/parcel), easy to transport and easy to handle without special conditions. It can be transported in a backpack or in a small container like the one CA uses in the cargo-bike (see Figure 5).

Clients usually have some urgency in their deliveries and request CA's services frequently (on a daily basis or 2 to 3 times per week). Usually the amount of parcels per client is small (average of 1.5 parcels per client) and the services are normally planned in advance. In most cases, CA performs B2B deliveries.

4.1.2. Energy, Emissions and Costs' Calculation

Although the Pro-E-Bike's trial in CA only ends in March 2016, the data used in this dissertation only concerns the operation between May and July 2015 (during August, the rider was on holidays). However, before start registering data in the Pro-E-Bike form, the rider had one week to run some tests and to understand how the electric assistance works. Even before that, the company already used conventional cargo-bikes so the objective of this warm up period was to learn the best way to take advantage of the electric assistance in company's regular services. It is important to remind that this vehicle can travel without any power; its motor purpose is not to move the bicycle, but helping the rider to move it. Accordingly with the registrations during the pro-E-Bike project, it is possible to quantify their operation of the ePTW as in Table 14.

Table 14 – Indicative Pro-E-Bike daily registration on *Camisola Amarela* (56 registrations)

Indicator	Unit	Mean	Max	Min
No. performed deliveries with the ePTW	No./day	12.4	40	1
Total no. of delivered parcels	No./day	**19.0**	**45**	4
No. of round trips	No./day	**1.5**	**3**	1
Total round trip time per day	min/day	**195.1**	360	60
Travelled distance	km/day	**36.6**	80	5
No. of battery recharges	No./day	**1.1**	3	0
Remaining battery level (0, 25, 50, 75, 100%)	%	10.0	35	**0**
Average battery recharging duration	Hours	**5.8**	7	4
Average circulation speed (without stops to perform deliveries)	km/h	**15.4**	20	13
Estimated total weight carried per day	kg/day	**20.3**	**45**	2
Estimated total volume carried per day	m^3/day	0.09	0.14	0.01
Average distance in empty trip per round trip	km/day	3.8	10	1
Energy Consumption	kWh/km	**0.03**	0.05	0.01
Incidents including not performed deliveries, costumer complains, breakdowns (indicating associated cost), fees	No./day	0	0	0
Accidents	No./day	0	0	0

On a daily basis, CA delivers an average of 19 parcels, amount that can rise up to 45. When compared with the number of deliveries, a gap is noticed meaning that usually, the same client receives more than one parcel per day. Moreover, the rider performs more than one round trip per day having been recorded a maximum of 3 rounds in one single day. That number of round trips, were registered twice but, surprisingly, only in one of those times the vehicle was charged more than once.

Per day, the ePTW is usually driven for three hours and fifteen minutes but a 6-hour ride was already registered in a day when the distance travelled was 50km (more than the average) distributed between two round trips. In that day the battery was charged twice and the travelling speed was low (13km/h). However, it is worth to remember that this particular vehicle has the capacity to, once the battery is discharged, be driven without electric assistance. Nevertheless, in that day only 2km were performed with no parcels on the basket, what undoubtedly represented an enormous physical effort to the driver.

In a regular day 37km are travelled in this vehicle with more than one battery charging process, which usually lasts for 6 hours. Because this duration is lower than the night period, this means that the vehicle charges regularly also during the day between trips.

Regarding the mean speed, it is important to highlight that that value is not equal to the mean distance divided by the mean trip duration. This is because that speed do not account with stops whereas by dividing the total travelled distance in that day by the total trip duration, stops for unloading are included because that took time from the trip. As seen in Section 2.2, (electric) cargo-bikes' normal speed is between 10km/h (Table 3) and 20km/h. So, taking into consideration the heavy loads CA transports and the sloped roads, which are proved factors that contribute to speed reduction, the registered speed is within the expected range. Regarding that load, normal weights rounds the 20kg. This is one of the reasons Gruber, Kihm and Lenz (2014) used to consider an e-cargo-bike as a mix between bicycles and cars. Besides this average weight, there are registrations of loads rising up to 45kg, what corresponds to 143kg adding rider's and bike's weights. Moreover, the maximum registered volume matches the vehicle's capacity which can be seen as sign of an insufficient volume capacity.

Since the battery energy was not given by the producer, but only the battery capacity, in order to compute it, its capacity (250W) was multiply by the travel time recorded in the Pro-E-Bike form. For that, the average energy was selected between the days when the remaining battery level was not null because it is probable that in those days, part of the trip was performed using human energy. Obviously this is a simplified process since the battery was not used during all the trip all the days, the rider only used the battery whenever he felt the need to. That is also the reason behind the use of the average value and not the maximum. In these conditions, the energy provided by the battery is 0.600kWh. This result is, in fact, a bit higher than the energy of other e-cargo-bikes (Xtracycle EdgeRunner 10E, Juiced Riders ODK V3 which energy is between 0.300 and 0.423kWh). Nevertheless it was used cautiously.

For the type of services that CA performs, with that average daily distance, volume and weight, the ePTW can be the alternative for two fossil fuelled vehicles: both a 125cc scooter and a mini-van can be used. In order to assess which one is more suited for this service, a question placed in the rider's survey intended to find his opinion about the ePTW capacity to substitute one of those. The results suggest a good adequacy to both vehicles but more for the mini-van. Because the difference is not significant enough, these two hypotheses were tested in this case. It is important to highlight the importance of a good volume capacity, since, as seen above, that is one limitation of the studied e-cargo-bike. However, it is possible to carry big parcels even if it is a scooter, depending of the cargo box dimensions.

The inputs of CA case study for the two hypotheses can be defined as:

Hypothesis 1 – Shifting from a conventional mini-van to an electric cargo-bike:

Fossil Fuelled Vehicle's input: A 14 000€ diesel mini-van with the average consumption of 5.4l/100km, a maintenance cost of 1 000€/yr considering it is 5 years old, an insurance cost of 354€/yr and an annual taxation of 32€;

Electric vehicle's input: electric cargo-bike of 3 737€ (with no age specification), average energy consumption of 0.0243kWh/km and a maximum cargo capacity of 0.14m^3 and 110kg (without the rider). Its maintenance cost is 100€/yr, an insurance of 25€/yr and, because it is essentially a bicycle, it does not pay taxes;

Operation's inputs: average daily distance of 36.6km with the average load of 20.3kg and 0.09m^3, 242 days of work in one year (five days a week, twelve months per year).

The remaining inputs were already defined in Chapter 3 Section 3.2.3.

Taking these inputs into consideration, the simulator returned the follow information concerning the substitution of a conventional mini-van by an eTW:

Table 15 – Results for the CA case study – Mini-van

Results – Fossil Fuelled Fleet Analysis

Actual Situation

	Global	Diesel	Gasoline
Vehicles [n.º]	1	1	-
Distance [km/day.vehicle]	37	37	-
Fuel costs [EUR/100km]	6.5	6.5	-
Average annual costs [EUR/vehicle]	1 960	**1 960**	-
Emissions [kg CO_2/100km]	14.4	**14.4**	-
Average total costs per vehicle [EUR/vehicle]	63 790	**63 790**	-

Operational Lifetime Costs

	Global	Diesel	Gasoline
Energy cost [EUR/vehicle]	14 580	14 580	-
CO_2 cost [EUR/vehicle]	1 135	1 135	-
Pollutants cost [EUR/vehicle]	181.9	181.9	-
Total operational lifetime costs [EUR/vehicle]	15 897	**15 897**	-

Results - Electric Fleet Analysis

e-Cargo-bike

e-cargo-bike [n.º]	1
Distance [km/day.vehicle]	37
Costs [EUR/100km]	0.24
Average annual costs [EUR/vehicle]	**146**
Emissions [kg CO_2/100km]	**0.30**
Average total costs per vehicle [EUR/vehicle]	**4 561**

Operational Lifetime Costs

	Global
Energy cost [EUR/vehicle]	120
CO_2 cost [EUR/vehicle]	5
Pollutants cost [EUR/vehicle]	0
Total operational lifetime costs [EUR/vehicle]	**125**

Savings					
Costs per year of the fossil fuelled fleet			**Costs per year of the electric fleet**		
Economic	1 960	EUR/yr	Economic	146	EUR/yr
Environmental	1 227	kg CO_2/yr	Environmental	27	kg CO_2/yr
Savings					
Economic	**1 814**	EUR/yr			
Environmental	**1 200**	kg CO_2/yr			

First of all, some important considerations 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 all the annual costs (fuel, maintenance and taxes). The purchase cost was only approached in the "average total costs per vehicle" and a 10 years (225 000km) lifetime was considered for the fossil fuelled vehicles. Regarding the electric vehicle "average total costs per vehicle", a 50 000km (approximately 2.5 years for a vehicle performing 20 000km/yr) lifetime mileage was considered. All the costs not computed by the simulator are highlighted in light orange in the previous table. The operational lifetime costs depend on practical aspects such as the lifetime mileage but it also depends on aspects such as fuel cost and conversion factors which are much more difficult to quantify and prove them right. This costs are not presented in the simulator for the electric vehicles. However, in order to compare these two technologies operation, easy calculations were performed considering a 50 000km lifetime mileage, a 0.0986€/kWh electricity cost, an average energy consumption of 0.0243kWh/km, a 35€/ ton CO_2 cost and a 0.30kg CO_2/100km emission. Also, because the registered daily distance (36.6km) was higher than the maximum advised by the simulator (30km), this tool added an additional vehicle to the electric fleet. However, an additional daily distance of 7km is not critical in a courier company such as CA since all the messengers are correctly physically prepared. Hence, the final results were then modified in order to contemplate only one vehicle (for that matter, also the last rows of the table are coloured): the "costs per year of total electric fleet", both economic and environmental, were divided by the total number of electric vehicles.

These results, corresponding to a technological transfer from a conventional mini-van to an electrically assisted cargo-bike in an express delivery service performed by a courier company five days per week show that and considering the same operation for the two vehicles, whereas the electrically assisted cargo-bike involves an average annual cost of 146€, a diesel mini-van would cost more 1 243% than that first vehicle (substituting the mini-van for the electric model represents a saving of 92.6% of the average annual cost of the fossil fuelled one). Regarding the operational lifetime costs, the electric model corresponds to a 99.2% savings comparing with the fossil fuelled vehicle, however, whereas the lifetime of the mini-van is about 10 years, an electric motor only lasts a quarter of that time. Performing a simple comparison, it is possible to find that even purchasing a new electric vehicle every 2.5 years (this is an overstated estimative because the vehicle itself would be re-used, only its battery would be changed), a saving of 96.9% of the total operational costs of a fossil fuelled vehicle could be achieved considering that excessive battery energy. If usual energy values were considered, it would result in higher savings. Regarding the total lifetime costs ("average total costs per vehicle"), a saving of 59 229€ (92.8%). In what concerns to fuel costs, whereas a conventional scooter involves spending 575.72€/yr in gasoline, the electric scooter only implies 21.26€ in electricity (96.3% savings). Furthermore, in this particular case, choosing an electric vehicle to substitute a fossil fuelled represent a saving of 1 200kg CO_2/yr, which is 97.8% of the mini-van's emissions. This change also represents a 95.4% reduction in energy consumption (a mini-van with a fuel consumption of 5.4l/100km, performing 36.6km per day, 242 days per year represents 478.29l/yr. Since one gallon of diesel has an energy content of 37.7kWh (see Section 2.2), this means that the mini-van consumes 4 763.93kWh/yr in diesel whereas the electric scooter only spends 220.41kWh/yr, since it emits 27kg CO_2/yr and the conversion factor is 0.1225kg CO_2/kWh).

Hypothesis 2 – Shifting from a conventional scooter to an electric cargo-bike:

Then, the same analysis was performed using as a fossil fuelled vehicle a 125cc gasoline scooter with a purchase cost of 3 050€, an average consumption of 2.0l/100km, a maintenance cost of 485€/yr, an insurance of 145€/yr and 5.49€/yr of taxes. The remaining inputs stood unchanged and the results concerning the substitution of a conventional scooter by an eTW are in Table 16.

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, maintenance and taxes). The remaining costs (purchase and CO_2) were only included in the fossil fuelled fleet "average total costs per vehicle" and a 10 years (225 000km) lifetime was considered. Regarding the electric vehicle, the results obtained above were replied here. Also in this situation, all the costs computed after using the simulator are highlighted in light orange. The operational lifetime costs of the electric vehicle are the same as in the first hypothesis and for the conventional scooter the assumptions are identical to the ones of the mini-van. Again, a second electric vehicle was proposed by the simulator but not considered in the calculations.

Table 16 – Results for the CA case study – 125cc scooter

Results – Fossil Fuelled Fleet Analysis

Actual Situation

	Global	Diesel	Gasoline
Vehicles [n.º]	1	-	1
Distance [km/day.vehicle]	37	-	37
Fuel costs [EUR/100km]	2.9	-	2.9
Average annual costs [EUR/vehicle]	891	-	**891**
Emissions [kg CO_2/100km]	5.0	-	**5.0**
Average total costs per vehicle [EUR/vehicle]	25 684	-	**25 684**

Operational Lifetime Costs

	Global	Diesel	Gasoline
Energy cost [EUR/vehicle]	6 413	-	6 413
CO_2 cost [EUR/vehicle]	392	-	392
Pollutants cost [EUR/vehicle]	79.3	-	79.3
Total operational lifetime costs [EUR/vehicle]	6 884	-	6 884

Results - Electric Fleet Analysis

e-Cargo-bike

e-cargo-bike [n.º]	1
Distance [km/day.vehicle]	37
Costs [EUR/100km]	0.24
Average annual costs [EUR/vehicle]	**146**
Emissions [kg CO_2/100km]	**0.30**
Average total costs per vehicle [EUR/vehicle]	**4 561**

Operational Lifetime Costs

	Global
Energy cost [EUR/vehicle]	120
CO_2 cost [EUR/vehicle]	5
Pollutants cost [EUR/vehicle]	0
Total operational lifetime costs [EUR/vehicle]	**125**

Savings

Costs per year of the fossil fuelled fleet			Costs per year of the electric fleet		
Economic	891	EUR/yr	Economic	147	EUR/yr
Environmental	446	kg CO_2/yr	Environmental	27	kg CO_2/yr

Savings

Economic	**744**	EUR/yr
Environmental	**419**	kg CO_2/yr

In this particular case, a substitution of a conventional scooter with an eTW, a saving of 84.3% the conventional scooter annual costs would be achieved. Regarding the operational lifetime costs, the electric model corresponds to a 98.2% savings comparing with the fossil fuelled vehicle. Regarding the total lifetime costs ("average total costs per vehicle"), the electric model represents a saving of 21 123€ (82.2%). In what concerns to fuel costs, whereas a conventional scooter involves spending 256.86€/yr in gasoline, the electric vehicle only implies 21.26€ in electricity (91.7% saving). Also, regarding the environmental impact, the electric cargo-bike represents a saving of 93.9% in CO_2 emissions. When performing the conversion between the fuel consumption and the energy spent (as seen in Section 2.2, one gallon of gasoline has an energy content of 33.7kWh), whereas the eTW consumes 220.41kWh, the gasoline model spends 1 577.18kWh/yr (615.6% higher and a 86.0% savings).

The following table summarizes the main savings regarding the substitution of conventional vehicles by an electrically assisted cargo-bike performing 36.6km/day:

Table 17 – Savings summarization of the CA case study

	Annual [€/yr]	Total [€]	Operational Lifetime [€]	Fuel [€/yr]	Environ-mental [€/yr]	Energy Con-sumption [kWh/yr]
Mini-Van	1 814 (92.6%)	59 229 (92.8%)	15 772 (99.2%)	554 (96.3%)	1 200 (97.8%)	4 544 (95.4%)
Scooter	782 (84.3%)	21 123 (82.2%)	6 759 (98.2%)	236 (91.7%)	416 (93.9%)	1 357 (86.0%)

4.1.3. Perceived Experience

In the end of the trial period, both the owner and the rider responded to the correspondent survey. The responses can be consulted in Annex C. Their overall experience is positive although all of them pointed out some limitations and improvements that would definitely increase the benefits of the e-cargo-bike utilization.

The factors that most motivate *Camisola Amarela*'s owner to invest in ePTWs are related to the image and profitability of the company and the impact the company has in both the environment and in the public health. Nevertheless, the remaining factors are still relevant for the strategy of CA. The owner also revealed a concern about the diffusion of the benefits these vehicles have for both the companies (clients and messengers), the remaining people and the city itself. According to him, the economic and environmental advantages of these vehicles are still unknown for many entities (both public, private and individuals) in Portugal. In addition, he also claimed a low support by the legislation in fiscal terms, in what concerns to the cycling infrastructure that remains incomplete and regarding to traffic restrictions, since, accordingly with him, a wider selection of the road users can be achieved, balancing the percentage of two-wheelers and remaining road users using the infrastructure. Once solved, these factors could make the ePTWs a true solution for an urban problem. Altogether, the owner claimed that this experience presented positive results in all the perspectives. Mostly, the assistance the battery provides constitutes a necessary complement to their conventional technology, allowing to ride further, longer and to transport heavier loads. Hence, improving rider's productivity. For the owner, a future investment will certainly include purchase more electric batteries or electric cargo-bikes.

Regarding the rider's experience, he appealed to the still low battery's autonomy claiming that it must be improved. The battery is still very sensible and its potentialities remain hidden in cities like Lisbon where the topography is so irregular as already seen. He also claimed that the ePTW the company bought is a perfect substitute to mini-vans and a good substitute to conventional scooters as mentioned in the last section, but, when comparing a conventional cargo-bike with the study vehicle, the least is more difficult to ride and the safety is perceived as lower. On the other hand, the e-cargo-bike is easier to maintain than the conventional model. Regarding the charging process, that lasts for almost six hours in average as already seen, the rider told that he usually charges the vehicle independently of the amount of battery that will be needed: he fully charge it and plug it in whenever he has the chance to in order to assure that there are always enough battery for the next delivery. This result is consistent with both the conclusions about the charging duration and with the rider's concern about the battery's autonomy due to the vehicle's weight, even empty, but still being hard to climb when the battery is dead. The rider also agreed that this vehicle makes sense in the urban environment the company mostly operates and in the services they perform. He also believes that electric cargo-bikes have the potential to be used more often in Lisbon's companies. When asked about what features that he liked the most about the vehicle, he replied that the most positive aspect was the reduction he felt in the physical effort to ride the vehicle and how the productivity and efficiency increased after start using it.

Regarding the results obtained in the simulator, the biggest savings were achieved when comparing the e-cargo-bike with the mini-van, which means that the difference between these two modes is bigger than between this electric vehicle and the scooter, allowing to understand that, between these two fossil fuelled vehicles, the scooter is the most suited and that present the biggest rivalry with the e-cargo-bike.

These savings support the argument on the benefits of the use of electric two-wheelers to courier services with deliveries B2B (Logistic Profile type C). As already seen, this LP require a solution capable of meeting the need to quickly transport small and light parcels in highly dense and congested areas without jeopardizing client's timings. The solution is use an electric two-wheeler, more specifically an electrically assisted cargo-bike. The only "but" in this situation was the sloped roads and the basket capacity, which can be easily solved by adapting a new and bigger one.

4.2. Case Study 2: Food Delivery

O Marujo is a well-known sea food restaurant in Matosinhos, Portugal. Founded in 1978 and bought in 2012 by the catering group *Madureira's* and from that moment on the restaurant started performing also take away service (Madureira's 2015). Now, the restaurant is starting their home delivery service – in a radius of 8.5km – and their first vehicle is an electric scooter provided by the European Commission during the Pro-E-Bike project. During the trial, running from August 2015 until March 2016, the restaurant has been using the electric scooter in Figure 11 (Govecs Go!T 2.4+), which costed 6 270€. The vehicle weights 115kg, has a bulk capacity of 200l (0.2m^3), a maximum weight capacity of 110kg not including the driver – which was considered to weight 70kg – and a lithium battery of 3kWh with an autonomy ranging from 40 to 70km. The estimated charge duration is 4 to 5 hours and its life lasts for 50 000km which corresponds to more than three years assuming an annual distance of 15 000km. After that, the battery can be changed for a new one for the price of 3 060€, accordingly with an electric scooters' reviewer (Electric Ride Review 2015). Also, this scooter' maximum speed is 61.15km/h, which is sufficient since it mostly rides in residential areas where the limit speed is 50km/h or 30km/h.

Figure 11 – E-Scooter used by the restaurant

The restaurant is placed in a wealthy area, mostly residential but nearby to a business area, where the big share of commercial establishments are seafood restaurants as well. Regarding the topography, because that is a littoral area, there are no considerable slopes, it is essentially flat. However, a relatively high level of congestion both during winter (produced by the business activity) and summer (due to the proximity to the beach) is present. These two features represent advantages for eTW since the batteries are still highly sensible to slopes (and the higher the transported weight, the higher the difficulty to overcome slopes) and two-wheelers do not cause or suffer from congestion. Another circumstance fitting into electric scooter's advantages is the lack of parking lots. A two-wheeler does not need as much space to park as a mini-van. This fact constitutes an even more important plus in cases with fast deliveries such as these. The entire vehicle only occupies about $0.52m^2$ whereas a Renault Kangoo has an area of $8.33m^2$.

Because home deliveries are still beginning at *O Marujo*, the manager restricted the trial to a little group of frequent costumers of the take away service. These clients were the ones starting the trial but if the e-scooter is proved to be a success, the number of clients with home deliveries is expected to grow.

4.2.1. Logistic Profile

The logistic profile of this home delivery service can be consulted in Table 18. In a generic way, all the characteristics described are representative of the Logistic Profile type E (see Table 1), which corresponds to residential areas with local trade like it was expected.

Due to its littoral localization and the abundance of seafood in the area, this restaurant is placed in a residential neighbourhood mostly served by similar restaurants few meters apart from each other and with just few of other commercial activities (medium commercial density and homogeneity). The deliveries are being performed in similar residential neighbourhoods not too far away from the restaurant (the maximum registered distance was 8.5km). Because it is a residential area and the deliveries are performed when most of the people are at home (mostly at night), the parking lots are at their full capacity and there is only few places dedicated to load and unload activities during the day, so in logistic terms, accessibility is bad. The product consists in a package where the food to deliver is stored and is transported in the scooter's cargo box. The food is, therefore, easy to handle but has to be delivered in an acceptable temperature, meaning that the courier cannot spend much time in traffic – the delivery is urgent (the maximum recorded trip duration was 40 minutes meaning that from the time the order is packed until it arrives to costumer's house it takes approximately 20 minutes). Because the product is food, it is important to ensure an adequate storage in the cargo box to assure that the parcel stays motionless during the entire trip. For that matter delivering to more than one client in the same trip can mean special care and is not, for now, a reality.

Table 18 – *O Marujo*'s Logistic Profile

Restaurante Marujo's Logistic Profile (E)

City Area Features	
Commercial Density	Medium
Homogeneity	Medium (Residential area with local trade)
Logistics Accessibility	Bad (no parking lots)
Restriction Applied	Yes
Product Characteristics	
Easiness of Handling	Easy
Special Conditions	Special needs (perishable products)
Agents' Needs	
Urgency of Deliveries	Urgent
Frequency of Deliveries	Low
Amounts to be Delivered	Few
Planned Deliveries	(No) Defined routine

The frequency of the deliveries is low because it is a high standard restaurant and, therefore, the number of clients who can afford to order seafood to be delivered at their homes is quite low. Actually, during the home delivery's warm up period and until the e-scooter proves to be a success, the deliveries are only being performed to a limited number of frequent take away clients.

These clients usually order in the same days of the week so, for now, there is a defined routine in the deliveries but it is expected that it will no longer be that way soon. The ordered amounts are small and light, one to two deliveries per trip maximum with the maximum weight of 2kg.

4.2.2. Energy, Emissions and Costs' Calculation

The e-scooter operation in the restaurant only started in the beginning of August 2015, so the operation data available in this case study is only related to that month until the beginning of September 2015. In the beginning of the trial the frequency of the deliveries was very low, between the first two deliveries it was nine days and the next interval had a duration of eleven days. For this reason the warm up period was extensive and the driver only evaluated e-scooters' performance in those rare situations. This first phase coincided with the month commonly associated with costumers' holidays and the big share of them were away during this period so it is expected a higher frequency of deliveries in September. Unfortunately, there are no accurate estimates for that growth and the registered deliveries had to be used in the simulator. Accordingly with the registrations during the pro-E-Bike project, it is possible to describe the operation of the e-scooter as in Table 19. It is worth to mention that the missing parameters in that table were not registered during the trial period in this case study. Also, this home delivery service can be performed both by a mini-van and a conventional scooter, so these two hypothesis were tested and the inputs for each one was defined. Because there were some inconsistencies in both riders and owner's responses to the surveys, there was no possibility to use their perceptions in this analysis as performed in the previous case study.

Table 19 – Indicative Pro-E-Bike daily registration on *O Marujo* (8 registrations)

Indicator	Unit	Mean	Max	Min
No. performed deliveries with the ePTW	No./day	1	**1**	1
Total no. of delivered parcels	No./day	**1.1**	2	1
No. of round trips	No./day	1.1	2	1
Total round trip time per day	min/day	**19.6**	**40**	5
Travelled distance	km/day	**6.1**	17	2
No. of battery recharges	No./day	-	-	-
Remaining battery level (0, 25, 50, 75, 100%)	%	-	-	-
Average battery recharging duration	Hours	-	-	-
Average circulation speed (without stops to perform deliveries)	km/h	-	-	-
Estimated total weight per day	kg/day	**1.5**	2	1
Estimated total volume per day	m^3/day	-	-	-
Average distance in empty trip per round trip	km/day	3.1	8.5	1
Energy Consumption	kWh/km	**0.0698**		
Incidents including not performed deliveries, costumer complains, breakdowns (indicating associated cost), fees	No./day	0	0	0
Accidents	No./day	0	0	0

Hypothesis 1 – Shifting from a conventional mini-van to an e-scooter:

Fossil Fuelled Vehicle's inputs: A 14 000€ diesel Renault Kangoo Express mini-van with the average consumption of 5.4l/100km. Its maintenance is 1 000€/yr considering it is 5 years old, the insurance is 354€/yr and the taxes are 32€/yr.

Electric vehicle's inputs: A 6 270€ Go!T2.4+ Govec with an average energy consumption of 0.0698kWh/km and a maximum cargo capacity of 0.2m^3 and 110kg (without the rider). Its maintenance is about 350€/yr, its insurance is 48€/yr and no taxes are paid since it referees to an electric vehicle.

Operation inputs: average daily distance of 6.1km with the average load of 1.5kg and 288 days of work per year (6 days a week, 12 months per year).

Due to the scarce utilization of the electric vehicle in this first phase, there was no need to charge its battery every day, so the average battery consumption could not be computed as the average of the division between the energy the battery provides and the distance travelled every day. Instead, it was assumed that during the entire month of August and the beginning of September, there was only one charge previously to the first delivery. This assumption makes sense since the autonomy of the fully charged battery is between 40 and 70km and the total travelled distance in that period is 43km. Taking this into consideration, the average battery consumption results from the division between the energy the battery provides and the total travelled distance during that period (one month). The transported volume was not controlled and because, in a single trip only one delivery is performed, the cargo box capacity is enough. Therefore, volume is not a critical factor. In addition, there is no results depending on this parameter.

The remaining inputs were already defined in Chapter 3 Section 3.2.3 and the results regarding the substitution of a conventional mini-van by an e-scooter can be consulted in Table 20.

Table 20 – Results for the restaurant case study – Mini-van

Results – Fossil Fuelled Fleet Analysis			
Actual Situation			
	Global	Diesel	Gasoline
Vehicles [n.º]	1	1	-
Distance [km/day.vehicle]	6	6	-
Fuel costs [EUR/100km]	6.5	6.5	-
Average annual costs [EUR/vehicle]	1 500	**1 500**	-
Emissions [kg CO_2/100km]	14.4	**14.4**	-
Average total costs per vehicle [EUR/vehicle]	206 110	206 110	-
Operational Lifetime Costs			
	Global	Diesel	Gasoline
Energy cost [EUR/vehicle]	14 580	**14 580**	-
CO_2 cost [EUR/vehicle]	1 135	1 135	-
Pollutants cost [EUR/vehicle]	181.9	181.9	-
Total operational lifetime costs [EUR/vehicle]	15 897	**15 897**	-

Results - Electric Fleet Analysis	
e-Scooter	
e-cargo-bike [n.º]	1
Distance [km/day.vehicle]	6
Costs [EUR/100km]	0.69
Average annual costs [EUR/vehicle]	**410**
Emissions [kg CO_2/100km]	**0.86**
Average total costs per vehicle [EUR/vehicle]	**17 939**
Operational Lifetime Costs	
	Global
Energy cost [EUR/vehicle]	**344**
CO_2 cost [EUR/vehicle]	15
Pollutants cost [EUR/vehicle]	0
Total operational lifetime costs [EUR/vehicle]	359

Savings

Costs per year of the fossil fuelled fleet			**Costs per year of the electric fleet**		
Economic	1 500	EUR/yr	Economic	410	EUR/yr
Environmental	253	kg CO_2/yr	Environmental	15	kg CO_2/yr

Savings		
Economic	**1 090**	EUR/yr
Environmental	**238**	kg CO_2/yr

All these results were computed in constant monetary costs. Moreover, the annual costs only consider the costs paid annually like maintenance and insurance, they do not consider the purchase as an annualized cost.

In order to compute the missing operational lifetime costs of the electric vehicle, the same parameters as before were used except the average energy consumption, which is 0.0698kWh/km in this case study, to this vehicle performing this operation. These and the remaining costs not computed by the simulator are highlighted in light orange in the previous table. However, a call for attention is needed in this situation: since the e-scooter only performs 6.1km/day, it would take more than 28 years to achieve battery's lifetime mileage. This is an excessive duration for a battery, therefore, the results of the average total costs of the electric vehicle are here presented with caution. The reason behind this fact is that the annual costs vary with the vehicle's age (the older the vehicle, the higher the maintenance cost, for instance) and in this calculations constant costs were considered. It was due to this excessive lifetime that the average total costs per vehicle is so high.

The presented results, correspondent to a six days a week food delivery service, permit to understand that, considering the same operation for the two vehicles, a technological transference from fossil fuelled to electric would represent a 1 090€/yr (72.7%) annual saving (comparing with the conventional vehicle costs). Moreover, in environmental terms, the total annual savings in CO_2

that restaurant would get by simply shifting from a conventional technology to an electric one are 238 kg CO_2/yr (94.1%) of the annual CO_2 emissions of a diesel mini-van. Due to the low daily distance, no additional electric vehicles would be needed until an average distance of 61km/day were achieved, as 60km is the average daily maximum distance advised by the simulator. For this reason, the results provided by the simulator did not needed an update.

Moreover, in this particular case, choosing an electric vehicle in substitution of a fossil fuelled one represent a saving of 102€/yr (89.4%) in fuel costs, 188 171€ (91.3%) in average total costs per vehicle in its lifetime, 15 538€ (97.7%) in operational lifetime costs and 822kWh/yr (87.0%) in energy consumption (a mini-van with a fuel consumption of 5.4l/100km, performing 6km per day, 288 days per year represents 94.87l/yr. Since one gallon of diesel has an energy content of 37.7kWh (see Section 2.2), this means that the mini-van consumes 944.91kWh/yr in diesel whereas the electric scooter only spends 122.45kWh/yr).

Hypothesis 2 – Shifting from a gasoline scooter to an electric scooter:

The new inputs are the fossil fuelled Vehicle's: A 3 050€ 125cc gasoline Honda PCX125 scooter with the average consumption of 2l/100km, a maintenance cost is 485€/yr, the insurance is 145€/yr and the taxes are 5.49€/yr. The remaining inputs stood unchanged. The results the simulator returned and the additional calculations performed regarding the substitution of a conventional mini-van by an e-scooter are in Table 21.

Table 21 – Results for the restaurant case study – 125cc scooter

Results – Fossil Fuelled Fleet Analysis			
Actual Situation			
	Global	Diesel	Gasoline
Vehicles [n.º]	1	-	1
Distance [km/day.vehicle]	6	-	6
Fuel costs [EUR/100km]	2.9	-	2.9
Average annual costs [EUR/vehicle]	685	-	**685**
Emissions [kg CO_2/100km]	5.0	-	**5.0**
Average total costs per vehicle [EUR/vehicle]	90 781	-	90 781
Operational Lifetime Costs			
	Global	Diesel	Gasoline
Energy cost [EUR/vehicle]	6 413	-	6 413
CO_2 cost [EUR/vehicle]	392	-	392
Pollutants cost [EUR/vehicle]	79.3	-	79.3
Total operational lifetime costs [EUR/vehicle]	6 884	-	**6 884**

Results - Electric Fleet Analysis

e-Scooter

e-cargo-bike [n.º]	1
Distance [km/day.vehicle]	6
Costs [EUR/100km]	0.69
Average annual costs [EUR/vehicle]	**410**
Emissions [kg CO_2/100km]	**0.86**
Average total costs per vehicle [EUR/vehicle]	**17 939**

Operational Lifetime Costs

	Global
Energy cost [EUR/vehicle]	**344**
CO_2 cost [EUR/vehicle]	15
Pollutants cost [EUR/vehicle]	0
Total operational lifetime costs [EUR/vehicle]	359

Savings

Costs per year of the fossil fuelled fleet			Costs per year of the electric fleet		
Economic	685	EUR/yr	Economic	410	EUR/yr
Environmental	86	kg CO_2/yr	Environmental	15	kg CO_2/yr

Savings

Economic	**275**	EUR/yr
Environmental	**71**	kg CO_2/yr

All these results were computed in constant monetary costs. Moreover, the annual costs only consider the costs paid annually like maintenance and insurance, they do not consider the purchase as an annualized cost.

The operational lifetime costs are the same as in the previous hypothesis and both the modified and the additional costs are signalized in light orange in the previous table. The same call for attention is needed in this scenario: the low daily distance performed using this vehicle limits the conclusions one can take from the e-scooter operational lifetime costs.

Contrasting with the replacement of a mini-van, if a conventional scooter was being replaced by the e-scooter to perform the restaurant deliveries, annual savings of 275€/yr (40.1%) and total average lifetime savings of 72 842€ (80.2%) would be achieved. In what concerns with the operational lifetime costs, a saving of 6 525€ (94.8%) would be achieved by simply change a conventional scooter by an electric one. Regarding the fuel costs, this conventional scooter involves a bill of 50.11€/yr in gasoline. On the other hand, the electric scooter only implies 11.89€/yr in electricity (38.22€/yr or a 76.3% saving). Also, regarding the environmental impact, the electric scooter represents a saving of 71kg CO2/yr (82.6%) in CO_2 emissions. When performing the conversion between the fuel consumption and the energy spent, whereas the electric scooter consumes 122.45kWh, the gasoline model spends 312.84kWh/yr (the electric model represents a 190kWh/yr (60.9% saving)).

The following table summarizes the main savings regarding the substitution of conventional vehicles by an electric scooter concerning the restaurant operation:

Table 22 – Savings summarization of the restaurant case study

	Annual [€/yr]	Total [€]	Operational Lifetime [€]	Fuel [€/yr]	Environmental [€/yr]	Energy Consumption [kWh/yr]
Mini-Van	1 090 (72.7%)	188 171 (91.3%)	15 538 (97.7%)	102 (89.4%)	238 (94.1%)	822 (87.0%)
Scooter	275 (40.1%)	72 842 (80.2%)	6 525 (94.8%)	38.22 (76.3%)	71 (82.8%)	190 (60.9%)

4.2.3. Perceived Experience

In the end of the trial period, both the owner and the rider responded to the survey. The responses can be consulted in Annex C. Their experience seems to have been positive, however, they present concerns about the battery. The rider claimed that the e-scooter is charged more often than what is need, possibly to assure some possible demand peaks. He also referred that the topography is not much a limitation, however, this is because that area is essentially flat and the distances he drives are small. The owner perceives the use of this vehicle as an incentive to clients. In order to justify this, he also mentioned that many clients were pushing him to proceed with the scooter acquisition during the process. However, he is not sure about the economic benefits of the vehicle and, therefore, he still haven't decide about a future investment.

Regarding the clients' perception – only two responses were registered and can be consulted in the same annexe as the previous responses –, they all agreed that the use of this vehicle has changed their perception of the restaurant. They also agreed, one more than the other, that if they were not clients of the service, they would start to be if they knew that an electric vehicle was being used. These results might be explained, not due to their environmental concerns – as the remaining answers clarify – but because of the novelty, because this service is not used by many sea food restaurants or other similar (companies like Telepizza and PizzaHut are not included because they belong to a service much more common and worldwide spread) and there is no other similar service in that particular area. Regarding the environmental concern, one of the clients claimed that the use of an electric vehicle is, indeed, an incentive for him to use the service, however, that same client said that he would not ask the service less often if another technology was being used. This enforces the conclusion that this new technology is, indeed, an attraction but due to the novelty it represents. The second client, apart of claiming that he does not perceive this electric technology as an incentive of the service, his answers also point out the impact of that innovation. Hence, it is safe to conclude that these clients value the most the service and the originality than the environmental impact of the service.

Regarding the benefits' quantification, the results show obvious conveniences in using an electric scooter to perform home deliveries that is part of a service belonging to the Logistic Profile type E. The main characteristics of this LP induce to the need to use a vehicle that presents advantages in residential areas, with restrictions and bad logistics accessibility and for the transport of goods easy to handle. Not all of those attributes are covered by a motorized scooter, only an electric model, apart from assuring an easy access to low accessibility areas, an easy parking, an adequate, however not perfect, handling form, it also assures a silent riding. To all this benefits, the environmental impact is also a plus of this vehicle for all the agents, as the simulator showed.

In a business perspective, the differentials between total annual costs from the alternative modes is significant and justify the investment in an electric scooter independently of the motorized vehicle being benchmarked. However, higher savings were obtained when comparing the e-scooter with the mini-van than when comparing it with the gasoline scooter. These results were already expected, since the mini-van does not only represent higher costs (both fix and variable) but it also has an excessive capacity, when compared with the type of service analysed here. On the other hand, the economic savings (reduction of 40.1% in total annual costs) obtained in the comparison of the two scooters are not relevant. This lack of competitiveness mostly concerns the proximity between the two models. An important aspect to take into consideration is the acquisition cost of an electric scooter as well as the duration of the battery. Because this electric technology is not still mature, there are still many aspects waiting for improvements but these two are the main causes behind the low diffusion, according to direct consultation of e-bike retailers.

4.3. Case Study 3: Errand Service

Moço de Recados (MR) is a small company that started in 2012 and it is a new concept of services' provider in Portugal. The messengers do whatever one needs, whenever one does not have the time or opportunity to do it. They go pick something one forgot at home and is needed at the office, they walk people's dogs, feed them, pick one's deliveries at a certain delivery point or just arrange a surprise for someone the client cares about. They do it all using scooters, whenever it is possible, in an area that essentially covers Lisbon and Oeiras (Figure 12), 84.9 and 46km^2, respectively (Caleia & Ramires 2014; CM. Oeiras 2015). The company is composed by two scooter riders – one of them is now using and e-scooter for the Pro-E-Bike project – and two car drivers to perform the furthest, most sensible, voluminous and heaviest deliveries. The Pro-E-Bike's trial started to this company in July 28th 2015 and it will end on March 2016. During this period, the e-scooter is complementing the service of a conventional one. Since that conventional scooter constitutes available real data, in this case study the fossil fuelled vehicle was considered to be that scooter so the computed savings achieved correspond to the money and emissions MR would save if they choose to change that conventional scooter for the one they are using for the project.

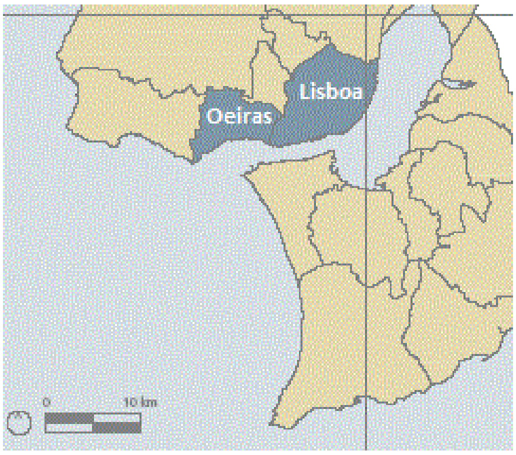

Figure 12 – Lisbon and Oeiras Municipalities' localization (Adapted from the Municipality of Oeiras (2015))

In the one hand, the conventional scooter MR has been using is a Vespa (Figure 13), it costs approximately 3 550€ (Vespa 2014), has an average consumption of 5l/100km, a maintenance cost of 1 310€/yr and an insurance cost of 92.77€/yr. This vehicle does not pay IUC nor other taxes. Although it is 39 years old, its total travelled distance is 85 200km and considering an average annual distance equal to the one in 2014, which was 17 650km, it is possible to estimate that this vehicle has been active for 5 years.

Figure 13 – Conventional scooter used by *Moço de Recados* (Campos 2012)

Figure 14 – E-Scooter used by *Moço dos Recados*

On the other hand, the electric vehicle is a 7 000€ Scutum S02 (Figure 14) which maximum speed is 80km/h. This e-scooter has a weight capacity of 105kg plus the rider and it weights 145kg (e-scooter plus the battery). The battery is a LiFePo4, has an electric capacity of 6kWh and it takes 10 hours to fully charge from de null power. It has three function modes (Eco, Cruise and Sport) and an average autonomy of 100km. It is estimated that when the 100 000km distance target is achieved, there is a capacity lost up to 80%. In addition, a cargo box was added allowing to carry parcels up to 40l (0.04m^3). Since the trial only occurred during one month, there is no reference costs regarding neither maintenance nor insurance. As so, reference values from direct consultation with repair shops and insurance companies were considered: 350€/yr and 48€/yr, respectively.

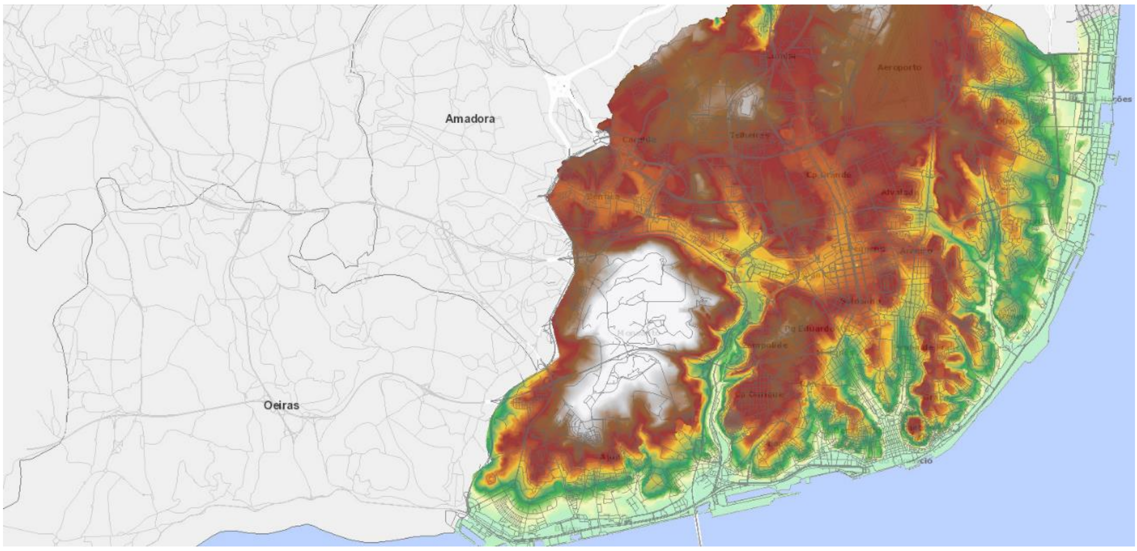

Figure 15 – Oeiras location and Lisbon's Digital Terrain Model without scale (Lisbon Municipality 2015b)

Figure 16 – Oeiras' Slopes and Major arterials' representation without scale (Gabinete de Desenvolvimento Municipal - Câmara Municipal de Oeiras 1993)

Moço de Recados has a business share of 60% particular clients and 40% companies requesting their services and they operate in Lisbon and Oeiras without a particular location preference. They ride both in narrow and highly congested urban roads and in wider peripheral higher speed roads (highways and even freeways) and both in flat and slopped areas. Figure 15 (where red and white represent the highest elevations and yellow and green represent the lowest) and Figure 16 (where the red lines represent the altimetric isolines and the purple lines represent road infrastructures) illustrate Lisbon's Digital Terrain Model and Oeiras' slopes, respectively but they also clarify the major road arterials' location within each zone and between municipalities. These two maps, make it possible to notice how sloped are some of these connections and the bigger the slopes and the heaviest the load, the more pronounced the speed lost, especially when using the electric scooter. But since the majority of services the company performs are within Lisbon – urban context and lower speed limits –, the speed lost is not such a problem, it is more an inconvenience (the average speed registered by the e-scooter during the trial was 30.5km/h).

In a service of this type, where all the expenses with the services are paid by the client, the biggest cost the company faces is the variable costs related to fuel consumption. It is important to remember that the conventional scooter's consumption is 5l/100km, which represents a really high expense. Hence, the profitability of the company would exponentially rise if those costs were eliminated or, at least, minimized. The solution can be the replacement of such a conventional vehicle with an electric one. A lower fossil consumption scooter could also be an alternative, however, mainly the environmental costs would be probably higher than the solution here studied. In this particular case, because the services are mostly urgent, it is important to overcome traffic congestion and this can easily be achieved with a two-wheeler, as referred previously. Between all the types of electric two-wheelers, an e-scooter is the one that suits better to this service due to the terrain's topography (an e-(cargo)bike would implicate contracting riders with a more accurate physical preparation, what can represent higher personal expenses) but mainly due to the average daily distance that, in a weak month like August can rise up to 116km/day. More advantages of riding an electric scooter in these areas are, again, the reduced emission zones in Lisbon where vehicles older than 2000 are forbidden to circulate and also the extensive network of charging points all over the city, allowing the rider to charge his vehicle whenever it is not being used.

4.3.1. Logistic Profile

Due to the variety of services this company provides and the large area where they operate, it is not possible to define a logistic profile. The variety of services the company provides are enormous but the most requested are, by this order, transporting parcels, shopping, feeding or walking pets, paperwork and buying gifts. There are, however, a few characteristics that remain constant no matter what the service is. One of those is the easiness of handling (because the parcels the company mostly transports are small like documents and small boxes), which is easy, and the amount to be delivered, which is few. The services are also usually urgent and booked in the last minute. The frequency is always low because the clients request the service mostly when they forgot to do something very important.

4.3.2. Energy, Emissions and Costs' Calculation

It is important to take into consideration that the recorded data concerns MR's weakest month: August. During this month – traditionally associated with holidays for the majority of people – the services the company performed the most are related neither with deliveries nor with long ride's period. Instead, they performed mostly services where non or only low-cargo is present, like pets' feeding.

Since MR already had a conventional scooter previously to the trial, the warm up period – on-going during this first month of the trial – only concerned the electric assistance utilization. Mostly, in this period, the rider got used to e-scooter's limited speed and he learnt the best strategy to charge the vehicle in order to assure that there was enough battery to perform the entire service. Accordingly with the registrations during the pro-E-Bike project, it is possible to describe the operation of the e-scooter as in Table 23.

Table 23 – Indicative Pro-E-Bike daily registration on *Moço dos Recados* (21 registrations)

Indicator	Unit	Mean	Max	Min
No. performed deliveries with the ePTW	No./day	2.6	4	1
Total no. of delivered parcels	No./day	1.1	3	0
Total round trip time per day	min/day	**118.8**	220	40
Travelled distance	km/day	**62.0**	116	21
No. of battery recharges	No./day	1.4	**4**	1
Remaining battery level (0, 25, 50, 75, 100%)	%	49.8	**85**	**2**
Average battery recharging duration	Hours	**8.1**	12	**5**
Average circulation speed (without stops to perform deliveries)	km/h	**30.5**	38	23
Estimated total weight per day	kg/day	1.7	**10.5**	0.5
Estimated total volume per day	m^3/day	0.0	0.0	0.0
Average distance in empty trip per round trip	km/day	41.1	80	8
Energy Consumption	kWh/km	0.12	0.30	0.05
Incidents including not performed deliveries, costumer complains, breakdowns (indicating associated cost), fees	No./day	0	0	0
Accidents	No./day	0	0	0

During the trial, *Moço de Recados* performed an average of 2.6 services per day but the rider only delivered parcels once a day with a maximum amount of 4. Hence, only 40% of the services involved delivering parcels. Nevertheless, average and maximum trip duration of 2 and 4 hours were registered, respectively.

The average distance per day is 62km, which is lower than the battery autonomy in 38km, however, a maximum of 116km was registered in a day when 2 charges were needed and there was only 2% left of the battery in the end of the day. However, 2 charges is not the maximum registered number of charges, permitting to conclude that, in that day the rider did not travelled in sloped nor many urban roads (there was no heavy weights being carried during that day). Because the trial occurred during the weakest month in the MR operation, the average distance considered as input in the simulator was the average distance performed in the “normal” months of operation, which, accordingly with the owner of the company is 100km/day. The equivalent could have been done regarding the load weight, however, this parameter is not usually registered for the conventional scooter.

The maximum number of battery recharges went up to 4 in one of the last days of the month, which meets the conclusion that during the first month, the rider learnt that the best way to avoid unpleasant surprises is to charge the vehicle whenever it is not being used. This is especially important in a service like this because the rider do not always know when an extra battery charging will be needed. This is why the remaining battery level were unstable during the trial period, ranging from 2% to 85%. On the other hand, the average charging duration permit to understand that, however, during the entire month the biggest share of recharges occurred during night time. This is because the learning process takes time and the biggest amount of recharges during the day only started in the last days of the month, in order to respond to the battery limitations.

Another limitation of this still recent technology is the average speed. This particular model has a maximum speed of 80km/h but travel in a city like Lisbon where the topography is irregular, results in considerable speed lost – the registered average speed is less than 40% of the maximum speed but it includes riding in residential areas where the speed limit is 30km/h. Another factor that contributes this lost is the weight carried. Like it could have been anticipated, the day where the lower speed was registered coincides with the day when the maximum weight was transported.

Regarding the total carried weight, only the days when parcels were transported were considered in the calculation, so a medium real weight could be computed. As so, only regarding the effectively carried weights, an average of 1.71kg was registered, which is a low value, so it is possible to conclude that weight is not usually a parameter with much importance in this vehicle autonomy.

Since the average distance is considered to be 100km in normal months, the energy consumption was computed using that value. Then, this parameter took the value 0.06kWh/km instead of 0.121kWh/km. By considering this, the input is actually closer to the normal standard proposed in the simulator, which is 0.0512 kWh/km. This last parameter is much higher in this case than in the remaining because although the daily distance is higher, the energy the battery provides is also the double of the last case.

Due to the nature of these services, it is easy to understand that a mini-van is not suited for MR, except for some specific services. In this particular aspect, the rider answered in his survey that, comparing a mini-van and a conventional scooter, the latter would probably be more suited to perform this type of services.

It is now possible to define MR’s specific inputs:

Fossil Fuelled Vehicle’s input: A 3 550€ gasoline scooter with the average consumption of 5.0l/100km, a maintenance cost of 1 310€/yr, an insurance of 92.77€/yr and no taxes are paid. This vehicle was considered to be active for 5 years.

Electric vehicle's input: electric scooter of 7 000€, average energy consumption of 0.06kWh/km and a maximum cargo capacity of 0.04m^3 and 105kg (without the rider). Its maintenance cost is about 350€/yr, an insurance of 48€/yr.

Operation's inputs: average daily distance of 62km with the average load of 1.71kg and no significant volume, 288 days of work in one year (six days a week, twelve months per year).

The remaining inputs were already defined in Chapter 3 Section 3.2.3.

Taking these inputs into consideration, the simulator returned the follow information concerning the substitution of a conventional scooter by an electric model:

Table 24 – Results for the MR case study – scooter

Results – Fossil Fuelled Fleet Analysis

Actual Situation

	Global	Diesel	Gasoline
Vehicles [n.º]	1	-	1
Distance [km/day.vehicle]	62	-	62
Fuel costs [EUR/100km]	7.1	-	7.1
Average annual costs [EUR/vehicle]	2 675	-	**2 675**
Emissions [kg CO_2/100km]	12.5	-	**12.5**
Average total costs per vehicle [EUR/vehicle]	37 257	-	**37 257**

Operational Lifetime Costs

	Global	Diesel	Gasoline
Energy cost [EUR/vehicle]	16 031	-	**16 031**
CO2 cost [EUR/vehicle]	980	-	**980**
Pollutants cost [EUR/vehicle]	79.3	-	**79.3**
Total operational lifetime costs [EUR/vehicle]	17 091	-	**17 091**

Results - Electric Fleet Analysis

e-Scooter

e-scooter [n.º]	1
Distance [km/day.vehicle]	62
Costs [EUR/100km]	0.59
Average annual costs [EUR/vehicle]	**504**
Emissions [kg CO_2/100km]	**0.74**
Average total costs per vehicle [EUR/vehicle]	**8 411**

Operational Lifetime Costs

	Global
Energy cost [EUR/vehicle]	296
CO_2 cost [EUR/vehicle]	13
Pollutants cost [EUR/vehicle]	0
Total operational lifetime costs [EUR/vehicle]	309

Savings						
Costs per year of the fossil fuelled fleet			**Costs per year of the electric fleet**			
Economic	2 675	EUR/yr		Economic	504	EUR/yr
Environmental	2 223	kg CO_2/yr		Environmental	131	kg CO_2/yr
Savings						
Economic	**2 171**	EUR/yr				
Environmental	**2 092**	kg CO_2/yr				

It is worth to reminder once again that the calculations were made in constant monetary terms and the purchase cost was not annualized. In order to assess the electric vehicle "average total costs per vehicle", a 50 000km lifetime mileage was considered. This and the remaining modified or added costs are highlighted in light orange in the previous table. Because the daily distance is higher than the recommended distance, the simulator retrieves the costs for two vehicles and, consequently, that output was modified in order to include only one vehicle. Using the same procedure as before, the operational lifetime costs of the electric vehicle were computed.

The obtained results, indicate a 2 171€/yr savings regarding the e-scooter annual average costs, meaning that that electric vehicle represent a saving of 81.2% of the conventional scooter. In the same way, a total saving of 28 846€/yr (77.4% of the fossil fuelled vehicle's cost) can be achieved if that conventional scooter was substituted by an electric model like the one used in the Pro-E-Bike trial in this same company, since these two vehicles have a similar operation. In what concerns to operational lifetime costs, the electric vehicle represents a saving of 16 782€ (98.2%) of the total costs of the conventional scooter.

Regarding the environmental impact of the studied vehicles, it is worth to notice that a changing from the conventional model to the electric one constitutes saving of 2 092kg CO_2/yr, which is 94.1% of the conventional scooter emissions. Furthermore, this investment would also implicate a saving of 6 880kWh/yr (or a 86.5% saving) in energy consumption (7 949.10kWh/yr of the gasoline scooter vs 1 069.39kWh/yr of the electric model).

The following table summarizes the main savings regarding the substitution of the conventional scooter MR currently uses by an electric model:

Table 25 – Savings summarization of the errant case study

	Annual [€/yr]	Total [€]	Operational Lifetime [€]	Fuel [€/yr]	Environmental [€/yr]	Energy Consumption [kWh/yr]
Scooter	2 171 (81.2%)	28 846 (77.4%)	16 782 (98.2%)	1 162 (91.7%)	2 092 (94.1%)	6 880 (86.5%)

4.3.3. Perceived Experience

After a month using the e-scooter, both the owner of MR and the rider answered the respective surveys. The responses can be consulted in Annex C. Both the entities believe that one month is not enough to understand whether the vehicle represent benefits or not. So their opinion is still not consolidated and, for instance, the owner was not already convinced that in the future he would invest in an electric fleet. In addition, it is worth to highlight that the clients do not knew an electric vehicle was being used, mostly because a big share of them request the service by telephone or e-mail and do not contact directly with the service provider.

Regardless this uncertainty, the owner strongly agreed on the benefits these vehicles constitute to the city, to the people and to the environment and those are the benefits that motivate him the most to use these vehicles. He also claimed that lower purchase prices and higher autonomies would undoubtedly improve this vehicles' attractiveness.

The rider also agreed that the autonomy is still low for their needs, as already verified from Table 23. However, they are trying new strategies to charge the vehicle in order to increase its potential. He also mentioned that being silent makes the vehicle less safe than a conventional model because the remaining road users do not notice his presence. Nevertheless, he believes that this vehicle have characteristics that make it an advantage in the urban context, yet he is not sure about its potential to be used to transport freight.

During the trial, the survey was delivered to ten clients of *Moço de Recados* via Internet. Almost all the clients answered that the duration was adequate, so the limited speed in not that much of a problem. 40% agreed that an electric vehicle constitutes an incentive to use the service and 10% (one client) strongly agreed on that statement. Half of the sample did not agreed or disagreed on whether they would requested or not the service less frequently if a fossil fuelled vehicle was being used, partly because until that moment they believed the service was being performed using a *Vespa*. About the remaining clients, the majority showed an environmental friendly behaviour regarding the same question. However, when asked about their reaction on the novelty, they did not showed a positive response, meaning that the environment factor is more important for them than the novelty's.

The results from the simulator permit to respond to the doubts the owner presented about whether there is economic benefits on purchasing an e-scooter to perform an errant service. The answer is positive. The electric technology allows savings of 2 171€/yr and reductions of 87% in energy consumption and 94% in CO_2 emissions.

Regarding the multiplicity of geographical areas and services the company performs, the most suited technology would be one with low sensibility to topography, with advantages in high congested areas and in high speed roads, with no special requirements regarding the load and with an autonomy higher than 100km. The electric scooter *Moço de Recados* acquired only meets these requirements in part, however, this vehicle presents benefits and can be easily complemented with a second e-scooter. No other type of vehicle would achieve advantages in the order of magnitude of e-scooter's: the light and small loads together with the high annual costs, do not present credits to mini-vans, the environmental impact (emissions and energy consumption) constitute disadvantages for gasoline scooters, a bicycle (even if electrically assisted) will never cover such big distances in such short time.

4.4. Survey Results

The group of respondents was composed by: 5 owners (3 from the pilots and 2 external), 5 riders (3 from the pilots and 2 external) and 13 clients (12 from the pilots – 10 from the *Moço de Recados* and 2 from the restaurant – and 1 external).

The overall experience can be classified as positive, however, there are still entities with some doubts mainly in what concerns the economic benefits of this technology. Factors like the low battery autonomy, the relatively short batteries' life, the high sensibility to slopes and weights and the really high purchase cost contribute to this cautious behaviour.

Regarding the owners' opinion, 80% believes that using this new technology has been working as an incentive for clients to request the service. This belief is what motivates them to participate in the project in the first place, so it has to be relatively strong. 40% of the sample seemed to be hesitant in purchasing vehicles of the same type in the future. These owners are the restaurants' and the MR's. When they answered the inquiry they were still in the beginning of the trial and they showed great concerns about the factors described above. All of the respondents stated that these vehicles make actually sense in their urban environment, so they acknowledge all the benefits about congestion, parking, noise, and both environmental and social impact. Actually, 67% strongly agreed that what motivates them the most to use these vehicles was their impact in the environment and in the public health. When confronted with what they believe that would turn these vehicles more attractive, 50% referred lower purchase costs and another half referred higher autonomies. The owner of *Camisola Amarela* also expressed his concern about a lack in awareness of the real advantages of these vehicles by both clients and other courier companies. According to him, proving these entities about the gains this change occur, would result in more users of electric two-wheelers. Regarding legislation, a respondent from the Netherlands stated that in his country both regulation and bike infrastructures are adequate and incentive their use. However, 67% of the Portuguese respondents feel cheated by the authorities. They claimed better cycling infrastructures and more fiscal benefits in order to support purchase costs. One of them also claimed that there should be more traffic restrictions so cars would have less importance in the road space.

Only one in five riders already used an electric vehicle. This result shows how poorly diffused is this technology and mainly its advantages. Half of the respondents think that the electric two-wheeler they are using perfectly replaces a fossil fuelled scooter but it does not, by far, replace a mini-van. These results are mostly explained by the volume capacity of the compared vehicles.

Two-wheelers, whether it be a fossil fuelled or an electric, have a much lower volume and weight capacity than a mini-van and the respondents were using two-wheelers in services where two-wheelers make sense and there is no a great need for volume capacities as the one offered by a mini-van. Regarding the battery, no one strongly agreed on a sufficient autonomy, on the contrary: 80% denies that statement or does not know. In what concerns with the charging scheme, all the respondents claimed to recharge the battery not only the amount they believe they will need, they mostly charge it whenever they have the chance in order to ensure the battery will not die during a service. This concern was mostly reported by 60% of them, who felt the impact the topography has in these vehicles. None of the riders believes that the electric vehicle they use is safer than a conventional model but all of them recognize that these vehicles have inherent advantages in cities. 75% believes that eTW have the potential to be widely used in urban freight transport and the majority did not feel any significant differences in the ridding itself when comparing with a conventional vehicle. 60% confirmed their biggest concern as the autonomy and the rider in Netherland (who used an e-cargo-bike) only refereed the relation between his vehicle and the weather conditions. Regarding their favourite aspects of this technology they all pointed out different aspects: easiness to use, easy to overcome congestion, environmental footprint and, when the vehicle is an e-cargo bike, the riders also pointed out reduction in effort, increase in productivity and attention from the people when they pass by.

In what concerns with the clients' opinion, different perspectives were registered according with the geographical area. Whereas in Matosinhos clients worry the most about the novelty, in Lisbon that was not a relevant factor. In the latter, people worry the most about their environmental footprint.

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5. Conclusions

This chapter starts with a revision of the dissertation’s motivations and objective followed by a brief summary of the methodology applied. The chapter continues with a collection of the main results. This first section allows the reader to organize their thoughts about the implications of each one of the solutions in each case study. Then, the main methodology limitations are presented. This section permits the reader to understand what could be additionally taken into consideration in this approach but that was not. In the end of the chapter, are the possible future developments based in this work and others that can and must be performed.

5.1. Work Review

This dissertation emerge from the need to understand whether a new technological transfer could benefit companies performing deliveries and services in urban environment. The biggest challenge may be related with finding a sustainable solution not only capable of reducing costs but also increase productivity and income for those companies. A possibility is substituting their conventional fleets by electric ones, more specifically, electric two-wheelers as their benefits are the sum of the ones related with the electric energy (sustainability) and the benefits of a small and light vehicle (productivity and economy). Hence, this work aimed to quantify both the economic (direct costs) and the environmental (gases emissions and energy consumption) benefits of electric two-wheelers in the transport of goods in urban areas.

That objective was almost completely achieved. Although significant savings were registered, some additional parameters would be interesting to study: pollutants emissions, noise level, safety cost and both the social and national economy impact. That was not possible to address due to lack of available methodologies.

In order to compute those pretended savings, a costs simulator was used. The inputs included several types of costs (purchase, maintenance, insurance, fuel and energy costs, CO_2 cost), operational parameters (transported weight and volume, daily distance) and vehicles specifications (consumption, load capacity, lifetime mileage). This simulator computes the costs (annual, total lifetime, operational lifetime, environmental) of the two technologies and outputs the savings one can get by simply substituting a conventional vehicle by an electric two-wheeler. The costs and savings were all computed in constant monetary terms. In order to assess how real those benefits are, three different surveys were responded by the three entities most directly affected by the fleet substitution: company owner, driver and client.

All the results components (savings and surveys) weighted, the overall experience was positive to all the pilots, however, two of them (*Moço de Recados* and *O Marujo*) were still hesitant about the economic benefits of this technology, meaning that, besides they know that these vehicles represent benefits, they are only aware of the environmental ones (60% of the respondents sample are in this situation). That unawareness is something that this work tries to solve by showing companies electric two-wheelers benefits. It is worth to highlight that the costs and savings presented by the simulator are only indicative. For instance, the maintenance a vehicle needs depend on the utilization, depends on the driver and depends on many more factors and the same for the energy consumptions, which is correlated with the percentage of time it is stopped, the traffic lights, if it moves mostly on peak or off peak hours, it depends on the maintenance the vehicle has and, an important factor: it depends on the slopes. As already shown, Lisbon is a very sloped city and the bigger the slope, the higher the energy consumption so, in order to spend less, one can choose to travel in a smoother route. None of these factors are taken into consideration in the simulator and they should be. A more realistic approach would be based on the Mendes' (2015) work. Unfortunately, nor the measure equipment was available for the pilots to use it nor it permits a normal operation of the riders due to its weight and size.

Accordingly with the results that author got, a 30% and 54% reduction in fossil fuelled vehicles' energy consumption and CO_2 emissions, respectively can be achieved when measuring them in the well-to-wheel stage instead of tank-to-wheel (TTW). So, if the analysis' scope performed in this work was the TTW, an even higher differentiation between the two technologies would be achieved, however, it would not be fare, since the electric vehicles also emit and in the TTW stage these emissions are basically null. Regarding the pollutants emissions, it was not possible to measure and correctly compare them using the simulator, since they are automatically converted to economic costs. However, as seen in the State of the Art chapter, electric vehicles can only emit CO_2, SO_2 and NO_X during the energy production phase depending on the energy source and, obviously the involved quantities are much lower than the pollutant emissions involved in the fuel burning occurring in a minivan or motorcycle, however still unknown. Another parameter not taken into consideration in this analysis was the noise, which for scooters and mini-vans represents an additional cost of 125 million €/yr in national economy. A more robust analysis would also include the time savings. However, as seen earlier, the cost of a time unit depends on the service, on the good and other factors so it must be analysed by the owner of each company and a possible approach can be the one used in Section 2.2.

Another cost component that was not part of the assessment, was the safety cost. As seen in the same section, two-wheelers are much more hazardous to suffer an accident than cars, vans, trucks… Considering this cost component, two-wheelers (electric but also conventional) would definitely risk their benefits and give credit to mini-vans. So, when benchmarking an electric scooter with a conventional one the results would be equal but the same would not occur when a minivan was being compared with an electric two-wheeler, where the roles could actually invert.

Nevertheless, it is essential to highlight that this can also represent a call for attention: for now, there are more cars than two-wheelers on the roads, which represent increased risk for the latter but, if the amount of two-wheelers rise, the danger for them decreases.

The most relevant savings, summarized in Table 26, were computed for all the variables in study when assessing the consequence of substituting a fossil fuelled vehicle by an electric two-wheeler in real life operational conditions. In order to assure a more accurate comparison of costs in a long term, calculations relating to a ten year time were performed. Because electric vehicles have a shorter life than conventional ones, it was considered that during those 10 years additional eTW batteries would be bought but the vehicle was considered to remain the same. In that table, the top values represent the absolute savings (computed as the difference between that costs of the two technologies) and the bottom values represent the relative savings. This relation concerns the ratio between the absolute saving and the fossil fuelled vehicle correspondent cost. The bolt values correspond to the highest relative savings of each cost category.

Table 26 – Savings summary from all the case studies

			Camisola Amarela		*O Marujo* restaurant		*Moço de Recados*
eTW	Daily Distance		36.6km		6.1km		62km
	Energy Consumption		0.03kWh/km		0.0698kWh/km		0.12kWh/km
	Life time		6 years		29 years[15]		3 years
Fossil Fuelled Vehicle			Mini-Van	Scooter	Mini-Van	Scooter	Scooter
Savings	Annual [€/yr]		1 814 (92.6%)	782 (84.3%)	1 090 (72.7%)	275 (40.1%)	**2 171** (81.2%)
	Total [€]	Life Time	**52 229** (92.8%)	21 123 (82.2%)	188 171 (91.3%)	72 842 (80.2%)	28 846 (77.4%)
		10 years	45 193 (70.8%)	7 087 (27.6%)	-		12 877 (34.6%)
	Opera-tional Lifetime [€]	Life Time	15 772 (99.2%)	6 759 (98.2%)	15 538 (97.7%)	6 525 (94.8%)	**16 782** (98.2%)
		10 years	15 669 (97.0%)	6 656 (98.2%)	-		15 988 (93.5%)
	Fuel [€/yr]		554 (96.3%)	236 (91.7%)	102 (89.4%)	38 (76.3%)	**1 162** (91.7%)
	Environmental [kg CO_2/yr]		1 200 (97.8%)	416 (93.9%)	238 (94.1%)	71 (82.8%)	**2 092** (94.1%)
	Energy Consumption [kWh/yr]		4 544 (95.4%)	1 357 (86.0%)	822 (87.0%)	190 (60.9%)	**6 880** (86.5%)

Besides the obvious environmental savings, all the case studies got relevant economic savings from using an electric vehicle. The economic savings vary from 40 to 84% and the environmental savings range from 60 to 98%. It is also worth to highlight that regarding pollutants emissions, accordingly with the simulator, the conventional vehicles in all the case studies have the same pollution cost: 181.9€/veh for the mini-van and 79.3€/veh for the conventional scooter. This pollutants quantification are presented in Table 27 and the calculations were based on the information presented in Table 2 and Table 12.

[15] Not necessarily true.

Table 27 – Pollutant emissions

	Mini-van	Scooter
Cost (life time) (€/veh)	181.9	79.3
NOx (g/yr)	2 564	400
PM (g/yr)	10	0.6
NMVOC (g/yr)	-	347

Since eTW do not emit during their utilization, all these emissions associated with motorized vehicles are disadvantages when comparing with the electric solution.

Regarding the results in Table 26, both in relative and absolute terms, the biggest savings (more than 99% for the lifetime operation costs and more than 32 000€ concerning total lifetime costs) concerns the operation of the courier service *Camisola Amarela*. Actually, the total lifetime savings are higher in the CA case study, possibly because of the differential between the compared vehicles purchase cost. This is the only cost parameter considering this investment cost and this difference is higher in this most successful case. However, the errant service got the highest savings in all the remaining cost parameters. This outcome has two causes: MR is the service with a higher daily distance and the gasoline scooter used to compare the operation consumes more than twice than the Honda PCX, which was the vehicle compared in the CA and the restaurant case studies. The biggest problems the rider reported concerning the e-scooter was the battery's autonomy and the loss of speed. Regarding the latter, the only answer is wait until a more developed technology appears but regarding the battery question, a replacement battery can be purchased and transported in the cargo box, whenever it is not being use. Purchasing a second battery, which costs about 3 000€, still represents roughly the same savings (although the costs would be higher because a higher daily distance would be travelled, the number of performed services would also increase). This relation between purchase costs and savings can be explained by the similitude between the annual savings and the total ones. The total savings in the lifetime result from the multiplication of the annual costs by the lifetime of the vehicle to which the purchase cost is added. Because the difference is 15% maximum, this means that costs, in particular the purchase cost, do not have relevant impact in the savings. In addition, a close dependence between the savings and the daily distance can be easily perceived: the higher the daily distance, the higher the savings. This means that the savings related to the technological shift have a higher dependence of the vehicle usage – in particular it's distance – than of the purchase cost.

Regarding *Moço de Recados'* environmental impact, if they substitute the classic *Vespa* by the electric vehicle they purchased, an energy consumption saving of 86.5% would be achieved as well as a 94.1% save in GHG emissions.

These results show that the logistic profile with higher savings is the type C (express and light deliveries in highly consolidated zones). The biggest savings to this LP obviously correspond to the substitution of a mini-van (and not of a scooter) because this vehicle is not the most suited vehicle for an express delivery service due to general parcel characteristics, contrary to the rider response on the survey. In fact, in order to achieve the mini-van's lifetime cost with a purely electric fleet, almost nine electrically assisted cargo-bikes would be needed and even with such a fleet, 637€/yr and 984kg CO_2/yr would be saved. Following the same rationale, using a minivan to perform food home deliveries, especially with the registered low frequency, volume and weight, do not makes sense and the results only concerning the savings of substituting a conventional scooter for an eTW can be consulted in Figure 17. Because of these characteristics, it was in these case that the savings were higher. Because the electric vehicle's features are not fully used due to the low frequency of orders, nor the rider have the chance to learn the best way to take advantage of the vehicle nor the investment gets refunded. However, when compared with a conventional scooter, annual economic savings of 40.1% can be obtained as well as 60.9% savings in energy consumption and 82.8% in GHG emissions. Hence, if a service belonging to the Logistic Profile type E, with a higher delivery frequency uses an electric scooter, higher savings that the ones here reported can be achieved because the more an electric scooter travels, the higher their advantages. These results must, however, be used with caution as the recorded sample is small and, therefore, difficultly representative of the reality.

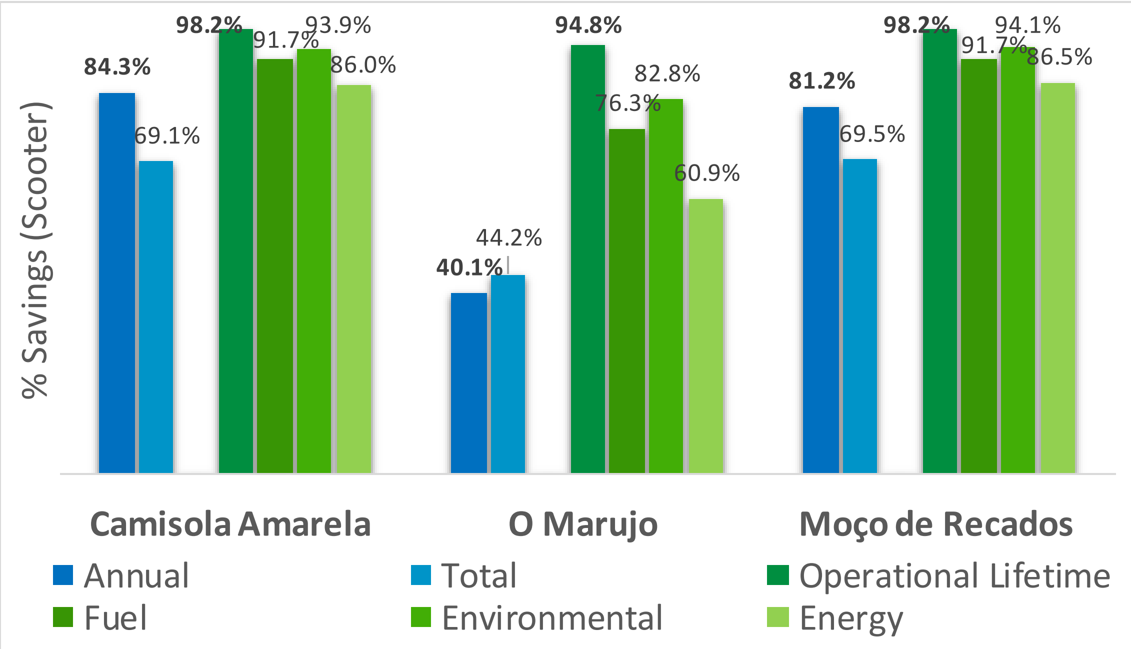

Figure 17 – Savings considering the shift of a scooter for an eTW

In spite of not being included in the economic and environmental benefit's quantification, time savings were also quantified in the State of the Art Chapter and it represents an additional benefit of eTW.

Altogether, like it was predicted, electric two-wheelers that travel mostly in high consolidate areas, performing urgent deliveries and longer distances (Logistic Profiles of type C and possibly D) present the situations where their economic and environmental advantages are more relevant. Even the remaining Logistic Profiles and services with low demand can obtain benefits by a simple fleet change from fossil fuelled to electric two-wheelers. Then, each company learn the best way to use the vehicle and exploit it.

Almost all the survey respondents pointed the battery's autonomy and duration as the elements that less encourage them to invest in the electric technology. This concern is based on the still low developed technology (the autonomy of an electric scooter can go up to 100km average and only lasts for 50 000km).

A frequent complain, besides the battery, is the high purchase cost of electric two-wheelers. Aside from the inexistent fiscal supports, there is no enough studies and publications performing the analysis here presented and, as a consequence, people do not know the benefits behind a technological change of this kind. As so, the calculations the companies perform, do not focus on all the aspects (insurance, fuel vs electricity cost, emissions costs) and because of that low diffusion people are only aware of these vehicle's limitations. From the survey results is possible to conclude that besides there is a strong acknowledge of the environmental benefits, the company owners do not are aware of the economic benefits of eTW and it is extremely important to invest in studies like this one in order to show them the amounts they can save from this technological change.

In what concerns the safety, it constitutes, for now, a disadvantage for electric two-wheelers. However, this fact is owed to the number of cars, vans and trucks and their driving and is no directly correlated with the electric two-wheeler itself. So, when the share of this vehicles had risen enough, safety will no longer be a problem. However, because these vehicles are silent, it is important to invest and insist in pedestrians' education and respect for the traffic, especially children, however alternative solutions such as adding a characteristic noise to the vehicle has already been applied by some producers.

On the one hand, the survey respondents using electric scooters did not claimed anything about the driving itself, meaning that there is no significant difference between riding an electric two-wheeler or a conventional scooter, which is a plus for many riders. Some had mentioned some differences in the engine start, when the motor is turned on and the vehicle starts moving. But while some clamed a small discomfort, others enjoyed that. On the other hand, the electric cargo-bike of *Camisola Amarela* stated a bit difference. For the rider, it is slightly easier to ride a conventional cargo-bike than an electric one. This can be owed to the battery's weight, which were claimed by e-bike users as a disadvantage because once the battery is dead, it becomes really difficult to ride the bicycle.

These obtained results, both the savings and the benefits proofing from the surveys, permit to conclude that, effectively, electric two-wheelers do represent advantages for companies that perform services and/or deliveries in urban environment and also for the society in general. This advantages are not only environmental but also economic and social.

5.2. Limitations

When performing a benchmark between two solutions in general and technologies in particular, the more the parameters, factors and consequences directly derived from the solutions taken into account in the analysis, the more sophisticated the analysis will be must take into account all the. That is a limitation of the methodology here applied. Although significant advantages of this technological transfer were registered, parameters like noise, time cost, total emissions quantification, the real contribution a fleet change in all the companies would have in national economy and safety cost would increase the study's impact.

Regarding the methodology here applied, some improvements can be suggested: the quantity of inputs is insufficient because aspects like the driving, the usage (if the maintenance performed is proper and complete), the vehicle degradation and roads slopes are ignored. More technically measured operational on-road data should be a crucial input in this simulator because electric two-wheelers (the study object for which the simulator was designed) are still very sensible to trip conditions. Also the output could be more complete as aspects like pollutants quantification, energy consumption, time savings/losses are not available. Although it is possible to compute them, a direct approach would enrich the tool. The simulator also fails in the outputs representation: the computed parameters are not the same for the different technologies (limiting the comparison), wrongly assumes, for instance, that a new vehicle will be purchased in order to cover the daily distance and there is no paper or report explaining the parameters, the methodology and the assumptions which makes the user spend time to understand those. Another significant limitation of the simulator is the non-consideration of specific data regarding the company, the service, the type of good nor singular situations.

Nevertheless, these limitations was purposeful, since the Pro-E-Bike is a European Project that collects data regarding the pilots' operation. In order to be widely used, the non-consideration of such data was part of the objective. This limitation has to be taken into consideration in the main conclusions every time this tool is used. The results are not entirely real, they only represent an approximation.

Moreover, calculation simplifications were considered due to time, tools and resources limitations:

- The electricity costs assumed concerned a bi-phasic tariff and, as concluded using the surveys, the riders charge the vehicle whenever they have the chance to and not only during night time so this might not be the most adequate tariff for them. This simplification lead to lower electricity costs;

- The motorized vehicles consumption do not relate to urban environment, so, if realist consumptions were considered, the fuel and pollutant costs as well as emissions would be higher.

5.3. Outlook

In a generic away, all the limitations pointed out above should be considered and overtaken in future developments. In particular, an analysis capable of attending to all the important parameters regarding these services and companies would reduce companies concerns about using electric two-wheelers to transport goods in urban areas. In those future developments, factors like the social impact, the impact in efficiency, the influence in the number and gravity of road accidents, the effective space that can be saved by replace trucks by electric two-wheelers (including the space for urban consolidation centres), and more.

In this dissertation, only two logistic profiles were targeted. It would be important to assess the adequacy of electric two-wheelers for the remaining profiles with the objective to generalise these results and show urban companies that these vehicles are, indeed, part of the solution for the urban logistics challenges and that they can be widely used. It is important to show people that two-wheelers have the potentiality to transport freight in urban areas and it is even more imperative to prove people that these vehicles can replace cars and vans representing, above all, savings for all the parameters involved.

References

ACAP, 2014. ACAP. Available at: http://www.acap.pt/ [Accessed July 12, 2015].

APICS The Association for Operations Management, 2011. *Body of Knowledge Framework* Third., Chicago.

Assembleia da República, 2014. *Lei n.º 82-D/2014 Fiscalidade Verde*, Portugal.

Banister, D., 2008. The sustainable mobility paradigm. *Transport Policy*, 15(2), pp.73–80. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0967070X07000820 [Accessed July 10, 2014].

Becker, U.J., Becker, T. & Gerlach, J., 2012. *The True Costs of Automobility : External Costs of Cars Overview on existing estimates in EU-27*, Dresden. Available at: http://www.greens-efa.eu/fileadmin/dam/Documents/Studies/Costs_of_cars/The_true_costs_of_cars_EN.pdf.

Bellver, P., González, E. & León, J., 2013. *PRO-E-BIKE*,

Bishop, J.D.K. et al., 2011. Investigating the technical, economic and environmental performance of electric vehicles in the real-world: A case study using electric scooters. *Journal of Power Sources*, 196(23), pp.10094–10104. Available at: http://dx.doi.org/10.1016/j.jpowsour.2011.08.021.

Borken-kleefeld, J. & Ntziachristos, L., 2012. *The potential for further controls of emissions from mobile sources in Europe*, Laxenburg, Greece.

Browne, M., Allen, J. & Leonardi, J., 2011. Evaluating the use of an urban consolidation centre and electric vehicles in central London. *IATSSR*, 35(1), pp.1–6. Available at: http://dx.doi.org/10.1016/j.iatssr.2011.06.002.

Caiado, G.N. de L., 2004. *Transporte Urbano de Mercadorias: Linhas de Actuação para uma Gestão Integrada*. Instituto Superior Técnico, Lisboa.

Caleia, N. & Ramires, A., 2014. *Economia de Lisboa em Números*, Lisbon. Available at: http://observatorio-lisboa.eapn.pt.

Campos, L., 2012. Moço de Recados. Available at: http://www.mocoderecados.com/ [Accessed September 1, 2015].

Ceuster, G.D. (Transport & M.L. et al., 2004. *Griet De Ceuster, Transport & Mobility Leuven (ed.) Bart Van Herbruggen, Transport & Mobility Leuven Steven Logghe, Transport & Mobility Leuven Stef Proost, K.U.Leuven*,

CM. Oeiras, 2015. AML Map. Available at: http://www.cm-oeiras.pt/ [Accessed August 29, 2015].

Dekoster, J. & Schollaert, U., 2000. *Cycling: the way ahead for towns and cities*,

Dias, M. (DECO), 2015. Pedale Seguro por 45€.

EDP, 2015. EDP. Available at: http://www.edp.pt/ [Accessed July 7, 2015].

Edp, 2014. Rotulagem de energia elétrica EDP SU 2013. Available at: http://www.edpsu.pt/.

Electric Ride Review, 2015. eS's critic. Available at: http://electricridereview.com/ [Accessed August 28, 2015].

Entidade Reguladora dos Serviços Energéticos, 2015. *TARIFAS TRANSITÓRIAS DE VENDA A CLIENTES FINAIS EM PORTUGAL CONTINENTAL EM 2015*, Portugal.

European Commission, 2015. Clean Vehicle. *2015*. Available at: www.cleanvehicle.eu [Accessed August 21, 2015].

European Commission, 2011. *White Paper on transport*, Luxemburg: Luxembourg: Publications

Office of the European Union, 2011.

European Commission, E., 2014. *EU Transport in Figures.Statistical Pocketbook 2014*,

Gabinete de Desenvolvimento Municipal - Câmara Municipal de Oeiras, 1993. PDM Oeiras. Available at: http://pdm.cm-oeiras.pt/ [Accessed August 30, 2015].

Gruber, J., Kihm, A. & Lenz, B., 2014. A new vehicle for urban freight? An ex-ante evaluation of electric cargo bikes in courier services. *Research in Transportation Business & …*, 11, pp.53–62. Available at: http://dx.doi.org/10.1016/j.rtbm.2014.03.004 [Accessed November 16, 2014].

Hickman, J. et al., 1999. *Methodology for calculating transport emissions and energy consumption*,

Honda, 2014. Honda. Available at: http://www.honda.pt/ [Accessed July 12, 2015].

Ibeas, A. et al., 2012. Urban Freight Transport Demand: Transferability of Survey Results Analysis and Models. *Procedia - Social and Behavioral Sciences*, 54, pp.1068–1079. Available at: http://www.sciencedirect.com/science/article/pii/S187704281204284X\nhttp://pdn.sciencedirect.com/science?_ob=MiamiImageURL&_cid=277811&_user=532047&_pii=S187704281204284X&_check=y&_origin=article&_zone=toolbar&_coverDate=2012--04&view=c&originContentFamil.

Jorna, R. & Mallens, M., 2013. *PRO-E-BIKE Promoting electric bikes and scooters for delivery of goods and passenger transport in urban areas Current situation analysis Authors : Authors :*,

KOIKE, T., BLANCO, E. & PENZ, B., 2005. Logistic profile: A new concept for interfacing designers and logisticians in concurrent engineering environment. *ICED05: 15th International Conference on Engineering Design*.

Lenz, B. & Riehle, E., 2013. BIKES FOR URBAN FREIGHT? – EXPERIENCE FOR THE EUROPEAN CASE. *Transportation Research Record: Journal of the Transportation Research Board*, 2379(Freight Operations 2013), pp.39–45.

Lia, F. et al., 2014. Promotion of E-bikes for delivery of goods in European urban areas : an Italian case study.

Lisbon Municipality, 2015a. Lisboa Ciclável. Available at: http://lisboaciclavel.cm-lisboa.pt/ [Accessed August 21, 2015].

Lisbon Municipality, 2015b. Map generator. Available at: http://lxi.cm-lisboa.pt/lxi/.

LvsH, 2015. Larry vs Harry's Bullitt. Available at: http://larryvsharry.com/ [Accessed July 30, 2015].

Macário, R., 2011. TURBLOG: Business concepts and models for urban logistics.

Macário, R., Rodrigues, M. & Gama, A., 2011. *Deliverable 2 Business Concepts and Models for urban logistics*, Lisboa.

Madureira's, 2015. O Marujo. Available at: http://www.marujomarisqueira.com/ [Accessed June 30, 2015].

MDS Transmodal and CTL, 2012. *DG MOVE European Commission : Study on Urban Freight Transport*,

Mendes, M., Duarte, G. & Baptista, P., 2015. Introducing specific power to bicycles and motorcycles: Application to electric mobility. *Transportation Research Part C: Emerging Technologies*, 51(2), pp.120–135. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84921309574&partnerID=tZOtx3y1.

Ministério do Ambiente Ordenamento do território e Energia, 2015. Preço dos Combustíveis. Available at: http://www.precoscombustiveis.dgeg.pt/ [Accessed August 17, 2015].

Moura, C., 2015. Mercado português Renault liderou nos comerciais ligeiros em 2014. *Transportes em Revista*. Available at: http://www.transportesemrevista.com/Default.aspx?tabid=210&language=pt-PT&id=43726.

Occam, 2015. Costs Simulator Pro-E-Bike. Available at: http://www.pro-e-bike.org/.

Quak, H.J., 2012. Improving Urban Freight Transport Sustainability by Carriers – Best Practices from The Netherlands and the EU Project CityLog. *Procedia - Social and Behavioral Sciences*, 39, pp.158–171. Available at: http://linkinghub.elsevier.com/retrieve/pii/S1877042812005654 [Accessed November 21, 2014].

Reis, V., 2015. Freight Transport and Logistics.

Renault Portugal, 2015. Renault. Available at: http://www.renault.pt/gama/veiculos-comerciais/ [Accessed July 12, 2015].

Rodrigue, J.-P., 1998. THE GEOGRAPHY OF TRANSPORT SYSTEMS. Available at: https://people.hofstra.edu/geotrans/index.html.

Rogers, E.M. & Everett, M., 1983. *Diffusion of Innovation*,

Soares, M., 2015. Praças de Saldanha e Picoas vão ganhar passeios, árvores e uma ciclovia. *Publico*. Available at: http://www.publico.pt/.

Sørensen, L. & Kilde, N., 2000. *Emission Inventory Guidebook*,

The Motorcycle Industry, 2012. *Powered Two-Wheelers the SMART Choice for Urban Mobility*, Brussels.

U.S. Department of Energy, 2015. AFDC Energy. Available at: http://www.afdc.energy.gov/ [Accessed September 11, 2015].

Ventura, P., 2009. Camisola Amarela. Available at: http://www.camisolaamarela.com/ [Accessed June 30, 2015].

Vespa, 2014. Vespa. Available at: http://www.vespa.pt/ [Accessed September 4, 2015].

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Annexes

Annex A – Methodologies

Table A 1 – Summary of other author's methodologies

	Inputs	Outputs	Methodology	Scope of application	Results	Conclusion
(Gruber et al. 2014)	Trips' (O/D Matrix and time stamps) and goods' data of bicycle and car messengers;	Average: Distances; Number of shipments; Capacity of cars' and bikes' shipments; Speeds	Descriptive statistical analysis and binary logit model; comparison between bicycles' and cars' data with E-CB features;	Whenever the two studied modes are a "mixture" of the subject mode;	Average distances are compatible with E-CB's autonomy; In terms of capacity, 42% of car shipments would be replaced by E-CB shipments; E-CB's speed is higher than those modes;	There is a great potential for E-CB in the courier market.
(Browne et al. 2011)	On-road data from surveys and interviews before and during the trial (UCC, e-vans and e-tricycles);	Variation of Distance; Variation of CO_2 emissions; Variation of Daytime road occupancy (space and time);	Before and after comparison;	Whenever the operational conditions are similar and the aim is two compare two different modes;	∆Total distance=−20%; ∆unitary CO_2eq emissions= −54%; Distance per parcel rose; ∆Kerbside occupancy=−10%; ∆CO_2eq emissions within the city=−100%;	Even in a highly consolidated logistic process, it is still possible to achieve a more efficient system.

	Inputs	Outputs	Methodology	Scope of application	Results	Conclusion
(Ibeas et al. 2012)	Traffic counts of commercial and private vehicles; Telephone interviews to retailers and truck drivers;	Commodity flows per freight types, shipment size and transport service types; A model featuring the urban freight transport demand;	Descriptive statistical analysis followed by the development of a model (modelling system developed in (Nuzzolo et al. 2010))	Whenever there is two or more study areas with different characteristics;	The share of companies that sell the products in retailer transporting diverge in 20% between the two areas; Difference in deliveries' size; Grate difference in the type of the most common commodity;	It is not possible to generalize results and models, mostly the ones strongly correlated with city features.
(Mendes et al. 2015)	1Hz on road data;	CO_2 emissions and energy consumption;	Vehicle Specific Power	Whenever there are different technologies aiming to a comparison of their emissions and energy consumption in the TTW phase;	Trip time of an electric motorcycle is 36% higher than a conventional one; Trip time of an electric bicycle is 9.5% lower than a conventional one; TTW (WTW) energy consumption is 61% (30%) lower for the electric modes;	Electric vehicles are slower than motorized ones but faster than powered by humans' ones and they represent a huge reduction in energy consumption.

Annex B – Collected Data

SURVEY TO THE CLIENT

Satisfaction and opinion survey related to the delivery service

In a 1 to 5 scale, in which each represents: Service:____________________________

1- I totally disagree
2- I disagree
3- I am indifferent to it/ I do not know
4- I agree
5- I totally agree,

How would you classify each one of the following statements?

	1	2	3	4	5
The delivery service’s duration is satisfactory.					
The delivery being performed by an electric vehicle is perceived by me as an incentive to use the service.					
I would order the service with lower frequency if the vehicle was fossil fuelled.					
The way I perceive the company and its delivery service has changed because of the utilization of a non-pollutant vehicle.					
If I was not client of this service but I knew the vehicle was electric, I would start using the service.					

Thank you for your time!

SURVEY TO THE OWNER

Business point of view's survey related to the delivery service

In a 1 to 5 scale, in which each represents: Service:___________________________

1 I totally disagree

2 I Disagree

3 I'm indifferent to it/ I don't know

4 I agree

5 I totally agree,

How would you classify each one of the following statements?

	1	2	3	4	5
The electric two-wheeler (eTW) has been working as an incentive for people to use the service.					
After I tried an eTW, if I want to expand my fleet in the future, I will definitely invest in more vehicles of the same kind.					
Using eTWs makes sense in my business environment/city.					
The company's perception by (potential) clients motivates me to use this type of vehicles.					
The benefits of eTWs to (public) health (harmful gas emissions; physical exercise) motivates me to use this type of vehicles.					
The benefits of eTWs to the environment (Greenhouse gas emissions; noise) motivates me to use this type of vehicles.					
The benefits of eTWs to the city and quality of life (congestion; public space quality) motivates me to use this type of vehicles.					
The benefits of eTWs to the economy (higher productivity) motivates me to use this type of vehicles.					
The benefits of eTWs to the company itself (parking fees; accessibility; trip duration) motivates me to use this type of vehicles.					

1. What do you think it could be made to achieve a more attractive utilization of eTWs'?

____

2. In what extend do you believe local regulation an advantage/disadvantage?

____

Thank you for your time!

SURVEY TO THE RIDER

Operational point of view's survey related to the delivery service

In a 1 to 5 scale, in which each represents: Service:____________________________

1 I totally disagree

2 I disagree

3 I'm indifferent to it/ I don't know

4 I agree

5 I totally agree,

How would you classify each one of the following statements?

	1	2	3	4	5
It was my first time running an electric two-wheeler (eTW).					
The autonomy fills the needs.					
The eTW I am using can easily replace, for the same service, a fossil fuelled van.					
The eTW I am using can easily replace, for the same service, a fossil fuelled scooter.					
The volume capacity of my eTW fills the needs.					
I only charge the eTW the amount of battery I will need in that day.					
I only charge the eTW when I need it.					
An eTW is easier to maintain than a conventional two-wheeler.					
An eTW is easier to ride than a conventional two-wheeler.					
An eTW is safer than a conventional two-wheeler.					
Trip features has a greater impact in eTWs' than in conventional vehicles.					
Using eTWs makes sense in my business environment/city.					
ETWs have the potential to become common in urban environment for freight delivery.					

1. What did you like the most in the eTW's driving?

____

2. What did you like the least in the eTW's driving?

____

Thank you for your time!

Pro-E-Bike Monitoring Form

Table A 2 – Pilot Performance Monitoring from Pro-E-Bike (Adapted from (Bellver et al. 2013))

PRO-E-BIKE promoting-electric-bike-delivery

PILOT PERFORMANCE MONITORING

Co-funded by the Intelligent Energy Europe Programme of the European Union

Indicator	Un	1	2	...
No. performed deliveries with the ePTW	No.			
Total no. of delivered parcels	No.			
No. of round trips	No.			
Total round trip time per day	Min			
Travelled distance	km			
No. of battery recharges	No.			
Remaining battery level (0, 25, 50, 75, 100%)	%			
Average battery recharging duration	Hours			
Average circulation speed (without stops to perform deliveries)	km/h			
Estimated total weight per day	kg			
Estimated total volume per day	m3			
Average distance in empty trip per round trip	km			
Incidents including not performed deliveries, costumer complains, breakdowns (indicating associated cost), fees	No.			
Accidents	No.			

Annex C – Pilots' Survey Responses

Camisola Amarela

INQUÉRITO AO RESPONSÁVEL

TÉCNICO LISBOA

Inquérito do ponto de vista empresarial relativo ao serviço de entrega

Numa escala de 1 a 5 em que: <u>Serviço prestado:</u> CAMISOLA AMARELA

1- Discordo Totalmente
2- Discordo
3- Sou Indiferente/ Não sei
4- Concordo
5- Concordo Totalmente,

Como classificaria as seguintes afirmações?

	1	2	3	4	5
O veículo eléctrico de duas rodas tem funcionado como incentivo para atrair utilizadores do serviço.				X	
Depois da experiência com um <u>veículo eléctrico de duas rodas</u> (VEDR), se no futuro quiser expandir a frota, de certeza que investirei em veículos do mesmo tipo.					X
A utilização de um VEDR faz sentido no meu ambiente de trabalho/cidade.					X
A percepção da empresa por (potenciais) clientes motiva-me a utilizar este tipo de veículos.					X
Os benefícios dos VEDR para a saúde (pública) (emissão de gases nocivos; exercícios físico) motivam-me a utilizar este tipo de veículos.					X
Os benefícios dos VEDR para o ambiente (emissões de gases de efeito de estufa; barulho) motivam-me a utilizar este tipo de veículos.					X
Os benefícios dos VEDR para a cidade e qualidade de vida (congestionamento; qualidade espaço público) motivam-me a utilizar este tipo de veículos.				X	
Os benefícios dos VEDR para a economia (maior produtividade) motivam-me a utilizar este tipo de veículos.				X	
Os benefícios dos VEDR para a própria empresa (custos estacionamento; acessibilidade; tempo de viagem) motivam-me a utilizar este tipo de veículos.					X

1. O qua acha que ainda está por fazer para tornar a utilização de VEDR mais atractiva?

UMA MAIOR CONSCIENCIALIZAÇÃO POR PARTE DE VÁRIAS EMPRESAS (CLIENTES E TRANSPORTADORAS) EM PORTUGAL PELAS VANTAGENS ECONÓMICAS E AMBIENTAIS

2. Em que sentido considera que a legislação actual é uma vantagem/desvantagem para a aquisição deste tipo de veículos?

É UMA DESVANTAGEM POIS AINDA NÃO HÁ BENEFÍCIOS FISCAIS, DE INFRAESTRUTURAS OU DE RESTRIÇÕES SUFICIENTES PARA ESTES VEÍCULOS SEREM UMA VERDADEIRA SOLUÇÃO DE UM PROBLEMA URBANO.

Obrigada pelo seu tempo!

INQUÉRITO AO CICLISTA/CONDUTOR

TÉCNICO LISBOA

Inquérito do ponto de vista operacional relativo ao serviço de entrega

Numa escala de 1 a 5 em que: Serviço prestado: CAMISOLA AMARELA

1- Discordo Totalmente
2- Discordo
3- Sou Indiferente/ Não sei
4- Concordo
5- Concordo Totalmente,

Como classificaria as seguintes afirmações?

	1	2	3	4	5
Foi a primeira vez que conduzi um veículo eléctrico de duas rodas (VEDR).	X				
A autonomia satisfaz a necessidade.		X			
O VEDR que estou a utilizar permite substituir, neste serviço, uma carrinha a combustível fóssil.					X
O VEDR que estou a utilizar permite substituir, neste serviço, uma scooter a combustível fóssil.				X	
A capacidade volumétrica do meu VEDR satisfaz a necessidade.		X			
Apenas carrego o veículo com a quantidade de bateria que vou precisar naquele dia.	X				
Apenas carrego o veículo quando preciso.	X				
Um VEDR é mais fácil de manter que um veículo de duas rodas convencional.				X	
Um VEDR é mais fácil de conduzir que um veículo de duas rodas convencional.		X			
Um VEDR é mais seguro que um veículo de duas rodas convencional.		X			
A topografia (inclinação das ruas, curvas) tem mais impacto num VEDR que num convencional.				X	
A utilização de um VEDR faz sentido no meu ambiente de trabalho/cidade.					X
Os VEDRs têm potencial para se tornarem comuns em ambiente urbano para transporte de mercadorias.					X

1. O que gostou mais na utilização do VEDR?

DIMINUIÇÃO DO ESFORÇO FÍSICO E AUMENTO DA PRODUTIVIDADE E EFICÁCIA.

2. O que gostou menos na utilização do VEDR?

AUTONOMIA NUMA CIDADE COM TOPOGRAFIA MUITO VARIADA.

Obrigada pelo seu tempo!

C2

O Marujo restaurant

INQUÉRITO AO GERENTE/RESPONSÁVEL

Inquérito do ponto de vista empresarial relativo ao serviço de entrega a casa

Numa escala de 1 a 5 em que:

1- Discordo Totalmente
2- Discordo
3- Sou Indiferente/ Não sei
4- Concordo
5- Concordo Totalmente,

Como classificaria as seguintes afirmações?

	1	2	3	4	5
O veículo eléctrico de duas rodas tem funcionado como incentivo para atrair utilizadores do serviço.				X	
Depois da experiência com um veiculo eléctrico de duas rodas (VEDR), se no futuro quiser expandir a frota, de certeza que investirei em veículos do mesmo tipo.			X		

1. Se respondeu afirmativamente ao investimento future; porquê?

Porque é "amigo" do ambiente e tem vantagens a nível de marketing e no aspecto ambiental

2. Na sua opinião, quais os pros e contras de um VEDR em comparação com um convencional?

Principalmente a sua autonomia

3. O qua acha que ainda está por fazer para tomar a utilização de VEDR mais atractiva?

Uma maior autonomia.

4. Em que sentido considera que a legislação actual é uma vantagem/desvantagem para a aquisição deste tipo de veículos?

Acho que caminham para que o utilizador se sinta atraído para a sua aquisição

Obrigada pelo seu tempo!

INQUÉRITO AO CICLISTA/CONDUTOR

Inquérito do ponto de vista operacional relativo ao serviço de entrega a casa

Numa escala de 1 a 5 em que:

1- Discordo Totalmente
2- Discordo
3- Sou Indiferente/ Não sei
4- Concordo
5- Concordo Totalmente,

Como classificaria as seguintes afirmações?

	1	2	3	4	5
Foi a primeira vez que conduzi um veículo eléctrico de duas rodas (VEDR).					X
A autonomia satisfaz a necessidade.			X		
Apenas carrego o veículo a quantidade de bateria que vou precisar naquele dia.	X				
Apenas carrego o veículo quando preciso.	X				
Um VEDR é mais fácil de manter que um veículo de duas rodas convencional.	X				
A topografia (inclinação das ruas, curvas) tem mais impacto na utilização do VEDR que de um convencional.		X			

1. O que gostou mais na utilização do VEDR?

A Suavidade na sua utilização e Conforto

2. O que gostou menos na utilização do VEDR?

Autonomia

Obrigada pelo seu tempo!

INQUÉRITO AO CLIENTE

Inquérito de satisfação e opinião relativo ao serviço de entrega ao domicílio

Numa escala de 1 a 5 em que:

1- Discordo Totalmente
2- Discordo
3- Sou Indiferente/ Não sei
4- Concordo
5- Concordo Totalmente,

Como classificaria as seguintes afirmações?

	1	2	3	4	5
O serviço de entrega ao domicílio é satisfatório em termos de duração.			X		
O facto de a entrega ser realizada por um veículo eléctrico serve de incentivo à requisição do serviço.			X		
Pediria o serviço com menos frequência se o veículo fosse de combustível fóssil.		X			
Não requisitaria o serviço se o veículo fosse de combustível fóssil.				X	
A forma como vejo o restaurante mudou devido à utilização de um veículo não poluente.				X	
Se não fosse cliente do serviço e soubesse que estaria a ser utilizado um veículo eléctrico, começaria a usar o serviço.				X	

Obrigada pelo seu tempo!

INQUÉRITO AO CLIENTE

TÉCNICO LISBOA

Inquérito de satisfação e opinião relativo ao serviço de entrega ao domicílio

Numa escala de 1 a 5 em que:

1- Discordo Totalmente
2- Discordo
3- Sou Indiferente/ Não sei
4- Concordo
5- Concordo Totalmente,

Como classificaria as seguintes afirmações?

	1	2	3	4	5
O serviço de entrega ao domicílio é satisfatório em termos de duração.				X	
O facto de a entrega ser realizada por um veículo eléctrico serve de incentivo à requisição do serviço.				X	
Pediria o serviço com menos frequência se o veículo fosse de combustível fóssil.	X				
Não requisitaria o serviço se o veículo fosse de combustível fóssil.		X			
A forma como vejo o restaurante mudou devido à utilização de um veículo não poluente.				X	
Se não fosse cliente do serviço e soubesse que estaria a ser utilizado um veículo eléctrico, começaria a usar o serviço.					X

Obrigada pelo seu tempo!

Moço de Recados

INQUÉRITO AO RESPONSÁVEL

TÉCNICO LISBOA

Inquérito do ponto de vista empresarial relativo ao serviço de entrega

Numa escala de 1 a 5 em que:

Serviço prestado: Moço dos Recados

1- Discordo Totalmente
2- Discordo
3- Sou Indiferente/ Não sei
4- Concordo
5- Concordo Totalmente,

Como classificaria as seguintes afirmações?

	1	2	3	4	5
O veículo eléctrico de duas rodas tem funcionado como incentivo para atrair utilizadores do serviço.			X		
Depois da experiência com um <u>veículo eléctrico de duas rodas</u> (VEDR), se no futuro quiser expandir a frota, de certeza que investirei em veículos do mesmo tipo.			X		
A utilização de um VEDR faz sentido no meu ambiente de trabalho/cidade.					X
A percepção da empresa por (potenciais) clientes motiva-me a utilizar este tipo de veículos.					
Os benefícios dos VEDR para a saúde (pública) (emissão de gases nocivos; exercícios físico) motivam-me a utilizar este tipo de veículos.					X
Os benefícios dos VEDR para o ambiente (emissões de gases de efeito de estufa; barulho) motivam-me a utilizar este tipo de veículos.					X
Os benefícios dos VEDR para a cidade e qualidade de vida (congestionamento; qualidade espaço público) motivam-me a utilizar este tipo de veículos.				X	
Os benefícios dos VEDR para a economia (maior produtividade) motivam-me a utilizar este tipo de veículos.				X	
Os benefícios dos VEDR para a própria empresa (custos estacionamento; acessibilidade; tempo de viagem) motivam-me a utilizar este tipo de veículos.			X		

1. O qua acha que ainda está por fazer para tornar a utilização de VEDR mais atractiva?

Preços mais acessíveis e baterias com maior autonomia.

2. Em que sentido considera que a legislação actual é uma vantagem/desvantagem para a aquisição deste tipo de veículos?

Tenho pouco conhecimento da legislação

Obrigada pelo seu tempo!

INQUÉRITO AO CICLISTA/CONDUTOR

TÉCNICO LISBOA

Inquérito do ponto de vista operacional relativo ao serviço de entrega

Numa escala de 1 a 5 em que:

Serviço prestado: Moço de Recados

1- Discordo Totalmente
2- Discordo
3- Sou Indiferente/ Não sei
4- Concordo
5- Concordo Totalmente,

Como classificaria as seguintes afirmações?

	1	2	3	4	5
Foi a primeira vez que conduzi um veículo eléctrico de duas rodas (VEDR).					X
A autonomia satisfaz a necessidade.		X			
O VEDR que estou a utilizar permite substituir, neste serviço, uma carrinha a combustível fóssil.		X			
O VEDR que estou a utilizar permite substituir, neste serviço, uma scooter a combustível fóssil.			X		
A capacidade volumétrica do meu VEDR satisfaz a necessidade.			X		
Apenas carrego o veículo com a quantidade de bateria que vou precisar naquele dia.	X				
Apenas carrego o veículo quando preciso.					X
Um VEDR é mais fácil de manter que um veículo de duas rodas convencional.			X		
Um VEDR é mais fácil de conduzir que um veículo de duas rodas convencional.			X		
Um VEDR é mais seguro que um veículo de duas rodas convencional.		X			
A topografia (inclinação das ruas, curvas) tem mais impacto num VEDR que num convencional.					X
A utilização de um VEDR faz sentido no meu ambiente de trabalho/cidade.					X
Os VEDRs têm potencial para se tornarem comuns em ambiente urbano para transporte de mercadorias.			X		

1. O que gostou mais na utilização do VEDR?

NAO Sei!

2. O que gostou menos na utilização do VEDR?

A autonomia e Ruidos [illegible] [illegible] [illegible] limitados
ser silenciosa, ñ se faz notar no trânsito

Obrigada pelo seu tempo!

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