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

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Extended Abstract

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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 fuel 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 regarding 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 this technology is still not fully mature, mainly concerning the battery that constitutes a barrier to its diffusion, besides prices discouraging its purchase. In the future, a cost benefits analysis would strengthen these outcomes.

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

1 Introduction

Urban logistics permits the satisfaction of urban populations' demand but a better quality of life will only be perceived if the negative impacts of human activity are minimized. This increasing quality of life enhances city's attractiveness for both people and companies, which represents a growing need for mobility, eventually leading to higher motorization rates and, therefore, higher congestion, pollution and CO_2 emissions, if no technological changes occur. A technology capable of minimizing those impacts is the electric one, more specifically electric two-wheelers: they can access pedestrians roads and areas restricted to motorized vehicles, they are less noisy, they do not cause nor suffer from congestion because their smaller dimensions allows them to easily overcome stopped vehicles, they are easier to park because of their smaller dimensions, they do not pollute during their utilization, etc. However, specifically in what concerns with urban logistics, the study of their benefits and suitability is still scarce. No one has, until now, proved urban companies that transporting freight with electric two wheelers (eTW) is not just possible and non-pollutant but it is also easier and cheaper than with their conventional choices.

In urban logistics previous studies, methodologies involving simple descriptive statistical analysis, the development of models and before and after comparisons where operational data were analysed (distance, load capacity, speed and CO_2 emissions). In a general urban mobility perspective, methodologies such as vehicle specific power were developed in order to compare CO_2 emissions and energy consumption of different two-wheelers' technologies. However, it was still missing a study where both economic and environmental savings of this technological transfer were balanced in order to compare the conventional technology with the electric one.

Is that body of knowledge that this work aimed to fill. This work's objective was to answer the question "Do eTW represent economic and environmental benefits in urban logistics? How big are the savings?". To find the answer to this question and prove eTW adequacy to urban logistics, three Portuguese case studies using eTW were considered and the respective economic and environmental savings were computed. Surveys were then distributed in order to verify those benefits veracity on real and practical terms.

2 Methods

The search for eTWs' benefits started with an exhaustive literature review. But, in order to prove the economic and environmental benefits it was necessary to select case studies to record operational data. Three of the Portuguese pilots in the Pro-E-Bike project of the European Commission were chosen. Their context and service were then defined through their logistic profile (LP). During the trial period, each company ran the corresponding vehicle in usual conditions and recorded data (total daily distance, weight, volume, etc.) in consecutive working days in a standard sheet from that project. The benefits quantification was performed using a cost simulator developed by a Portuguese partner (Occam) in the same project. This simulator receives the inputs presented from Table 1 to Table 3.

Table 1 refers to the inputs related to the conventional fleet. Although the electric vehicles being effectively used, in the first two case studies, the conventional vehicle here assumed are not. For that matter, the 2014 best-selling commercial models of both a mini-van (Renault Kangoo Express (Moura, 2015)) and a 125cc scooter (Honda PCX 125 (ACAP, 2014; Honda, 2014)) were considered as reference. In the third case study the e-scooter has being used alongside with a conventional one and, in order to ensure a more realistic approach, data regarding that specific conventional vehicle were used in that case so the two vehicles could be compared.

Because the aim of this study is not fleet design, a single vehicle fleet was considered for the two technologies and also a purchased and not leased conventional vehicle. The conventional vehicles characteristics such as consumption and prices were collected from direct consultation with official dealers of each brand and can be consulted in Table 4. The operational data (daily distance, load and volume) resulted from the records on the Pro-E-Bike standard sheet. Direct consultations with motorcycles' and mini-vans' dealers, repair shops and insurance companies allowed to determine maintenance, insurance and taxation costs of the different vehicles and the result can be consulted in Table 4.

Regarding the lifetime costs, since the simulator proposed realistic data from reliable sources (European Commission, 2015) and easily transferable from case to case, the average of those proposed values was considered in all cases (lifetime of 225 000km and 35€/ton CO_2). 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 1 – Simulator's Inputs: Fossil fuelled fleet (Occam, 2015)

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

Average Global Costs					
Fuelled Fleet		*Reference Value*			
Acquisition [EUR]	-	10 000-25 000	Leasing [EUR/year]	0	3 000-25 000
Maintenance [EUR/year]	-	750-1 500			
Insurance [EUR/year]	-	500-1 000			
Other costs [EUR/year]	-	(e.g. taxes)			

Fossil fuelled fleet				
Operational lifetime costs			*Reference Value*	
	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	

In Table 2 are the electric fleet inputs. The simulator permits to choose the electric two-wheeler to analyse, if an e-(cargo-)bike or an e-scooter. As mentioned above, one vehicle was analysed.

In what concerns the costs of the electric vehicles, the purchase costs were provided by the pilots themselves but because the trial period only started a few months ago, the remaining costs remain unknown and, therefore, the considered values also resulted from a direct consultation with the respective and proper entities. They are presented in Table 4.

In what concerns the conversion factors (Table 3), values of the fuel-CO_2 conversion proposed by EDP - Energias de Portugal (2014) and European Clean and Energy Efficient Vehicles

Directive (2015) were considered in this work. Default amounts of pollutants in each fuel proposed by the last source were also adopted. The pollutants price was considered to be the mean between the suggested values.

Table 2 – 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:
Average Global Costs		
e-Bike/e-Cargo-bike		*Reference Value*
Acquisition [EUR]	3 737	3 500-1 500
Maintenance[EUR/year]	100	100-150
Insurance [EUR/year]	25	50-100
Other costs [EUR/year]	0	(e.g. taxes, employees, etc.)
e-Scooter		
Acquisition [EUR]	-	1 500-2 500
Maintenance[EUR/year]	-	100-150
Insurance [EUR/year]	48	80-100
Other costs [EUR/year]	0	(e.g. taxes, employees, etc.)

Table 3 – Simulator's Inputs: Conversion factors from fuels to gas (Occam, 2015)

Conversion factors				
			Reference Value	
	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	1.1000×10^{-5}	0.000011	g/km
	Gasoline	1.6800×10^{-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

Table 4 – Summary of reference values from four different vehicle technologies

	Purchase[1] [€]	**Maintenance[2] [€/yr]**	**Insurance[3] [€/yr]**	**Taxes[4] [€/yr]**
e-Cargo-Bike	3 737	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

Before going any further, it is important to highlight that the analysis here performed was based on the assumption that a conventional fleet is being substituted by an electric one and the savings here mentioned relates to that substitution.

[1] Direct consultation to official dealers of each brand (own source)
[2] Direct consultation to motorcycles' repair shops (own source)
[3] Direct consultation to Portuguese insurance companies (own source)

This simulator outputs are CO_2 emissions and savings – of fossil fuel burned and electricity generation (estimative) –, fossil fuel and operational lifetime costs of the fossil fuel technology, gases costs. Some of the outputs were not calculated to the electric technology and, therefore, additional calculations were performed. 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 (considered to be 50 000km), the carbon dioxide cost was computed by multiplying the CO_2 cost (35€/ton CO_2) with the emissions (from 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. Similarly, the "average total costs per vehicle" were also computed afterwards for the same lifetime mileage (approximately 2.5 years considering 20 000km/yr) accordingly with:

$$Average\ annual\ costs\ per\ vehicle\ \left[\frac{€}{yr}\right] \times \frac{50\ 000\ [km]}{20\ 000\ \left[{}^{km}/{}_{yr}\right]} + Purchase\ cost[€]$$

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 costs paid annually or during the year (fuel, maintenance and taxes). Only in the "average total costs per vehicle" the purchase costs were considered.

In order to ascertain electric two-wheelers adequacy to urban logistics, three surveys were distributed to the three entities directly affected by the technological change: the company owner, the driver and the clients. These surveys were distributed to the pilots, to the Pro-E-Bike partners and in social networks (Facebook and LinkedIn). The owner survey aimed to understand which benefits does that entity acknowledge and what motivates him to use the technology. The rider's 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. In what concerns with the clients survey, the aim was to find clients' perception and affinity with this technological transfer. 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).

3 Case Studies and Results

3.1 Case Study 1: Urban Delivery Company

The operation of *Camisola Amarela*'s (CA) electrically assisted cargo-bike was recorded from May to July 2015. This vehicle has a bulk capacity of 0.14m^3 and 110kg and a 250W battery. Considering the battery posterior adaptation, the total purchase cost of this vehicle was 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 and off the electric assistance without stopping the vehicle; it do not need electric power to start moving and it only assists the rider when he needs it.

Camisola Amarela mostly operates in the central business areas of Lisbon (Saldanha and Campo Pequeno) which are highly consolidated, relatively sloped and with high traffic levels. Its clients are companies and services that request express mail (documents or parcels) deliveries and that care much about their image and environmental impact. CA main routes between the major clients and CA warehouse (in the downtown of Lisbon with a height differential of 200m from the clients and 18% slopes) have bicycle parking lots and bicycle lanes in avenues with lower slopes, which obviously helps riders travelling and parking in these areas. In addition, the downtown part of the route has traffic restrictions to vehicles produced before 2000 and in this 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.

This company, because of the services performed (express deliveries) and the areas served (central business areas), can be classified as a Logistic profile type C.

Between the recorded data during the trial period it is possible to determine some simulator inputs: an average daily distance of 36.6km/day, an average total weight of 20.3kg/day, an average total volume of 0.09m^3/day and an average energy consumption of 0.0243kWh/km. An operation of 242 days per year was considered in the analysis. Because, considering a conventional vehicle, this service can be performed whether by a scooter or by a mini-van, these two hypothesis were assessed and the correspondent inputs can be consulted in Table 5. This theory was confirmed in the rider survey.

Table 5 – Simulator Inputs for the CA case study

	Purchase Cost [€]	Annual Cost [€/yr]			Consumption [kWh/km], [l/100km]
		Maintenance	Insurance	Taxes	
eTW	3 737	100	25	0	0.0243
Mini-Van	14 000	1 000	354	32	5.4
Scooter	3 050	485	145	5.49	2.0

3.2 Case Study 2: Food Delivery

The restaurant *O Marujo*, in Matosinhos (near Oporto) was been using an e-scooter for one month when the data was shared. The investment costed 6 270€ and has a bulk capacity of 200l and 110kg, a lithium battery of 3kWh with an autonomy ranging from 40 to 70km.

This restaurant is placed in a wealthy, mostly residential zone and near to a business centre. It is located in a littoral and, therefore, flat area. Because the restaurant is placed in a bustling area, a two wheeler is an advantage and because its silent characteristic is pleasant in a residential neighbourhood. Because of the service features in an area with these particular characteristics, the logistic profile of this service can be classified as type E.

The recorded on-road data allowed to determine the operational simulator inputs: an average daily distance of 6.1km/day, an average weight of 1.5kg/day, a residual volume and an average energy consumption of 0.0698kWh/km. An operation of 288 days per year was considered.

Because this service can also be performed by the two studied conventional vehicles, these two hypothesis were assessed as well and the correspondent inputs can be consulted in Table 6.

Table 6 – Simulator Inputs for the restaurant case study

	Purchase Cost [€]	Annual Cost [€/yr]			Consumption [kWh/km], [l/100km]
		Maintenance	Insurance	Taxes	
eTW	6 270	350	48	0	0.0698
Mini-Van	14 000	1 000	354	32	5.4
Scooter	3 050	485	145	5.49	2.0

3.3 Case Study 3: Errant Service

Moço de Recados (MR) perform many types of services in Lisbon (84.9km^2) and Oeiras (46km^2) (Caleia & Ramires, 2014; CM. Oeiras, 2015) (including deliveries) and due this variety no logistic profile could be defined. This company started its trial period on the Pro-E-Bike in July 28th 2015 (one month of recordings) by using an e-scooter to complement a conventional one's operation. The simulator inputs of both vehicles' are showed in Table 7. It is worth to highlight the scooter consumption: 5.0l/100km. This consumption allied with grate daily distances was told by the owner as the cause of MR greatest expense: fuel cost.

The electric model has a capacity of 105kg and 40l. The battery's electric capacity is 6kWh and an average autonomy is 100km. Because the company covers such wider areas, the messengers use both narrow, highly congested urban roads and freeways and both flat and slopped areas, however, a big part of their services are within the city of Lisbon. This constitutes an advantage for the use of an e-scooter due to the already mentioned reduced emission zones in Lisbon and due to the extensive charging points' network.

The recorded data permitted to infer the following simulator inputs: an average daily distance of 62km/day, an average weight of 1.7kg/day, a residual volume and an average energy consumption of 0.12kWh/km. This last parameter is much higher in this case than in the remaining because although the daily distance is much higher, the energy the battery provides is the double of the last case. An operation of 288 days per year was considered.

Table 7 – Simulator Inputs for the errant service case study

	Purchase Cost [€]	Annual Cost [€/yr]			Consumption [kWh/km], [l/100km]
		Maintenance	Insurance	Taxes	
e-scooter	7 000	350	48	0	0.12
Scooter	3 550	1 310	93	0	5.0

3.4 Results

The results summary of all the three case studies is presented in Table 8, where 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 8 – Savings summary from all the case studies

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

Regarding the total lifetime costs, the higher savings were found in the LP C (CA case study). A possible cause can be the differential between the purchase costs of the mini-van and the electric vehicle because this is the only cost parameter considering this investment cost and this difference is higher in this most successful case. Nevertheless, annual savings up to 92.6% were registered as well as annual CO_2 emissions savings of 97.8%.

Altogether, considerable savings (above 40% and up to 99%) were found. The highest savings concerning the vehicle utilization (annual, operational, emissions and energy consumption) correspond to the errant service. The reduced difference between the economic costs (annual and total) relates to the conclusion that the purchase cost (only parameter differing from each cost component) do not have a relevant effect on savings. On the other side, the case studies where the registered distance was higher achieved higher savings, so the savings depend more of the vehicle usage than the purchase cost itself.

Regarding the surveys, 5 owners (3 from the pilot's and 2 external), 5 riders (3 from the pilot's and 2 external) and 13 clients (12 from the pilots – 10 from the *Moço de Recados* and 2 from the restaurant – and 1 external) shared their experiences.

In what concerns the owners' perspective, 80% believes that using this technology has been working as an incentive for clients to request the service but 40% (MR's and restaurant's) seemed to be hesitant in purchasing more of these vehicles. This shows some lack of awareness regarding the

[4] Not necessarily true.

economic benefits of these vehicles, however none of them doubt about the adequacy of this technology in urban environment, which means that they acknowledge other type of benefits (congestion, parking, noise, and 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. Regarding what could be changed in order to become these vehicles more attractive, the sample was divided between lower purchase costs and higher autonomies. Also about the battery, the majority of the riders claimed that they usually charge it whenever they have the change to so they can be more sure that the battery will not die during the service (60% felt the topography impact on the autonomy). Besides these acknowledged limitations, 75% believes in eTW potential to be widely used in urban freight transport. The reported favourite aspects of this technology was the easiness to use, easy to overcome congestion, environmental footprint and in both the companies using an e-cargo bike (two cases), 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, whereas in Matosinhos clients worry the most about the novelty, in Lisbon people worry the most about their environmental footprint.

4 Conclusions

Altogether, this study allowed to find significant savings (up to 2 171€/yr and 92.6% as well as 2 092 kg CO_2/yr and 97.8%) regarding the substitution of a conventional vehicle by an electric two-wheeler and prove its practicality. These economic and environmental benefits allied with the remaining advantages (small, quiet, etc) permits to respond in a positive way to this works' purpose: electric two-wheelers do represent a benefit to companies performing urban deliveries and services. In addition, this work showed that not only these benefits are real and considerable but eTW also has the potentiality to be widely used in urban logistics.

However, besides these positive results, it is important not to forget that this technology is still not mature and many developments are still to come. This developments, mostly the ones related with the battery have the potential to maximize those benefits. In addition, it is expected that the purchase cost will decrease as these developments will occur in order to attract more users. In addition, the results showed that the savings one can get by simply change a motorized vehicle for an eTW depend more of the usage – the travelled distance in particular – than of the purchase costs, factor that most of the times is responsible for people not to invest in this technology. Simultaneously, a wider awareness of these vehicles adequacy and advantages is crucial.

As a future developments of this work, the remaining logistic profiles can be tested to achieve a higher benefits transferability and a higher amount of benefits can also be taken into consideration (noise, time cost, etc). Also, based on this simulator limitations (reduced number and specificity of inputs and incomplete outputs, no consideration of variable monetary terms, etc), an improved version and new methodologies would also be interesting. Another lack in knowledge that is important to solve is the pollutants quantification in electricity production for different countries.

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