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ECONOMIC AND RISK FACTORS OF A TRANSHIPMENT SYSTEM USING ELECTRIC CARGO BIKES FOR URBAN COURIER SERVICES

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ABSTRACT

The distribution of goods in urban areas is a major challenge for managers in the public and private sectors, due to population growth, high density in large urban centers and, in many cases, lack of planning in urban cargo transport systems. In this context, the objective of this paper is to propose a novel collaborative urban cargo distribution system for logistics service providers, based on a transshipment terminal and usage of electric cargo bikes, highlighting the main aspects to consider on estimating its beneficial economic and environmental impacts in terms of emissions and the risk factors of the investment. The evaluation of this solution may be based on applying simple vehicle routing heuristics for assessing the distance travelled, costs and emissions. Also, a more sophisticated cost model is proposed to estimate the economic viability and risks associated to the use of electric cargo bikes. Finally, risk aspects can be evaluated through a structured methodology including both qualitative and quantitative approaches.

INTRODUCTION

According to the United Nations, it is estimated that by 2050 more than 66% of the world population will be living in urban centers (E.Commission, 2015). At present, the world population living in cities is about 55% of the total population of the planet (against 30% in 1950). In Europe, this proportion is approximately 74% and is expected to increase to 82% by 2050 (E.Commission, 2015). This expansion will occur mainly in developing countries, which lack the necessary infrastructure to support this growth without major social and environmental impacts. In Brazil, for example, 85.7% of the population is already living in urban areas, expecting reaching 91% in 2050 (ONU, 2014). The distribution of goods in urban areas accounts for 1/4 of the total local traffic of a city (Dablanc, 2007) as a function of the economic needs of the cities. It is a key activity in the development of the cities, with significant importance in sustaining the lifestyle of the citizens and maintaining the competitiveness of industrial and commercial activities (Dablanc, 2007).
The freight transport plays a key role, with the road transport representing around 98% of this service and accounting for about 40% of all CO2 emissions of road transport and up to 70% of other pollutants generated by transports (E. Commission, 2015). In order to mitigate these problems in urban areas, the concept of city logistics was introduced by Taniguchi et al. (2001), who defined this concept as a set of strategies to improve the efficiency of cargo distribution in urban areas, considering new and smart technologies not only to tackle environmental challenges but also to deal with congestion, noise, accidents and reduced accessibility due to obsolete infrastructure or environmental and traffic restrictions. One of the recent urban logistics initiatives most frequently implemented and analyzed is the Transhipment Terminal. The transhipment performs an important strategic role in reducing the challenges of urban logistics, in terms of environmental, economic and social aspects as well as potentially improvement of the efficiency of freight distribution and enabling a change to more environmentally friendly vehicles (Alen *et al.*, 2012). The transhipment includes both a logistics facility for consolidation located in a city area, where different logistics service providers (LSPs) leave their products, and the outbound transportation system that performs the deliveries to receivers in the urban area. Urban transhipment terminals can also perform activities such as storage and pre-retail activities.
Some studies have addressed already the distribution of goods from the transhipment and their environmental impacts (Oliveria *et al.*,2014). The economic and cost evaluation of urban transhipment systems in different countries is presented in the literature (Morana *et al.*, 2014). Solutions based on the delivery of goods through clean, ecological and clean transport modes (i.e., small electric vehicles, bicycles, and tricycles for last mile delivery) are already a reality in many European countries such as France, Spain, Italy, United Kingdom, Germany, Netherlands and USA. This study addresses the case of a transhipment systems combined with cargo-bikes and evaluates the possibility of replacing conventional diesel fleets by electric cargo bikes (e-CBs). A review on the topic is presented, addressing the economic, environmental impacts and related risk factors. The results of the study pointed out that this electric alternative is economically viable and better than the diesel fleet, as well as it reduces the environmental impact of logistic operations in the city centre.

URBAN TRANSHIPMENT TERMINALS AND ELECTRIC CYCLE LOGISTICS

Overview

With the global look focused on the environmental aspect, urban freight transport companies have been innovating in the search of alternative technologies in the fight against the emission of greenhouse gases and atmospheric pollutants. In this sense, cycle logistics have the ability to contribute to a cleaner and smoother environment and can overcome many of the negative aspects to the last part of the delivery, the so-called last mile: smaller vehicles do not need parcels to reach a higher load factor, they do not take up much space when they park, do not pay to park and even to use the street itself, helping to lessen the congestion. Thus, a solution that addresses some important concerns in the transportation of goods in urban areas is cargo cycles, such as bicycles, cargo bikes and cargo tricycles, that can be electric powered or not. Cycle logistics has emerged as an attractive concept for areas with high potential of reducing energy and environmental impacts (Ortúzar, 2015). Cycle logistics means the delivery or collection of products for small businesses using bicycles (2, 3, or 4 wheels, human-powered or electrically assisted) and load tricycles. The specific use of electric bicycles has the advantage within the logistics operation, such as reduction of driver fatigue and a greater payload due to the ease of energy to move the vehicle. They are soft modes of transport, non-pollutants and do not make noise. All these advantages are common to traditional modes (non-motorized vehicles such as bicycles). What electrical energy has in favour is the possibility of helping delivery companies carrying heavier loads and mounting inclined areas. For example, Lenz and Rhiele (2013) suggest that cycle freight can represent around 25% of commercial traffic in city centre in medium term that a potential market does exist. The recent outcome of the European Project "*Cyclelogistics"* indicates an even higher potential, stating that, in average, 51% of all motorised trips in European cities that involve transport of goods could be shifted to bikes or cargo bikes. According to Decker (2012), cycle logistics can bring important economic advantages to retailers, wholesalers and service providers logistics. Ormond Junior (2017) analysed the case study of a Courier, Express and Parcels (CEP) company in the city of São Paulo (Brazil) and concluded that replacing diesel trucks with electric bicycles or cargo tricycles for this company can save up to 31% on operating costs and approximately 20 tonnes of CO2eq per year, reducing by at least 97% the CO2 emissions of the company. Gruber et al. (2014), in a study conducted in Germany, showed that between 19% and 48% of the mileage of messenger logistics services currently made by vehicles with combustion engines could be replaced by electric bicycles. Nevertheless, more studies are needed to restrict and describe the target group of potential users of electric cargo bikes.

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

To mitigate these effects, new trends in the retail and commerce organization, such as technological innovation in the supply chain and distribution planning, have led decision makers to consider collaborative strategies to reduce the overall cost and environmental hazards related to last mile distribution in dense urban zones (Gonzalez-Feliu & Salanova, 2012). The alternative distribution system uses a combination of electric cargo bikes (e-CBs) with the installation of a transhipment terminals. E-CB's do not have limitations to access the restricted area because they are a different vehicle class. In addition, they are agile and do not pollute the air. On other hand, transhipment terminals are facilities that can increase the participation of more transport operators. A transhipment terminal offers shelter and security for the transhipment, which also facilitates the work of the company that manages the last mile delivery of the terminal. The new urban logistic concept consists on the use of a support terminal that can accommodate more transport operators in the initiative ant promote the use of this alternative in the area. One of the main differences with previous approaches is that the different transport operators who transfer their products in the terminal could share the same vehicle in the delivery of the last mile. Another major difference is that transfers always occurs in the terminal, providing advantages for the transport operator and terminal (Navarro et al., 2016). This can lead to an effective and highly efficient horizontal collaborative logistic system for services such as urban courier services. The main objective of transhipment is to reduce the amount of freight transportation flow and related negative externalities in the city center while maintaining the same level of service of deliveries and pick-ups. However, the applicability and success of alternative distribution set-ups largely depends on the local context (e.g., restrictions, density, congestion level) and transferability of set-ups is complicated (Timms, 2014). Differences between cargo tricycles and diesel vans can be identified in Table 1, where vehicles specifications of a typical cargo tricycles and van are shown (see Ormond Junior, 2017; Conway et al., 2011; Esteruelas, 2016). Cargo tricycles have many advantages. Because of their small size, tricycles require minimal parking space and can be parked legally on and off the street, on the sidewalks or inside the customer's own (Tipagornwong *et al.*, 2014). A diesel van would need to park on the street, increasing the walking time and distance to make a delivery, and generally requiring the vehicle to be idle while waiting for a parking space. The driver of a delivery van has to cross a long route to get a suitable place to unload, and this can sometimes take 15 to 45 minutes, which increases the cost, emissions and traffic congestion. Using tricycles, customer service times can be reduced.

Table 1 – Specifications of typical Vehicles

Specification	**e-Cargo Tricycles**	**Diesel Van**
Make	Cycles Maximus	Sprinter Md311
Price {€}	5100[a]	25000[b]
Battery size or tank size	864 watt-hours [a]	80ltrs[b]
Payload (volume)	500-1500 ltrs[a]	6500- 17000 ltrs[b]
Maxpayload (weight*)	170 -300 kg[a]	5000kg[b]
Curb weight	227kg[d]	2100Kg[b]
Battery Weight	35kg[c]	-
Recharge time (full)	4-8h	-
Cargo volume	1,5m^3	17m^3
Maximum range(battery autonomy)	50 - 90km[a]	700km[e]
Max Speed in urban traffic	15km/h[f]	14,5km/h[h]
Driving	Easy	Easy
Guide in adverse conditions	Easy	Easy
Emmisions	Low	High
Costs	High	Very high

*not included the rider weight[1]

Logistics cost models

A company's overall profitability depends not only on sales prices being able to recover product costs, but also whether that gross margin is sufficient to cover the cost of serving the customer (Shapiro *et al.*, 1987). Cost of serving the customer includes the complexity of the cost of the logistics process (ordering costs, transportation costs, storage and handling, inventory costs), customer attributes and characteristics of the city. Nevertheless, the measurement and allocation of logistics costs is complex. This is due to the lack of information on the indirect costs, the high complexity of logistics activity and the fact that most companies consider logistics costs as merely indirect and period costs (Goldsby & Closs, 2000). By knowing these costs, companies can protect profitability, even in a very competitive environment. However, this requires that the cost model used be accurate and detailed enough to capture the many factors that influence the cost of serving the customer. Thus, freight carriers need accurate cost information. In the triad relationship between suppliers, logistics service provider and customers, knowledge of costs is essential.

Different logistic cost models have been developed for freight transport in urban areas. Gevaers (2013) has designed a formula in which the last mile cost per unit shipped is calculated. It starts with a time and distance cost function, where the costs of pre-run distance, time costs during operation and overhead costs are included. The total transport time is multiplied by a certain coefficient of time, while the total distance travelled is multiplied by a distance coefficient. Daganzo (1984) developed a simple empirical formula to estimate the length of the routings. A more elaborate function was suggested by Gevaers (2013) by adding a stopping coefficient and unit coefficient. The focus of this model is on selling businesses to customers (B2C). To compare the competition between vans and tricycles, Tipagornwong and Figliozzi (2014) developed a cost model that incorporated models of ownership and operation, as well as logistical constraints, such as time windows, cargo capacity, fuel consumption and energy use. They adapted the model proposed by Daganzo (1984) of continuous approximation. To incorporate constraints and routing costs, continuous approach models were used by Davis and Figliozzi (2013) and Tozzi *et al.* (2013). Continuous approximation models are based on the originally proposed by Daganzo for a capacited vehicle routing problem (CVRP) (Daganzo, 1984). Other model is also able to solve this problem by modelling alternative distribution set-ups, which contains mathematical Kin *et al.* (2018). These authors developed a mathematical model to calculate the costs of alternative distribution configurations for the last mile supply chain with small, fragmented volumes. Travel distances and the inefficient movement can be reduced by applying optimization.

CRVP = $2\bar{r}m + 0.57\sqrt{nA}$

where:
CVRP = average distance travelled (km);
$\bar{r}$ = average distance between customers and depot (km);
n = number of customers;

[1] [a] Cycles Maximus;[b] Mercedez Benz;[c] Odyssey Batteries;[d] Provided by B_Line;[e] Based on the fuel economy;[f] Conway et al. (2011);[h] experience the author

C = capacity of a vehicle, that is, number of customers visits per vehicle;
m = number of vehicles, that is, ratio of C or $m=n/C$; and
A = size of service area(km^2).

Vehicle capacity is assumed to be equal to the demand of at least six customers ($C \geq 6$). The number of customers is assumed to be at least 24 ($n \geq 24$). Daganzo's approximation works better in elongated areas as the routes were formed following the strip strategy (Daganzo, 1984). Figliozzi (2008) proposes a modification of the approximation model to deal with fewer customers per route, the vehicle routing problem (VRP).

$$\text{VRP (V)} = k_l \frac{n-m}{n} \sqrt{nA} + 2\bar{r}m$$

where VRP(V) is the average distance traveled for a fleet of V vehicles (km) and kl is the local service area coefficients. The equation above can be used for distribution areas with random (R), clustered (C), and mixed random and clustered (RC) customers and time windows. Values of the kl coefficients can be calibrated empirically by using regression analysis (Figliozzi, 2008). Davis and Figliozzi (2013) propose a cost minimization model to compare electric and diesel trucks. Feng and Figliozzi (2013) examine the economic and technological factors affecting the cost competitiveness of electric commercial vehicles. They analyze emissions costs assuming a carbon dioxide (CO_2) cost of $18/ton and find that CO_2 emissions costs represent a small percentage of delivery costs.

Assessment and Management of Risk

The term "risk" comes from the Italian word, "risico or rischio", which in turn derives from the classical arabic rizq ("what comes to providence"). The term refers to the proximity or contingency of a possible damage. for many years, the term risk was associated with gambling. In the nineteenth century, the term was adopted in the insurance industries in England and from the 1950s and 1960s the auto industries became interested in the concept of risk. This path arose due to the sector's competitiveness and the need to account for possible occurrences of various types in the decision-making process. Traditionally, risk is considered the risk has been considered from the financial and insurance point of view. Currently, the term risk is seen in a holistic way as an integral part of business strategy. In the literature many definitions of risk can be found [Kin *et al.*, (2018); Figliozzi *et al.* (2008)].

According to Kin *et al.* (2018), the risk can be described as "a measure of the occurrence of future events when the probability is measurable". According to this same author, uncertainty about the project's return determines the risk of investment in relevant projects that must be addressed in the decision-making process on an investment. For Feng and Figliozzi (2013), the risk is the probability of occurring or not a financial loss in the future in a different amount than expected. The risk involved not only differs substantially from project to project, but the higher the risk, the higher the expectation of high returns, because investors are compensated for the additional risk they assume in their investments Vukoviciv *et al.* (2011). The risk definition proposed by the Project Management Institute in the PMBOK Guide was the risk was defined as an uncertain event or condition that, if it occurs, has a positive or negative effect on the project objective. In all these definitions of risk, we can see that they have two dimensions: uncertainty and impact on objectives. Therefore, risk management includes developing guidelines to determine the significance of risk based on probability occurrence and impact on project implementation.

Risk management in the Urban Freight Transport (UFT) area is difficult and complex and requires the efficient management of processes throughout the lifecycle of UFT measures, in close collaboration with all stakeholders involved. Several studies have developed standards and guidelines for risk management (Ferma, 2002) (E.Commission., 1999). However, in the case of the UFT, there are no guidelines and standards that allow stakeholders to perform effective risk management. This study proposes the classification of the sources of risk adapted to the UFT measures that considers the risks in the implementation of urban transport measures and addresses the threats that impede their realization.

Also, the sources of risk are divided into external and internal risks. The sources of external risks are socio-political, economic, availability of infrastructure, technological innovations, natural disasters and civil unrest. Internal sources of risk include management, human resources, marketing, information technology and financial (see Kiba-Janiak, 2016). The identification of risk indicators is indicated in relation to separately selected measures and takes into account their entire life cycle (creation-construction, operation, maintenance and disposal).

The tool for risk factor identification for UFT measures

In the literature, several different classifications of UFT measures can be found (Taniguchi, 2014;Kiba-Janiak and Cheba, 2014;; C-liege, 2012). In this work, the classification of UFT measures developed in the C-liege (2012) research project was applied. These are associated with a set of impact areas, criteria and indicators to quantify their impacts. All these categories are defined in Table2.

Table 2: Selected impact areas

Impact areas	Description
Economy and Energy	Energy is a major field that is directly connected with economy in modern communities. Energy availability, demand, price and actual consumption have short term and long term impacts on lifestyles. The creation of a sustainable economy requires partial utilization of energy and development within environmental limits. Continuous utilization of nonrenewable energy sources results in depleted energy sources and increased energy pricing, therefore unsustainable communities.
Transportation and Mobility	Transportation and mobility are two concepts that are becoming more and more popular at local, national and European level. The continuous pursuit of improving transportation of goods and mobility of people is usually translated into terms of attractiveness, accessibility, level of service, safety as well as availability of infrastructure
Society	Ultimate aim of the implementation of UFT measures is the positive impact of them to the society. Society is defined as different groups of people that interact with other people in a community. Societal impacts of logistics can be described adequately with respect to sustainability, convenience and living standards of the community
Policy and Measure Maturity	The policy and measure maturity impact area express mainly the involvement of stakeholders into the implementation of a proposed UFT measure. More specifically, it is related with the awareness of stakeholders towards the measure, their managerial skills as well as their related knowledge, experience and willingness to adopt
Social Acceptance	The social acceptance impact area can be discerned into two levels; the social approval level, i.e. the extend that a measure is welcomed and respected by the society, regulations' compliance and measure enforcement.

For each of these categories, risk factors were then assigned on the basis of the practices described in the above-mentioned EU projects as well as experience and knowledge. According to Nathanail et al.(2018), the risk analysis includes 64 indicators, which are associated with "Economic-Financial Risks", "Security and Protection", "IT, Infrastructure and Technology", "Life Standards", "Management Risks" and "Social Approvals".
There is a need to understand if a new technological, more environmentally friendly alternative has the potential of benefiting companies that deliver goods and services in an urban environment. The replacement of the fleet of diesel vans by cargo bikes or electric cargo bikes comes from the reality of a better future.

CONCLUSIONS AND FURTHER RESEARCH

Combining the use of e-CB's with the installation of a transhipment terminals may be a viable solution for many cases, particularly in large cities. An adequate implementation of a transhipment terminal can increase the participation of more transport operators. The transhipment terminal offers shelter and security for the transhipment, which also facilitates the work for the company that manages the delivery of the last mile of the terminal. The use of a support terminal might accommodate more transport operators in the initiative and promote the use of this alternative in the area. One of the main differences with previous approaches is that different transport operators who transfer their products in the terminal could share the same vehicle in the last mile delivery. Another major difference is that the transfer always occurs in the terminal, providing advantages for the transport and terminal operator. Moreover, the use of the e-CBs will allow to reduce emissions and will provide flexibility to the transportation in city centres.
Further work may be developed to validate this solution. For example, the evaluation of this novel logistics solution may be done using simple vehicle routing heuristics for assessing the distance travelled, costs and emissions. From this initial assessment, we will develop a more sophisticated cost model based on activity-based costing (ABC), to evaluate the sustainability of the project, to estimate the economic viability and risks associated to the new e-CBT concept. Finally, risk aspects can be evaluated through a structured methodology, including both qualitative and quantitative approaches, as well as the identification of risk factors and mitigation measures, on one hand, and sensitive and probabilistic analysis, on the other hand. The main costs items are purchasing costs, operating costs, maintenance costs and other costs related to equipment rental.

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