School of Industrial and Information Engineering

Master of Science in Management Engineering

Green Logistics in Last Mile Delivery (B2C E-Commerce)

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Master Graduation Thesis

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2016/2017 Academic Year

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Abstract

Many actions have been recently carried out within European cities with the aim of reducing the negative impacts on traffic and environment caused by home delivery such as: traffic congestion, reduction in road capacity and pollutant emissions. Beside the negative externalities, Last mile delivery is one of the most expensive and inefficient activities within the overall delivery process. Furthermore, due mainly to tough competition in E-commerce business, it has been offered highly customized delivery service which in return produces complex routes, and inefficient delivery process. Therefore, the introduction of alternative solutions to overcome all these issues is crucial importance. Thereby, BEV is one of the promising solutions which is able to defeat most of these obstacles in sustainable way.

Consequently, the aim of this work to check up the whole situation around last mile delivery in order to make an attempt to participate in future solutions by creating innovative ideas in general. and particularly, to assess the original situation in which we could operate by BEV, in last mile delivery service for B2C E-commerce, without any kind of intervention such as: governmental (i.e. incentives for BEV or more tax on conventional vehicles), moreover using average prices for all variables affecting the competition between BEV and conventional vehicle (presented by diesel-powered vehicle) to not make superior situation for one of them and make our model as general as possible to be applied wherever in Europe. Furthermore, we have checked how the shape of the competition will change by using supercharge stations which is able to charge 80% of the battery in 30mins. For this purpose, we carried out our assessment by developing Total Cost of Ownership model (TCO) to achieve ultimate accuracy and build up a comprehensive overview. However, our sensitivity analysis shows that TCO is subject to the development of vehicle and operating costs and thus uncertain. Furthermore, sensitivity analysis shows that total cost of ownership of BEVs can become equal or even lower than diesel vehicles depending on their utilization, future market conditions or government support.

Executive Summary

Introduction

Increasing the concern about the environmental issues caused by transportation in general and particularly home delivery logistics. Thereby, communities have started to carry out bunch of attempts to mitigate these damages. However, there is undeniable fact that last mile delivery has a significant role cannot be ignored in the economy of the community. Therefore, this situation emerges a considerable tradeoff between to achieve greener environment vs. to gain efficient logistics. Hence, putting logistics companies under pressure of more legislations and liabilities could have side effects on the economy in general. Based on this situation, companies try to acquire a solution which will be able to overcome this tradeoff which could be a promising competitive advantage to dominate the whole market by avoiding any future liabilities.

Purpose of the study

Due mainly to this tradeoff, it was necessary to carry out an attempt to understand the situation and figure out the obstacles to defeat this tradeoff. Therefore, the aim of this work to create promising solutions which could help to have greener environment and simultaneously, could bring an economic advantage. Furthermore, we deeply analyzed the economic feasibility of the integration between using BEV beside supercharge stations.

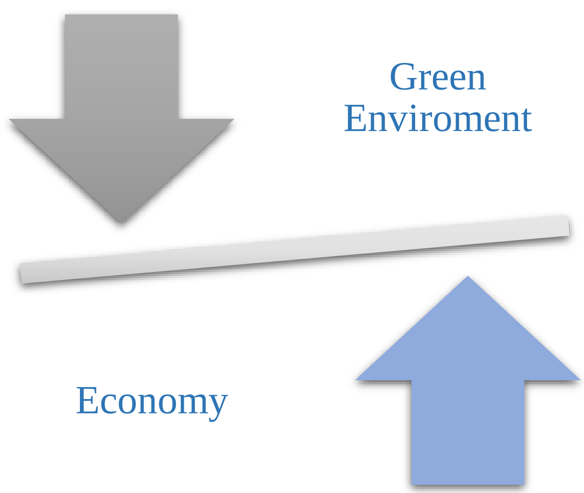


Figure 1: trade/off between green environment and economy

Brief notes on the extant knowledge

From the literature review, we observed that yet there is no research have been carried out for the combination between BEV and supercharge stations in last mile delivery. Mainly because supercharger stations are still at the early stage of diffusion. However, there are many scientific papers have taken into consideration the comparison between BEV and conventional vehicles in last mile delivery by applying the Total cost of ownership model and checked sensitivity analysis to understand how the situation and the competition of BEV could change in the future with higher performance of BEV's technologies such as: batteries.

Moreover, we have found that there are many interesting solutions could domain the last mile delivery market in the future. First solution, using drones for home delivery however, this solution just needs more time to be adopted mainly because there is a need for legislation to control and manage the flow of drones in the future and protect privacy of people as well. Another solution, could help to achieve green environment, is to use public transportation which are powered by electricity such as: subway. On the other hand, it could be possible to use hydrogen vehicle in home delivery service, however this could take longer time to be available in the market due to vehicle's complexity.

Methodology

The first step of the work is the literature analysis, in order to gain overview of the current situation related to the last mile delivery for B2C E-commerce and mainly to understand which are the most relevant variables and how they could influence the situation and change characteristics of the logistics market. Moreover, we have carried out deep analysis in order to define the most important challenges are facing last mile delivery. Simultaneously, we attempted to recognize expectations for last mile delivery and how the service will be in the future in order to satisfy consumers' need without destroy the environment. Based on challenges and future expectations in last mile delivery market, we have summed up the most innovative existing ideas which have been operated by logistics companies currently. In addition, we have created other two promising ideas which we believe that they will be able to participate in the future of last mile delivery.

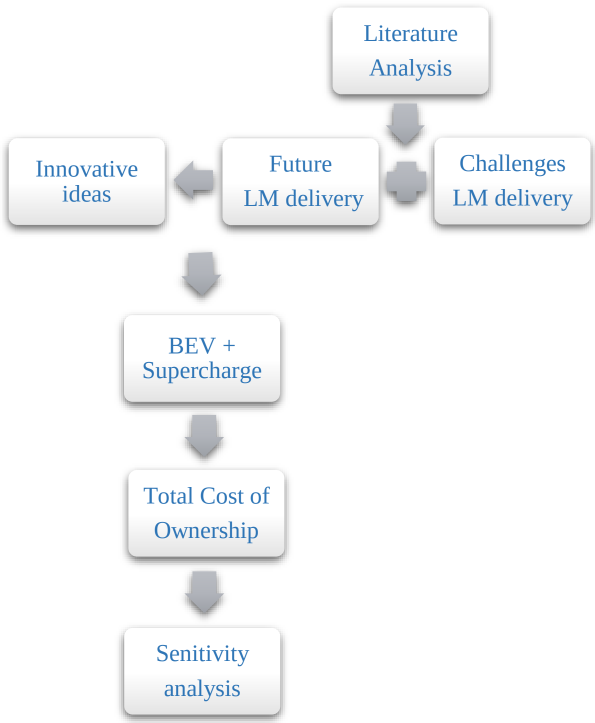


Figure 2: methodology

Based on these ideas and potential improvement of them in the future, we have picked up the integration between using BEV and supercharge stations which is the most applicable one and could be used in the near future due mainly to the existence of technologies in the market. Furthermore, we carried out deep analysis to understand the situation for using this integration, for this reason we applied Total Cost of Ownership model and check the sensitivity analysis for each parameter.

Main findings

Based on Total Cost of Ownership model, even though supercharger technology enables us to recharge the battery in short time (i.e. 80% of the battery in 30mins) which we could exploit this time for loading/unloading processes hence, we gain the same time utilization for both BEV and diesel vehicles, beside the low operating costs of the electric vehicles in terms of low energy cost and maintenance costs, we figured out the integration BEV with supercharge stations cannot enable BEV to compete against diesel vehicles in last mile delivery without any shape of government intervention. Which we found that TCO of the diesel equals to 0.14018 € / km less than TCO of BEV which is equal to 0.1687 € / km as shown in Figure 3, with the highest portion in BEV's costs is the battery cost with %38.

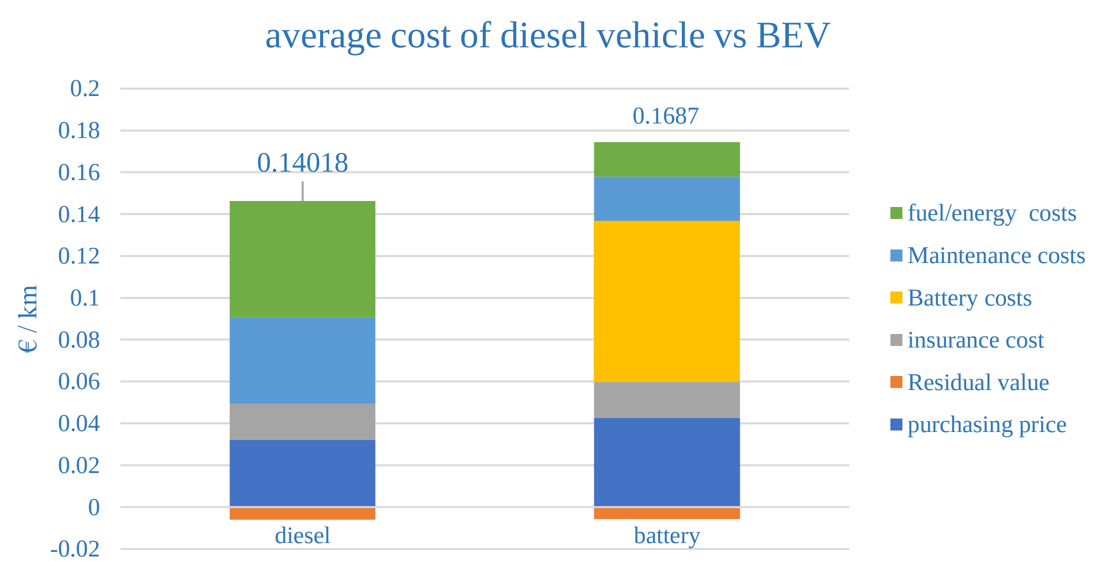


Figure 3: Basic Scenario (average cost of diesel vehicle vs BEV)

Due mainly to high initial investment of BEV and low performance of the electric battery in terms of low number of cycles (battery life time) and energy density. However, by using lithium-ion battery which not reach its maturity yet, we could expect that BEV will reach high performance and compete diesel vehicle in the near future because of the high concentration of investors and researchers in the lithium-ion battery field. Therefore, we can expect the main improvement in the performance of the battery will be specially in both price and lifetime of the battery to reach the breakeven between total cost of ownership of BEV and diesel vehicles which could happen when price of the battery decreases by 27% and at the same time, lifetime of the battery increases 27%.

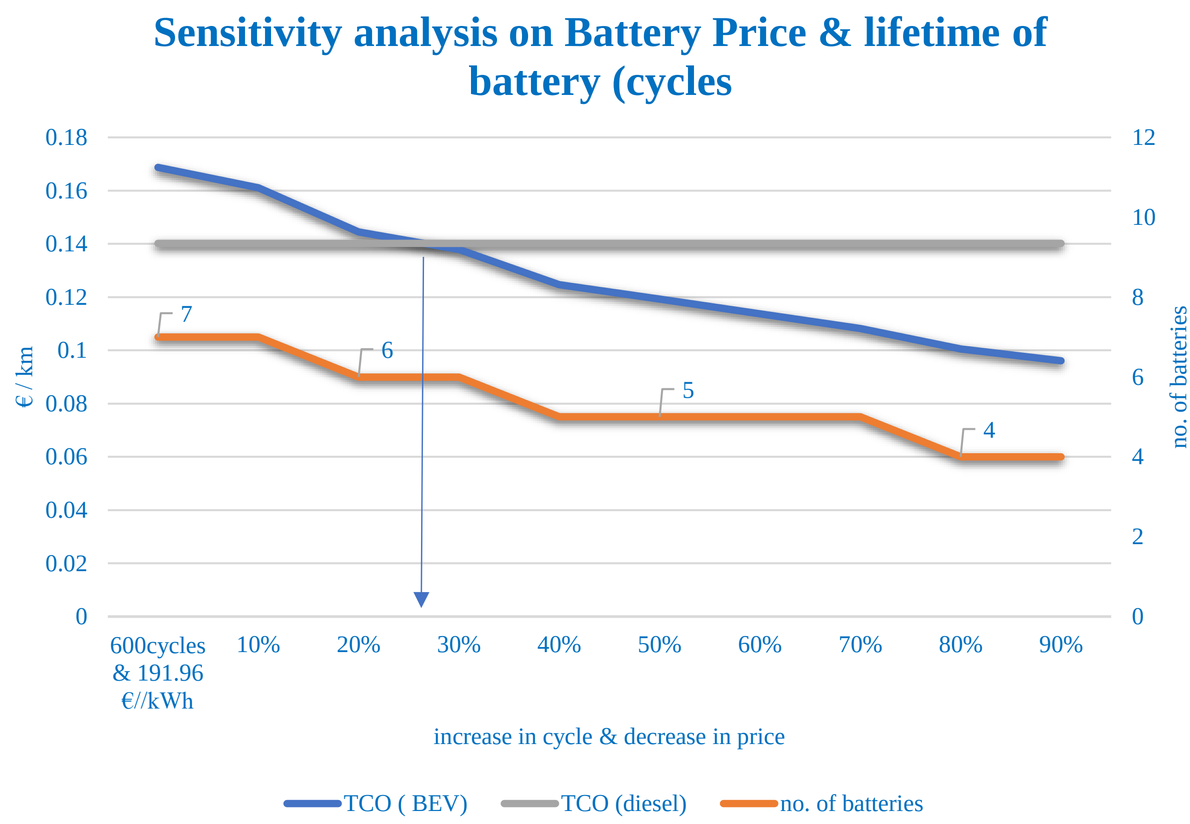


Figure 4: Sensitivity analysis on Battery Price & lifetime of battery (cycles)

as we see in Figure 4, we will save one battery during the lifetime of the vehicle comparing with basic scenario therefore, we will need to replace 6 batteries in the whole lifetime of the vehicle instead of 7 batteries with the current price and performance of the battery. Plus in this case, each battery will cost 140.13 €//kWh instead of 191.96 €//kWh of the basic scenario.

Limitations and future developments

There are still several steps to be completed and a lot of aspects to be studied in detail, especially considering that the potential of these schemes is strongly affected by the economic and financial context. More in detail, we have taken into account that the maintenance cost for both BEV and Diesel vehicles are fixed which is not so accurate. In order to better analyze the competition between BEV and Diesel, the age of the vehicle should be taken in the consideration. One of the most important limitations and there is a need to develop the analysis in the future is that we have not considered the cost of the infrastructure of the supercharging stations for BEV.

Introduction

Home delivery is increasing significantly since growing E-sales worldwide which expected to reach $2.356 trillion in 2018 (emarketer, 2013) and the market share of internet shopping grows and substitutes traditional shopping. Therefore, competition between retailers operating in B2C market increases. Consequently, they try to attract more customers with higher service level especially express /just-in-time delivery to homes (Johan Visser and Toshinori Nemotob, 2014) which opens new market areas such as; food market thereby, on-time delivery increases reliability of the company and decrease percentages of return delivery. However, increasing service level means increase in the number of fleet of vehicles of last mile delivery service which means higher cost and more pollution. Due to increased environmental concerns, European commission pushes in the direction to have an almost CO2-free urban distribution by 2030 (Johan Visser and Toshinori Nemotob, 2014).

E-commerce firms have a higher likelihood of creating a sustainable competitive advantage and improving performance if they have strong logistics capability (Jay Joong-Kun Cho, 2008). Many factors (such as; availability of the product, delivery, and returns policy) are obviously based on efficient logistic performance of the company (Ramanathan, 2010). Fast delivery such as same-day delivery becomes one of the main objectives of all E-retailers who try to achieve it as soon as possible. Currently subject to significant disruption, last-mile delivery, especially of small parcels, is getting a great deal of attention in the media, researchers and from investors as well (Martin, 2016). E-commerce firms consider express delivery as an opportunity to enter new markets, after a careful start, e-commerce is finally taking off in the food and beverage industry. Meanwhile, customers are demanding faster and faster delivery across the entire e-commerce sector (Sana Commerce, 2016).

Regulations will be changed significantly (e.g. liability for damages caused by conventional vehicles (Martin, 2016)), delivery and shipping vehicles use existing lanes and parking zones at their convenience. this creates traffic congestion in the city center when these vehicles double-park on narrow roads or park in designated public transportation (columbia university, 2016). A large concentration of logistic activities in populated areas causes a great deal of air pollution as well as noise (Pamucˇar, 2014). 2017 target: the law requires that new vans registered in the EU do not emit more than an average of 175 grams of CO2 per kilometer by 2017. This is 3% less than the 2012 average of 180.2 g CO2/km, 2020 target: the target is 147 grams of CO2 per kilometer – 19% less than the 2012 average (European Commission, 2017). So that it is important that logistics companies have to align with the new legislations, especially in Europe in which the policies are going to be more restrict with issues related to environment. Consequently, e-retailers must start new plan to reach certain level of being a green firm gradually, otherwise it could be a real threat to be sustainable in the future.

With the growth of the concern of customer for green purchasing during shopping, "green supply" or "green purchasing" can be confirmed as an effective way to improve industry's sustainability (Ken Green, 1996).

Having green logistic is able to create competitive advantage by decreasing cost and increasing revenues. Decreasing cost which E-firms can achieve by use Electric vehicle/light delivery vehicle which enable companies to lower fuel consumption cost and avoid future legislations and liabilities. On the other hand, increase revenue by enhancing the image of the company specially with increasing customer's awareness about environmental issues and increase the sustainable development. Moreover, enable companies enter markets which have already high concern about environmental issue such as western counties.

Mainly, using Electric vehicles in last mile delivery still faces some barriers which delays the progress of applying green logistics in wide range. The main barrier concerns cost competitiveness. Multiple efforts to (re)introduce electric vehicles have failed. Mainly, due to their high purchasing cost, technological immaturity and/or low functionality characteristics (Seraphim Kapros, 2014). Another barrier has a strong impact is that BEV needs long time for recharging the batteries which decrease the efficiency of EV versus the conventional one specially with limited time window of consumer and concerning about one-time delivery. Moreover, with short drive range, which forces EV to hit more than onetime recharging stations and lose more time in recharging or reduce the route of the delivery which will reduce the efficiency of EV.

Beside the barriers, there are many advantages for using BEV, apart from the green aspect of EV, also better fuel economy, less expensive to run (Ona & Long, 2012). Battery electric vehicles have become one of the major research areas in the automotive sector and increasingly BEVs are developed (Michael Schneider, 2012), with concentration of R&D in improvement of batteries functions makes EV in the future more reliable and efficient than conventional vehicles. By now some ideas come up to reduce drawbacks of BEV such as using automated station to exchange batteries in very short time “fast battery swap” (tesla, 2013) or using hybrid vehicles which gives more flexibility in fuel choice. Another way to reduce recharging time introduced by Tesla is supercharger which enable significant reduction in recharging time (Tesla , 2017).

1 Literature Review

1.1 Introduction

The literature review has a general objective to carry out the research and the analysis of scientific papers regarding green logistics and its application in the last mile delivery for B2C E-commerce. In order to carry out the search of the references for building the literature review, the following keywords and key phrases were chosen to perform it:

- Green last-mile delivery
- Green logistics
- Innovation in B2C e-commerce
- Innovation in last-mile delivery
- Urban/city logistics
- Total cost of ownership of BEV
- last mile delivery costs

1.2 Scope of analysis

The literature review was carried out with the aim of understanding the main variables affecting logistics under last mile delivery service for B2C E-commerce and, to understand how to measure the impact of each variables on the logistics costs. Moreover, to identify which stage has been reached and which technologies could be observed by the previous scientific papers (such as: using supercharging stations). In order to characterize the actual situation and the possible gaps and predict which could be the future research direction in this subject. Moreover, it was important to find out the most challenges are facing logistics companies to adopt eco-friendly technologies as well as drivers which push toward green technologies.

1.3 Methodology

After the initial research, we have made the classification for the papers according to the information that can be extracted from them, which means that how the paper is able to answer the questions and doubts that may exist in the research area of logistics for last mile delivery in B2C E-commerce. The first step was to identify the main topics which could touch the core of the study and for further steps, to identify papers which are related to main topics with lower level of importance. That is why we have identified three categories:

- Core: the main objective of the paper was to describe of the topic.
- Ancillary: the topic was not the priority of the paper.
- Absent: the topic was not mentioned.

Table 1 Scientific papers' classification

							Addressed Themes		
No.	Topic	Auther	Journal	Date	Country	Main focus	Last-mile delivery description	Green logistics	Detailed last-mile delivery costs
1	A Green Vehicle Routing Problem	Sevgi Erdogˇan, Elise Miller-Hooks	Transportation Research Part E: Logistics and Transportation Review	2011	United States	Provides solutions to overcome limited driving range and infrastructure for green vehicle	Ancillary	Core	Ancillary
2	Green Logistic Vehicle Routing Problem: Routing Light Delivery Vehicles In Urban Areas Using a Neuro-Fuzzy Model	Goran C´ Irovic´, Dragan Pamuc, Darko Bozˇanic	Expert Systems with Applications	2014	Serbia	Proposes a model for routing light delivery vehicles in urban areas.	Core	Core	Ancillary

3	Operations Research for Green Logistics – An Overview of Aspects, Issues, Contributions and Challenges	Rommert Dekker, Jacqueline Bloemhof, Ioannis Mallidis.	European Journal of Operational Research	2012	Netherlands, Greece	highlights the contribution of operations research to green logistics	Ancillary	Core	Absent
4	Cost Modelling and Simulation of Last-Mile Characteristics in an Innovative B2c Supply Chain Environment with Implications on Urban Areas and Cities	Roel Gevaersa, Eddy Van De Voorde, Thierry Vanelslandera	8th International Conference on City Logistics.	2014	Belgium	simulates the B2C last mile costs per unit for green logistics	Core	Core	Core
5	Optimizing Last Mile Delivery	Rajeshwari Chatterjee	IEEE 41st Conference on	2016	Germany	develops a model, which uses existing	Ancillary	Core	Absent

	Using Public Transport with Multiagent Based Control		Local Computer Networks Workshops			Public Transport for last mile delivery			
6	The Use of Bicycle Messengers in The Logistics Chain, Concepts Further Revised	Jochen Maesa , Thierry Vanelslandera	Procedia - Social and Behavioral Sciences	2012	Belgium	improves efficiency and overall sustainability of logistics by using bicycle messengers	Core	Core	Ancillary
7	The Prospects of Different Last-Mile Delivery Modes of Ecommerce Logistics in Hong Kong	Zheng, Sirui	The Hku Scholars Hub	2015	Hong Kong	discusses the prospects of different last-mile delivery modes in Hong Kong	Core	Absent	Ancillary
8	Innovative Solutions for A “Last-Mile” Delivery – A	Maša Slabinac	Business Logistics in Modern Management	2015	Croatia	introduces innovative types of delivery vehicles that improve business in green way	Ancillary	Core	Absent

	European Experience								
9	A New Bicycle Delivery System for The Last Mile of E-Commerce	Jort Nijhuis	Delft University 0f Technology	2012	Netherlands	Introducing a bicycle as mode of transport for last-mile delivery for E-commerce in Amsterdam	Ancillary	Core	Absent
10	E-Vehicles in The Last-Mile Distribution	Sabrina Gries, Matthias Klumpp, Stephan Zaleski, Alessa Münchow-Küster	University of Duisburg-Essen	2014	Germany	to identify changes in costs and operational processes caused by the use of electric vehicles in the last-mile distribution	Core	Core	Core
11	Green City Logistics: Systems of Innovation to Assess The Potential Of E-Vehicles	Athena Roumboutsosa, Seraphim Kaprosa, Thierry Vanelslander	Research in Transportation Business & Management	2014	Greece, Belgium	introduces a methodology to examine the process by which electric vehicles may be introduced in city logistics	Ancillary	Core	Ancillary

12	Electric Fleets in Urban Logistics	Marcin Foltyński	1st International Conference Green Cities 2014 – Green Logistics for Greener Cities	2014	Poland	offers an overview of current developments by providing examples of European cities that have successfully introduced electric vehicles into their logistics fleets.	Core	Core	Ancillary
13	Trends, Challenges, And Perspectives In City Logistics	Teodor Gabriel Crainic Abderrahim Benjelloun		2009	Canada	presents an overview of City Logistics concepts, models, and planning issues	Core	Core	Ancillary
14	Total Cost of Ownership and Its Potential Implications for Battery Electric Vehicle Diffusion	Jens Hagman Sofia Ritzén Jenny Janhager Stier Yusak Susilo	Research in Transportation Business & Management	2016	Sweden	investigates the possible discrepancy between purchase price and the TCO between internal combustion engine vehicles (ICEVs), and BEVs	Absent	Ancillary	Core

15	Electric Versus Conventional Vehicles for Logistics: A Total Cost of Ownership	Cathy Macharis Philippe Lebeau Joeri Van Mierlo, Kenneth Lebeau	World Electric Vehicle Journal	2013	Spain	develops a total cost of ownership model to assess the competitiveness of light commercial vehicles in the Brussels-Capital Region.	Core	Core	Core
16	Electrifying light commercial vehicles for city logistics? A total cost of ownership analysis	Cathy Macharis Philippe Lebeau Joeri Van Mierlo, Kenneth Lebeau	European Journal of Transport and Infrastructure Research	2015	Belgium	develops a total cost of ownership model to assess the competitiveness of light commercial vehicles in the Brussels-Capital Region.	Core	Core	Core
17	Home Delivery and The Impacts on Urban Freight Transport: A Review	Johan Vissera Toshinori Nemotob Michael Browne	Procedia - Social and Behavioral Sciences	2014	Indonesia	discusses the latest developments in internet shopping, home delivery and the potential impacts on	Core	Ancillary	Ancillary

						city logistics and alternative vehicle use			
18	Strategies for Reducing the Impacts of Last-Mile Freight in Urban Business Districts	Alexandra Reisman		2011		reviews the challenges and consider policy and planning solutions for freight management and operations in urban areas	Core	Core	Ancillary
19	Urban Supply Chains and Transportation Policies	Romeo Danielis Elena Maggi Lucia Rotaris Eva Valeri		2012	Italy	characterizing the urban supply chains (USCs) by discussing how a USC can be modelled	Ancillary	Ancillary	Absent
20	Evaluation of Innovations in B2c Last Mile, B2c Reverse & Waste Logistics	Roel Gevaers		2013	Belgium	to understand the evaluation of Innovations in B2c Last Mile, B2c Reverse & Waste Logistics	Core	Ancillary	Ancillary
21	Characteristics and Typology of	- Roel Gevaers	Department of Transport And		Belgium	innovative concepts for urban distribution	Core	Core	Ancillary

	Last-Mile Logistics from An Innovation Perspective in An Urban Context	- Eddy Van De Voorde -Thierry Vanelslander	Regional Economics University of Antwerp			and "the last mile", that have significant positive impacts on logistics performance			
22	Challenges in Last Mile Logistics Of E-Grocery Retailers: A Developing Country Perspective	-Alicia Neva Weber -Snyman -Johanna A. Badenhorst -Weiss	The International Purchasing and Supply Education and Research Association (IPSERA)	2017	Germany	focuses on challenges in the last mile logistics of online grocery shopping within a developing country such as South Africa	Core	Ancillary	Ancillary
23	Total cost of ownership of electric vehicles compared to conventional vehicles: A probabilistic analysis and	-Geng Wu -Alessandro Inderbitzin -Catharina Bening	Journal of Energy Policy	2015	Switzerland	evaluates the complete cost for the consumer, focusing on individual vehicle classes, powertrain technologies, or use cases by using Total	Absent	Ancillary	Core

	projection across market					cost of ownership model			
24	Innovative Solutions for A "Last-Mile" Delivery – A European Experience	Masa Slabinac	15th international scientific conference Business Logistics in Modern Management	2015	Croatia	presents the innovative transport technologies in the "last-mile" delivery in developed European countries that provide an ecological and social sustainability as well as an increased competitiveness of the suppliers	Ancillary	Core	Ancillary
25	Comparative Analysis of The Carbon Footprints of Conventional and Online Retailing A "last mile" perspective	- Julia B. Edwards - Alan C. McKinnon - Sharon L. Cullinane	International Journal of Physical Distribution & Logistics Management	2009	UK	focuses on the carbon intensity of "last mile" deliveries and personal shopping trips.	Core	Ancillary	Ancillary

26	The Benefit of Green Logistics to Organization	Wijittra Srisorn	International Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering	2013	Thailand	studies green logistics and the expected benefit that organization gotten when adapted to green logistics	Ancillary	Core	Absent
27	Comparing the Use of Small Sized Electric Vehicles with Diesel Vans on City Logistics	- Sandra Meloa - Patricia Baptistaa - Álvaro Costab	16th Meeting of the EURO Working Group on Transportation	2014	Portugal	estimates the effects of adopting Small Sized Electric Vehicles (SEV) from the city perspective. Moreover, analyzes how the use of small sized electric vehicles such as tricycles and cargo cycles in city logistics affects traffic, energy efficiency and emissions	Core	Core	Core

28	Electric Vehicles for urban logistics improvement	- G. Napoli - L. Andaloro, - F. Sergi - N. Randazzo - V. Antonucci	National Research Council of Italy	2013	Italy	aims to support innovation in transport, by promoting a system based on sustainable mobility and RES (Renewable Energy Sources)	Core	Core	Ancillary
29	How battery electric vehicles can contribute to sustainable urban logistics: A real-world application in Lisbon, Portugal	- Gonçalo Duarte - Catarina Rolim - Patrícia Baptista	Sustainable Energy Technologies and Assessments	2016	Portugal	evaluates the adequacy of BEV in urban logistics in Lisbon, based on a real-world application	Core	Core	Core
30	Electrifying Last-Mile Deliveries: A	- Jesus Saenz Esteruelas - Miguel Figliozzi	International Conference on Smart Cities	2016	Spain	analyzes carbon footprint potential savings between electric tricycle last-	Core	Core	Ancillary

	Carbon Footprint Comparison between Internal Combustion Engine and Electric Vehicles	- Adrian Serrano - Javier Faulin				mile distribution against a traditional diesel-powered van system			
31	The effect of fiscal incentives on market penetration of electric vehicles: A pairwise comparison of total cost of ownership	- Petra Zsuzsa Lévay - Yannis Drossinos - Christian Thiel	Journal of Energy Policy	2017	Italy	conducts total cost of ownership (TCO) calculations to study how costs and sales of EVs relate to each other and to examine the role of fiscal incentives in reducing TCO and increasing EV sales	Core	Core	Ancillary
32	Total cost of ownership, payback, and	- Baha M.Al-Alawi	Applied Energy	2013	United States	performs a sensitivity analysis to understand the sensitivity of total	Ancillary	Ancillary	Ancillary

	consumer preference modeling of plug-in hybrid electric vehicles	- Thomas H.Bradley				ownership cost and payback period to model parameters and the modeled components of ownership costs			

1.4 Summary of review and discussion

With more pressure of competitiveness and environmental sustainability, there are many other literature reviews conducted to cover green last mile delivery (B2C E-commerce) for example: Optimizing Last Mile Delivery using Public Transport with Multiagent based Control by Rajeshwari Chatterjee, Christoph Greulich and Stefan Edelkamp (2016), however, they were not focusing with B2C market and not for E-commerce. Even though using public transportation helps reduce greenhouse gas emissions and reduce congestion as well. However, it is not completely green because not all public transportation is operating with electricity. Another example is provided by Goran C´ irovic´, Dragan Pamucar and Darko Bozanic (2014) for using light delivery vehicles for urban areas, although by using of light commercial vehicles helps to reduce exhaust emissions, logistics operating costs however, one of the area needs to be improved that problem related to the location for filling batteries on light delivery vehicles, and their optimal location in relation to the vehicle route (Pamucˇar, 2014). Another paper introduced by (Michael Schneider, 2012), despite the fact that they considered many important factors such as recharging times depend on the battery charge of the vehicle on arrival at the station. However, with the new technology of supercharger and decrease the duration of charging, or ability to swap batteries therefore, it is expected that the result will be changed significantly.

We have found that the two models 2013 and 2015 of Electric Versus Conventional Vehicles for Logistics: A Total Cost of Ownership by Cathy Macharis, Philippe Lebeau, Joeri Van Mierlo, and Kenneth Lebeau are the closest papers to our core topic which were very helpful and provided overview and general guidelines for our work. These papers help us to find out the main factors have a significant impact on the last-mile delivery. However, there was no consideration for supercharging stations among their analysis. Which could change the shape of the competitiveness between electric and conventional vehicles.

Due to the limited diffusion of B2C e-commerce, logistics processes and solutions in the online scenario are still evolving and improving. Furthermore, the measure of their environmental sustainability will be a key performance indicator for their future development (Mangiaracina, 2015).

2 Challenges in last mile delivery

2.1 Introduction

Generally, the challenges of home delivery are to limit and control the volume of freight vehicles operating in cities and improve the effectiveness and efficiency of the process, are also to reduce impact of the movement of freight vehicle on the city living condition and the goal is to enhance pollution mitigation, which actually damage the historic places, and to reduce emissions and to improve congestion and mobility while not affecting city's economic and social activities (Crainic, 2009).

Of course, the specific conditions for urban delivery vary depending on the location, layout, infrastructure, policies, trade activity, and consumer behavior of different cities (Reisman, 2011).

The number of freight vehicles moving within city is growing and is expected to continue to grow at a steady rate. In particular, due to the current production and distribution practices based on timely deliveries, and the high growth of B2C electronic commerce that generates significant volumes of personal deliveries (Benjelloun, 2009).

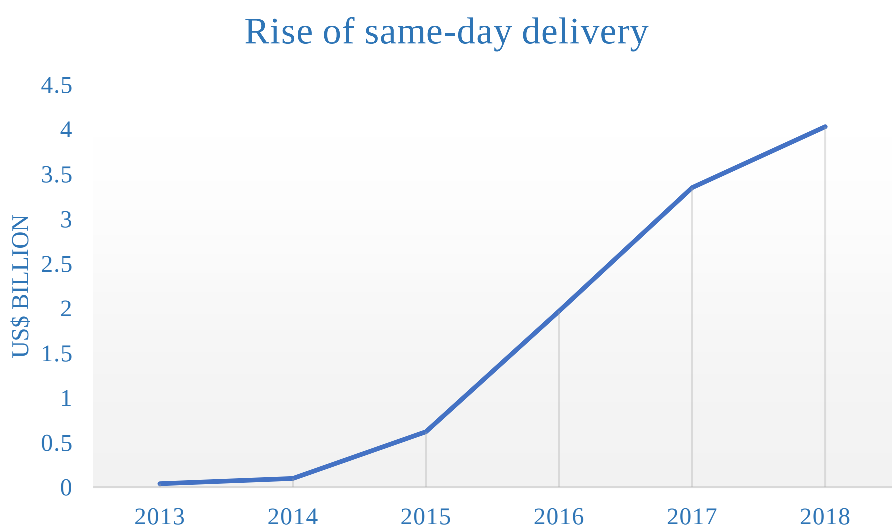


Figure 5: Rise of same-day delivery (atkearney.com)

Most delivery trucks are diesel/gas-powered and emit pollutions into the air, which contribute to climate change and poor air quality. Especially along crowded areas, public health suffers when streets are full of polluted vehicles. The public health and environmental problems caused by emissions could be a barrier to sustainability of delivery process.

Types of goods: nowadays, many online shops have launched grocery/food service which offering consumers the option of ordering their groceries via internet for home delivery. E-grocers are facing several challenges with this form of retailing, especially in the last mile of the supply chain such as:

1- reliable order fulfilment
2- cold distribution chain requirements
3- forward logistical challenges and reverse logistics
4- on-time home delivery

E-grocers need to respond to these expectations however, they need to have convenient logistical services while keeping costs as low as possible (Weber-Snyman, 2016). Focusing on cold distribution chain requirement, it is well known that temperature is an important parameter in food safety and quality (Kuo, 2009). Therefore, delivery vehicle should be equipped by cooling system and other requirement for keeping food and orders fresh and avoid destroying perishable food during the storage which in return it will increase the need for special vehicle which certainly will be more expensive than the normal vehicle due to the additional equipment of the cooling system. Moreover, operating cost of delivery vehicle could be higher as well mainly due to more energy consumed for cooling system.

By offering grocery/food delivery service, online shops take into account the necessity of reverse logistics mainly due to the high flexibility offered to consumers to refuse their orders because of many obstacles to meet customers' expectations. Respect to these requirement, the cost of delivery become very high. Consequently, the e-retailer indicated that they need to subsidize the delivery cost. Because they realize that a high delivery cost can be a barrier to customers to shop online.

Congestion problem in some cities which have high population density, consequently home delivery service pushes toward more congestion in the streets. Furthermore, long time of loading/unloading processes which require the vehicle to occupy the parking space more time. Thereby last mile delivery companies suffering from paying much fees for parking tickets, hence increasing the operation cost of home delivery (nbcnews.com, 2006). There could be a solution for limited parking space by dedicating parking space for loading/unloading vehicles in the city, or letting vehicles use bus lanes during certain times of the day (adlittle, 2015).

The public, industry, and government are increasingly challenged by these issues and there is a need to analyze, understand, and control freight transportation within urban areas to reduce its impact on living conditions e.g., congestion and pollution, traffic noise, accident reduction, and reduce emissions, while not penalizing the city activities. In particular, this aims to reduce the number of freight vehicles operating in the city, control their dimensions and characteristics, improve the efficiency of freight movements, and reduce the number of empty vehicle-km (Benjelloun, 2009).

2.2 Effects of growing cities on home delivery

Cities around the world has grown steadily, as more and more people migrate to cities for seeking jobs and better living conditions. The growth of cities and urban areas in the 21st century has put more pressure on resources and conditions of urban life. The growth of urban population has directly affected the city logistics as people consumed more goods and services which created big market for E-commerce companies, which in return increases the pressure on goods delivery and traffic in urban areas. The effects have always presented environmental challenges due to mainly operations of logistics. Companies have begun to look at outsourcing of logistics to specialized companies, consequently they can focus on their core business activities. Companies servicing the logistics are now in great demand. This has put all other related services in demand and hence affect the entire logistics chain (Essay UK).

2.3 Strategies for reducing the impacts of last mile freight

Generally, any solution depends on cooperation between the two parties who are capable of making changes to the system: public policymakers and freight transport companies (Reisman, 2011). The urban freight represents a diversified set of stakeholders, goals, and physical places. Because of its complicated nature, the urban freight problem will be solved gradually.

2.3.1 Vehicle size and delivery time regulations

There are some policies to reduce the impact of last mile delivery which is trying to regulate when, where, and which freight vehicles are allowed. Municipalities can regulate vehicles according to dimension, weight, loading factor, and emission factor or fuel type (Danielis, 2012). Therefore, for example, some specific vehicle could be allowed to access specific area at a certain time to avoid congestion during peak hours. However, there are some problem related to off-peak delivery times which probably at sleeping times, thereby it could emerge noise from deliveries which could be disrupting.

2.3.2 Sharing Economy

It could be a solution, that companies can start to share vehicle capacity between them to achieve more efficiency of the delivery trips and reduce the number of empty vehicle-km. Therefore, this can reduce number of trips in general. Thereby achieve significant reduction in the pollution and other problems related to deliveries. However, for this solution, it is needed to make very precise analysis and coordination between partners. Moreover, using more efficient handling and packaging systems could help the problem of wasting time during the delivery especially with the importance of time window of consumers (Reisman, 2011).

2.3.3 Urban distribution centers

By using more distribution centers within an urban area, it could have a significant impact on the last mile deliveries. However, design of these distribution centers should be carries out in high detailed level such as: size, location, customer segmentation, and functions.

There are many promising advantages by adopting this strategy

1- Reduce the trip of last mile delivery which could be a solution for congestion, pollution, and noise.
2- Reduction in cost of last mile delivery

3- Give opportunity to use BEV which has a problem related to short driving range.
4- It is easier to adapt other environment friendly means which could be considered as slow solutions such as: Cubicycle.

However, beside these benefits, there are disadvantage should be taken into account. Usually prices of real estate within city center are very high which put feasibility of the ideas in doubt. Which means that is it profitable to use expensive distribution center and try to be compensated with less operating cost for delivery trips such as: energy cost? another problem could face using urban distribution centers is that there is a conflict with the local government, in fact, the rules for accessing the city center are often very restrictive, and the obligation to use urban distribution centers as well (Lagorio, 2016)

2.3.4 Optimize task assignment based on routes

the first step is the most important which is to centralize the system in which all orders and delivery tasks get into. After uploading these data in the centralized system, it is critical to design these tasks with taking into account the optimal routes. Large companies, that carries out many of deliveries per month, have this process automated thereby there are many software could carry out this task in optimal way (bringg.com, 2016).

2.3.5 Customer last mile visibility and engagement

One of the most important innovation in logistics sector is visibility (bringg.com, 2016). Visibility could mean both internal (visibility over the supply chain) or on customer side, consumers will no longer accept long time for waiting until their delivery will arrive. Thereby consumers want real-time tracking via a map on their mobile device. By this capability, consumers can anticipate the time of arrival moreover they can assure that the delivery vehicle on the right route to the delivery point otherwise they could provide help by calling the driver to correct the wrong route. Which could reduce numbers of repeated deliveries and non-deliverables significantly. One of the real cases, UPS has adapted “Follow My Delivery” program which enables consumers to see exactly where the truck which is carrying their packages on a map from their smartphone or PC (theverge.com, 2016).

2.3.6 Combination between reverse logistics and normal flow

First: What is Reverse Logistics?

“Reverse logistics is the process of planning, implementing and controlling the efficient, cost-effective flows of raw materials, in-process inventory, finished goods, and related information from the point of consumption to the point of origin for the purpose of recapturing or creating value or for proper disposal.” (Rogers, 1998)

There are different types of reverse flow (Gevaers, 2013) :

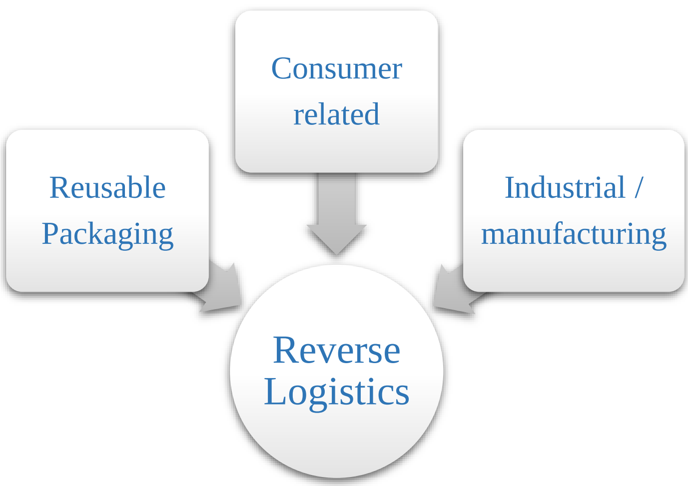


Figure 6: different types of reverse flow

Reusable packaging: which is related to the flow of reusable boxes and packaging tools for example: empty bottles, crates, boxes, etc. this flow starts from customers and back to the shippers and/or producers (storaenso, 2015).

Industrial / manufacturing: which is related to return of industrial machines. However, this is flow has very low return rate (Rogers, 1998).

Consumer related: which is the flow resulting from defective products from consumers to shippers/shops. Therefore, this flow is related to warranty agreement between the shops and consumers. However, it is not only defective products but also normal ones. This kind of returns is increasing with E-commerce mainly because of huge flexibility related to return policies for particular products such as: clothes and shoes. This kind of goods is characterized by medium value and has a high return rate due to free return policies and legislations for example: clothing and shoes have an average return rate of 61%, books, DVD's and CD's have a rate of 16% (Gevaers, 2013).

The major problem of reverse logistics is low efficiency mainly due to low volumes and many pickups and drops which means lower exploiting economies of scale. And for most of companies, reverse logistics are the most underestimated part in the supply chain.

Therefore, there is an opportunity to exploit synergies and take advantage of the combination between forward and reverse logistics. Which will need high level of coordination and collaboration between shippers. Furthermore, it will need to be integrated with the centralized center for forward logistics with the reverse ones to design the delivery and reverse routes in optimal way.

This solution could help E-commerce companies to:

First: cut costs resulting from inefficient way to operate reverse logistics thereby exploit economies of scale with more utilization of the space of the vehicle.

Second: by operating reverse logistics in optimal way, online shops could achieve competitive advantage by gaining customers loyalty due to offer them more flexibility for return policies which give customer more freedom for choosing their orders without any fears of losing money or ordering wrong piece. Specially, that clothing and shoes E-retailers push clients to buy more than one size per product with the objective that consumers will certainly keep the right size (Gevaers, 2013).

3 Future of last-mile delivery

3.1 Green future

City logistics is absolutely vital to the urban economy, whether it is the movement of information or the transportation of goods. Without this service, the trade which creates wealth and help us to maintain our lifestyle, could become unsustainable. However, this distribution has led to increase levels of freight traffic in urban areas which, in return, has led to problems such as: congestion, pollution, noise and collisions.

Local authorities are keen to make their city centers attractive places for people to come and spend their time and money. Local communities want to be able to enjoy the city center without these increasing problems (green-link.co.uk). Furthermore, Consumers fundamentally desire their orders to be delivered by environment- friendly modes of transportation.

European commission set regulations and also companies are applying green strategy with the aim of cutting air pollution, carbon emissions and, noise pollution in crowded urban areas. However, companies apply green strategy not only to foster environment-friendly behavior but also to enhance their green image and adopt more profitable business and on the other side, to anticipate the future trying to avoid liabilities. (European Commission)

3.2 Fast future

The last mile is seeing disrupted from new business models that address customer demand for faster delivery. Indeed, consumers who desires faster home delivery are growing significantly, indeed, some surveys show that 23% of customers are willing to pay more for the same-day delivery (mckinsey, 2016). With the rise of e-commerce, delivery companies pay attention for express delivery and they consider it as a competitive advantage. And we can see how largest E-commerce sites such as Amazon started to offer its consumers many level of fast delivery for instance: Same-Day Delivery and Amazon Prime Now which offer delivery in less than 2 hours (time, 2015). That is why most of delivery companies are seeking for new ideas and ways could be cost effective, environment friendly, meanwhile fast enough to meet the demand in order to guarantee business sustainability.

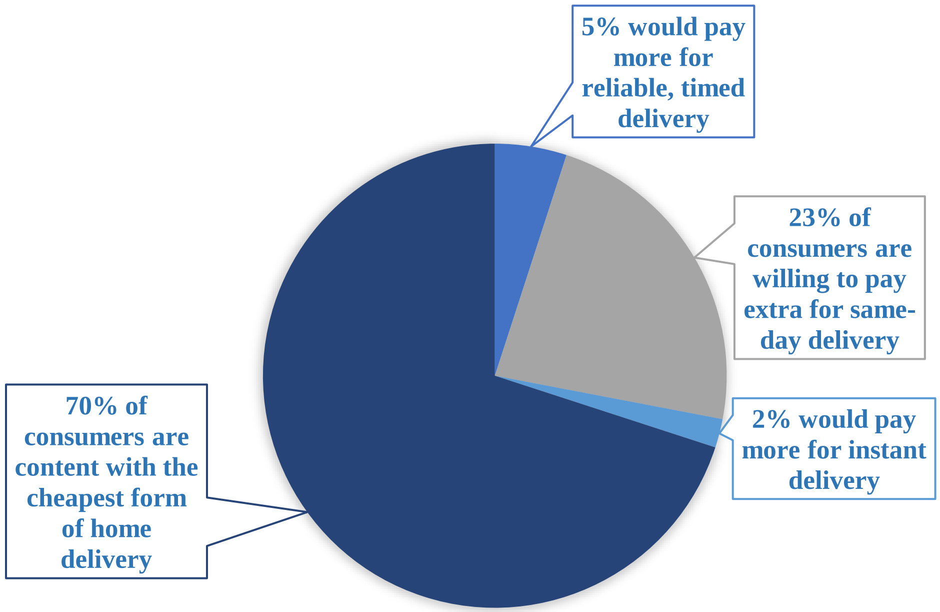


Figure 7: Delivery-Model consumer preferences (mckinsey, 2016)

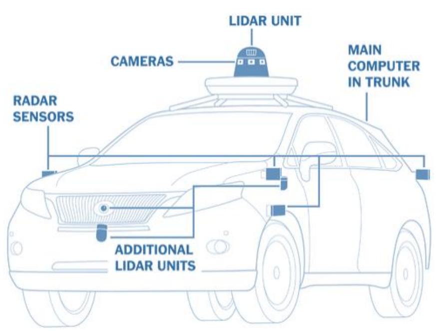
3.3 Existing Green Solutions

Respect to high competition between companies to offer premium service for delivery, creation new ideas became a necessity. However, because of different features of each city, it is significant for companies to choose the right and sufficient way to deliver in a certain area for instance; for rural areas with low average of density, it will be sufficient choice to operate with drone not with BEV. In this part, we tried to collect most innovative ideas for delivery in the market and we have created other two promising ideas.

3.3.1 Electric tricycle

electric tricycle which simply consists of a tricycle with an electric motor. it could offer good deal for city logistics as a green solution which is able to operate delivery of small parcels and pallets up to 200 kg which is considered as light commercial vehicles. Whereas, deliveries of over 200 kg will be done with trucks that meet the Euro 5 emissions standard (geodis-italia.it, 2011). This solution could help in solving the problem of congestion in cities with high density of population. Moreover, it is preferable because of its environmental aspect due to its electric motor which operating without emitting any emissions. However, there are some drawbacks beside its advantages for example; low speed and short distance can be made by one charge.

3.3.2 Self-driving vehicles



With the new technology of self-driving vehicles, logistics companies gain many benefits beside saving the salary of the driver. It is believed that Self-driving will make driving more efficient in terms of better traffic flow, but also less fuel consumption. Moreover, with the ideal way of driving, we can expect decline in the maintenance cost and number of accidents. Furthermore, driverless vehicles are designed to optimize efficiency in acceleration and braking, they will also help improve fuel efficiency and reduce carbon emissions (businessinsider, 2016).

There are many experiments have been carried out to test this new technology and to see how people react to receiving their orders via self-driving vehicles such as; Collaboration between Ford and Domino’s has taken place in US to delivery pizza to real customer. Ford are developing the autonomous vehicle technology, and Domino’s is focusing on the technology which concerning how to improve the delivery business. And they hope to commercialize the technology in the near future (techcrunch.com, 2017). However, there are some drawbacks, some of them are related to the technology itself such as: self-driving vehicles struggle to operate in bad weather like heavy snow and rain. And on the other side, some problems with the delivery way, such as: in the case of home deliver, there is a necessity to deliver to customers' door or delivery for people who have mobility issues which could not be available with driverless technology.

3.3.3 Electric vehicles

Nowadays, many companies are operating in last mile delivery market by BEV, however BEV cannot stand alone without government intervention. There are many drawbacks such as:

1- Long time of charging (supercharging stations reduced charging time to 30 mins) however, it is still considered long time comparing to charging time of conventional fuel like diesel.
2- Low number of charging stations.
3- Battery price is still high.
4- Short driving ranges (The maximum driving range of BEV is estimated around 80-100 km. (EEA , 2016)).

In this part, we will try to solve the problem of long time of charging and low number of charging stations:

The idea is to use Commercial Electric Vehicles which one of its features is that its battery could be removable. Therefore, the delivery system will be based on the electric vehicles for the delivery service plus there will be other trucks which will be equipped with automation system for replacing the empty battery from the delivery vehicle with full charged battery (mobile of battery swap program). Furthermore, it is suggested to design the locations of these trucks in the closest points to the routes of many delivery vehicles in order to serve many vehicles at the same location. Thanks to this idea, it will be possible to have the same time efficiency of conventional vehicle in terms of charging time. However, there are some drawbacks related to the automation system for replacing batteries, which is still considered as very complicated technology. Moreover, to be efficient for swapping program, it is needed to have many of full charged batteries in the mobility hub, consequently it would be considered as huge investment especially high cost of the batteries.

3.3.4 Drones

Drone deliveries look like the future: unmanned small quadcopter rapidly delivering packages to our doors, eliminating both wait times and the cost of human labor (flexport). Drone adoption is growing rapidly among both consumers and companies. Thereby it could serve different purposes for retailers. Furthermore, major retail and logistics companies around the world are testing drone delivery service to solve the problems of last mile deliveries we mentioned before.

There are some drivers and barriers for using drones:

Pros

1- Companies would save money on shipping costs, which would in return reduce costs for consumers.
2- Consumers would receive their packages more quickly and reliably, which would build consumer trust and encourage them to repeat purchasing.
3- Rural areas with low to average density of population, can be a solution however not all countries allow using drones.
4- Green and fast solution for last mile delivery and solving the problem of congestion and cut the air pollution.

Cons

1- Short distance could be made by the drones around 15miles (flexport). However, we could tackle this barrier by using automated truck as a drone-carriers to shorten the distance between the warehouse and delivery points (cnbc, 2017).
2- Consumers could concern about privacy, mainly because drones are using GPS and cameras to find homes and deliver package.
3- Problems related to regulations, not all countries have accepted to have many drones flying in their air without any control.

4- Using drones controls the size and the weight of the package. Consequently, not all deliveries could be made by drones.
5- Drones could make only one delivery per trip and after the drone makes its delivery, it has to fly all the way back to its base to recharge its batteries and pick up the next package. Which could be considered poor performance comparing to a delivery truck which can make an average of 120 stops a day to deliver hundreds or thousands of packages (flexport).

Many companies started already to carry out many deliveries by this technology such as:

Domino's Pizza: first delivery has been made by a drone in New Zealand which controlled by a team of drone experts through GPS navigation to drop off the pizza.

Another giant company entered this area is Amazon, Amazon plans to deliver customers' orders within 30 minutes through its Prime Air delivery program (businessinsider, 2017).

There are many types of drones in terms of the kind of energy. Mainly drones are working by electric batteries, however there are others working with gas which can operate for a longer period of time than the electric ones.

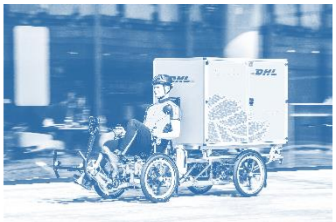
On the other hand, there many types of drones in terms of operating system and the application which made for.

Table 2: types of drones (auav.com, 2016)

type	Pros	Cons	Typical Uses
Multi-Rotor	Accessibility Ease of use Good camera control Can operate in a close area	Short flight times Small capacity	Aerial Photography and Video Aerial Inspection
Fixed-Wing	Large area coverage Fast flight speed	Launch and recovery needs a lot of space Harder to fly, more training needed Expensive	Aerial Mapping, Pipeline and Power line inspection

Fixed-Wing Hybrid	Long flight	Still in development	Drone Delivery

3.3.5 Cubicycle



In order to deliver small packages and mails, Cubicycle could be a solution. Cubicycle is an innovative cargo bike for urban distribution. DHL Express has introduced a new vehicle to its fleet in the Netherlands that will further enhance its efforts to improve its carbon efficiency.

This solution could help to improve the quality of air and reduce pollution in the big cities with high population density and also help to solve congestion problem. The low speed of the vehicle is one of the significant barrier. However, to counterbalance this problem, there should be more number of hubs and to be well distributed in order to be closer to delivery points. This solution could be sufficient in high deliveries concentrated areas. Even though, in these areas, companies may face high cost to acquire or lease place to allocate hubs, however, with low initial cost and variable cost (no fuel and no need for special drivers with driving license) of Cubicycle instead of using conventional vehicles, companies could counterbalance or even be better off with using Cubicycle. (dhl, 2015)

3.3.6 Sharing Economy

This is all about the sharing economy and focusing on delivery services. Which is based on individuals are able to borrow or rent assets owned by someone else. Sharing economy is specially used when a particular asset is expensive and is not totally utilized all the time. Nowadays, there are many businesses that are operating only based on sharing economy such as Uber and Airbnb. Which they are working as a platform for matching consumers and supplier of the service.

Currently, we can see that Amazon the world's biggest e-commerce company wants to control more of its own deliveries. Amazon is making agreement with Uber in order to use Uber's drivers for delivery service to speed up delivery times and simultaneously, to bring down delivery costs (theguardian, 2016)

Amazon relies on Another strategy to exploit the big opportunity in using sharing economy, which is based on mobile APP in order to create a platform for independent drivers separately from Uber. Amazon Flex program is a delivery program that hires independent contractors to complete Amazon deliveries for $18-25 an hour (flex.amazon.com, 2017).

In general, using mobile APP to connect people either as consumers or suppliers, it will be a good idea for making a platform for helping each other. The idea is based on when individuals (as consumers) need to order a package from someplace like a restaurant or a warehouse, they could ask a delivery service provider (as supplier) on the APP in order to make this process with a fee.

There are many benefits from using this idea. This could be a solution for greener environment and less congestion, due to the fact that the supplier of the service is already making the trip of the delivery but for another purpose such as; going home or work, hence it is a way to exploit more the utilization of the vehicle.

3.3.7 Other solutions

There are other innovative ideas in the market such as: parcel lockers and car trunk and collection box (parcelindustry.com, 2016) which could help to reduce the cost related to (Visser, 2014):

1- additional costs for repeated delivery (12% of deliveries have to be delivered a second time),
2- non-deliverables: 2% of the goods cannot be delivered.

Therefore, this could help to decrease number of times that delivery companies will need to resend again the order to the customer address. Consequently, the pollution will drop down due to the reduction achieved in the total distance needed for one order.

3.4 Innovative ideas

3.4.1 Integration between Subway and automation system

The idea is based on using the subway to deliver the orders instead of regular delivery system used nowadays. Mainly this idea consists of two parts:

First part: integration between an electric public transportation (for example: subway vehicles) and horizontal automation system for loading and unloading processes which will be located on the pavement of the subway. This automation system has a significant role where there is a major need to make these processes (load/unload) in fast and steady way. The main point is that the time needed, for loading and unloading parcels from the assigned vehicle in the subway's train, should be equal or less than the time needed for passengers get in/off the subway's train. Otherwise, this idea will be responsible for some delay in the trains. Moreover, the process should be steady without making any kind of movement or vibration in the subway. Otherwise, the idea will not be sustainable due to society rejection.

Back to the idea, and especially, the process which will start from the start point of the subway's line (i.e. Garage of subway) where we can load the packages of orders into the assigned vehicle to deliver them to the customers who live close to the area around the particular line of the subway. For more explanation, for each line: there are different customers, for example: in Milan, there are 4 lines (red, green, yellow, and purple) and each line serves different area with different customers. Therefore, if a customer ordered a product online and this customer live near to one of the station of the green line, consequently, we will need to send this order by the train of the green line etc. another point could be useful and to reduce time needed for the whole delivery process that it is more efficient to locate hubs near to each end of the line of the subway (i.e. Garage of subway).

Once the train arrive the allocated station which is near to the customer's address, then the horizontal automation system on the pavement of this station will retrieve the package once the train stops immediately and this process should not exceed few seconds before all regular passengers in the train entered/exited from the subway' train.

Second part: once the package arrives the pavement of the station which is on the basement level (under the street level), another vertical automation system will be responsible to arrange/sort the orders and elevate them up to the street level out of the station to be placed in a parcel locker which will work as a collection point. Therefore, when the vertical automation system lifts the package up to a particular box in the parcel locker, then the password of this box will be sent to the customer who will come to garb the order using this password to open the assigned box. However, we can offer the customer home delivery as well, in this case the parcel locker will work as collection point to LM delivery companies who will retrieve packages to make home delivery.

The aim of the idea to make the last mile distance much shorter, especially with the huge network in the big cities like Milan which reach almost all zones in the city, hence it will be near to most of customers live in/around Milan. another positive point that, there will be a huge reduction in the pollution and congestion due to not using vehicles for home delivery and using electric transportations which are not assigned particularly for this purpose. Only there may be a necessity for using vehicles for the very last distance between the subway station and the customer’s house.

Indeed, to apply this idea, there will be a need for a huge initial investment to integrate the automation system however there will be promising reduction in the cost for LM delivery companies.

From economic and social point of view, it will not easy to assess the whole situation due to many aspects we should consider and many stakeholders will be involved for judging and assessing the new system such as; the government, and there will be approvals needed for using public transportation. Moreover, there will be a need for warranty that there will be no delay or any other technical problems could happen for one of the most vital transportation means in the city because of this system which makes the process to have the approvals more complicated and strategic.

However, there are other barriers related to the huge initial investment needed for the automation system which will be installed in most of the stations which will leave a question, is it feasible to substitute the current delivery system plus all related cost such as energy cost, salaries, tax of vehicles, and others with only automation system? The answer could be not easy due to the lack of information about the cost related to the automation system. This point could be a start point for another research.

Sum up:

- Hubs are located at each end of the subway line (i.e. Garage of subway)
- Horizontal automation system in order to retrieve the packages from/to the assigned vehicle in the subway's train
- Vertical automation system in order to sort and elevate the package from pavement level to the street level.
- Parcel locker at the street level to work as a collection point either for final consumer directly or for last mile delivery companies.

<u>It has been carried out drawings of the idea by CAD for more explanation in detail.</u>

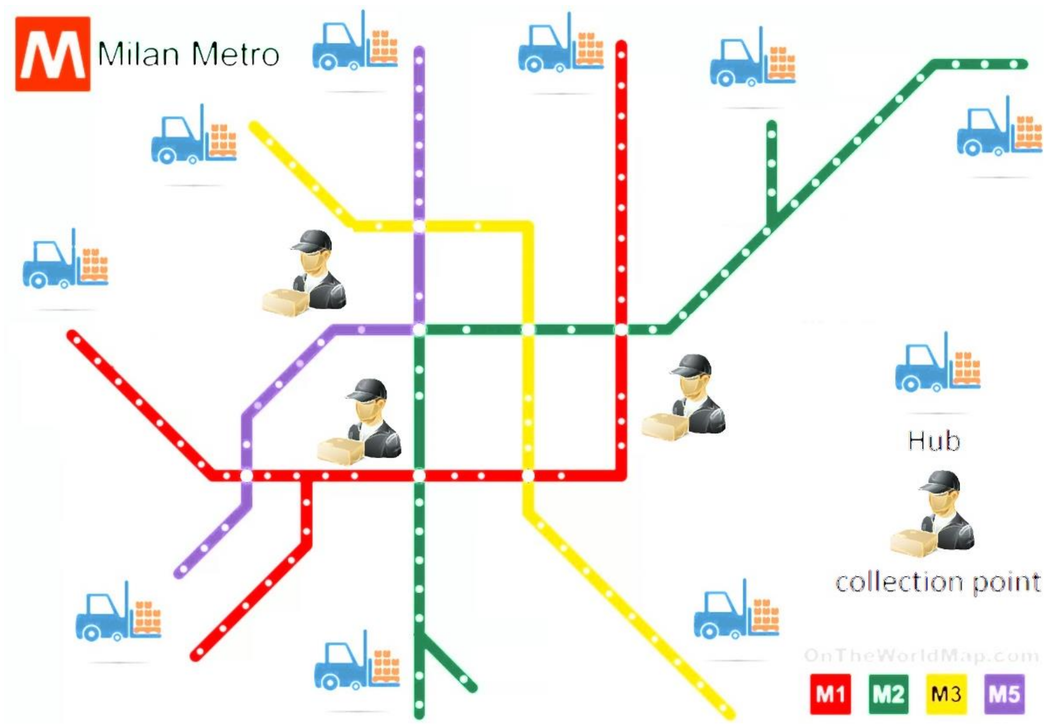


Figure 8: layout of the Subway's idea

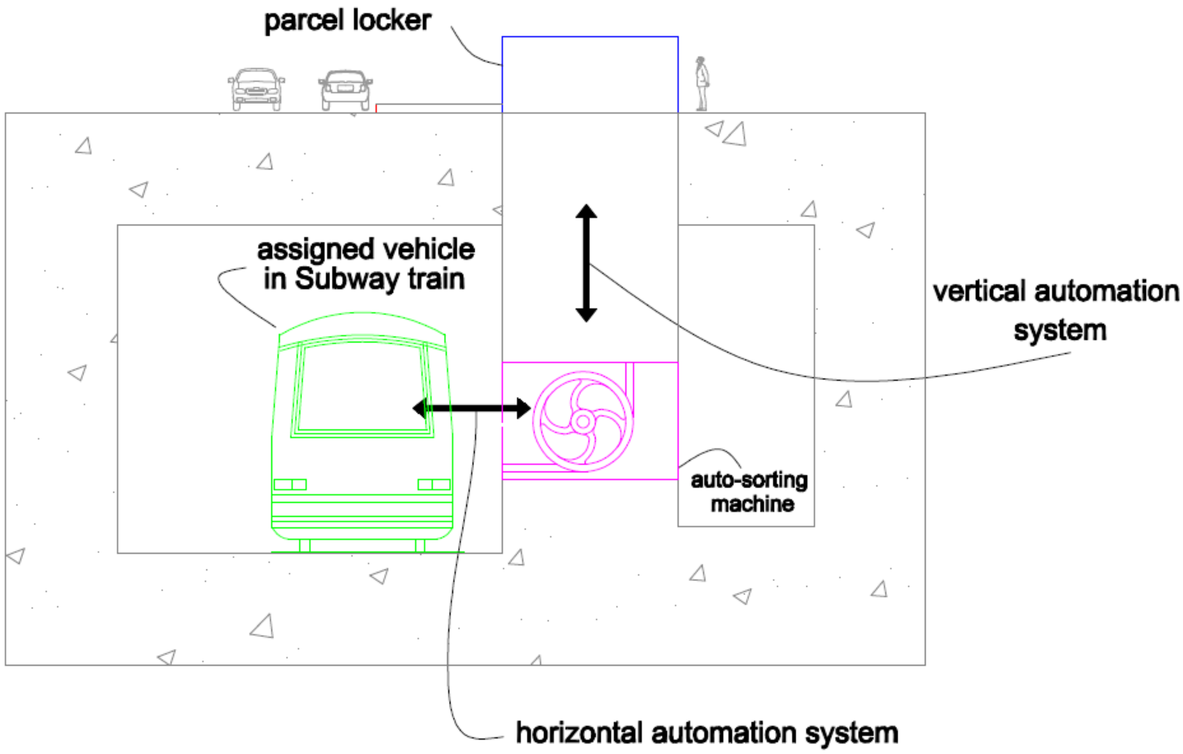


Figure 9: side view of the subway's idea

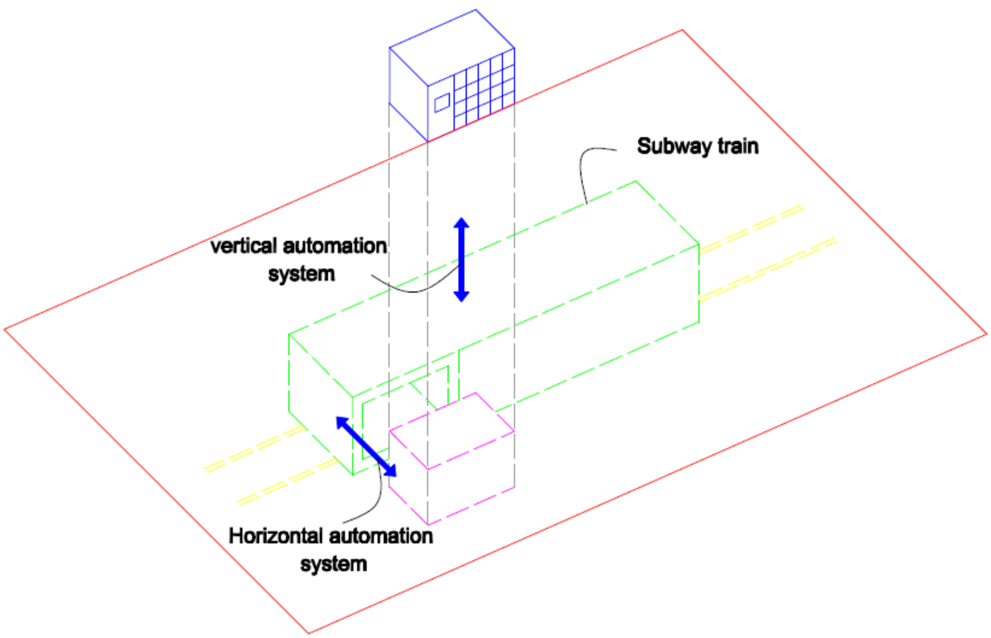


Figure 10: 3D view of the subway's idea

3.4.2 Drones APP

we would see in the future, there will be a mobile app for providing delivery service by drones based on sharing economies. This App will be able to match between drones' owners (i.e. Service providers) and customers who need their package to be delivered at home. Drones' owners could work from home to provide delivery service by remote control or program on PC by using cameras and GPS which attached to the drones. However, this idea could be possible in reality only after huge distribution of drones in our life beside high improvement in the performance of drones in terms of flight distance and to be more controllable and prices as well. On the other side, governments need to regulate, control, and prepare the atmosphere for using drones in efficient way without exercise negative externalities for the society.

Back to the idea,

- There are three partners on the APP:
  - Drones owners (i.e. Service providers)
  - Consumers
  - E-commerce companies

Drones owners: they need to provide the distance can be covered by their drones and the maximum and minimum package specification in terms of size, weight, and shape which it depends on the capability of the drone's type. There could be other important requirement like the height of the delivery point due to the limited height can be reached by drones.

Customers: they need to provide the location of the delivery point and some description of the landscape around the delivery point. Furthermore, if the customer cannot provide landing area on the ground to be suitable for drone due to many people live in buildings with many levels therefore, if they live in higher levels, so that they will need to provide a solution like delivery box can be attached to windows or balconies to be easily reached by drones.

E-commerce companies: they need to stablish the framework and policies to guarantee that the process can be made in most efficient and sustainable way to protect their business and assure safety for their consumers. Furthermore, E-retailers, need to provide the locations of the loading/unloading points for delivery service providers and the description of the landscape as well.

However, it is not expected during widespread of using drones, that e-retailers would rely on sharing economies due to the low investments needed for using drones which could be considered as cheap device.

3.5 Opportunities

3.5.1 Smart Grids

A grid to be smart should be working in two-way communication between the utility and consumers by Internet of Things, using sensors along the whole connection from the power plants to end-user's place also inside home and the plants. In general, smart grid is pushing toward greener environment thereby it could fasten green solutions adoption and especially BEV by installing more electric charging station in the network. Therefore, it could help the problem of BEV with short driving range hence last mile delivery companies could operate with BEV with long trips to exploit economies of scales without fears of empty-battery problem. Moreover, smart grid enhances using renewable energy for producing electricity thereby there will be potential reduction in energy cost for BEV which could be an opportunity to increase competitiveness of electric vehicles against diesel/gas powered vehicles by lower operating costs.

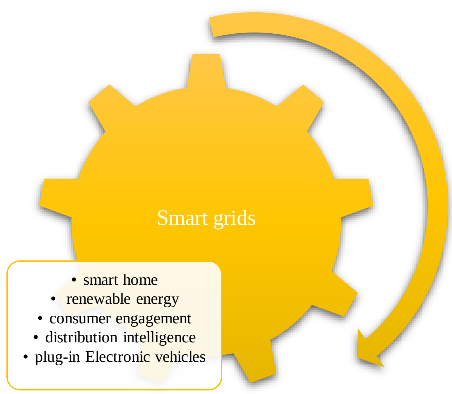


Figure 11: Smart grids

Another promising side of adopting smart grid is that by increasing number of people who integrate electric charging stations at home, therefore it could be possible for electric vehicle of delivery to get charged during time needed for unloading/loading and delivery. Respect to this opportunity, E-retailers can start to offer some discount or incentivize consumers who have charging station at home thereby it would be possible to charge electricity-powered vehicle of delivery during delivery time. Furthermore E-retailers compensate their consumers for the electricity used. However, this scenario could work efficiently if consumers could install supercharging station not the normal stations which will be able to offer convenient charge during the short time of the delivery. by considering that supercharge stations have the ability to charge 80% of the battery in 30mins, therefore, it will be a promising scenario if the delivery vehicle will be able to be charged even for short time (around 10 mins) at each delivery point which we can expect that BEV would not be out of charge during the whole trip.

However, because of the high price of the superchargers currently and we are still at the early stage of adopting smart grid, beside the low diffusion of EV among people in general. Therefore, we anticipate this scenario might take long time for being in reality.

3.5.2 EC Policy on Urban Logistics

In general, the objective of the EU policy is to promote sustainable urban distribution. This concept has been emerged to support the three pillars of sustainability Economic, Environmental, Social. Therefore, this concept is working to maximize the economic efficiency of distribution in urban areas, beside minimize the environmental and social impacts (MDS Transmodal Limited, 2012).

European commission (EC) has considered the main challenges of urban mobility as following:

- many urban areas suffer from intense congestion
- urban mobility accounts for 23% of CO_2 emissions from transport
- air quality
- urban road accidents

these challenges need huge work in different direction as well as with different stakeholders, therefore, EC has developed framework to face these challenges and support the future plan to guarantee sustainable future for next generations. This framework has been built up on four pillars (European Commission, 2017):

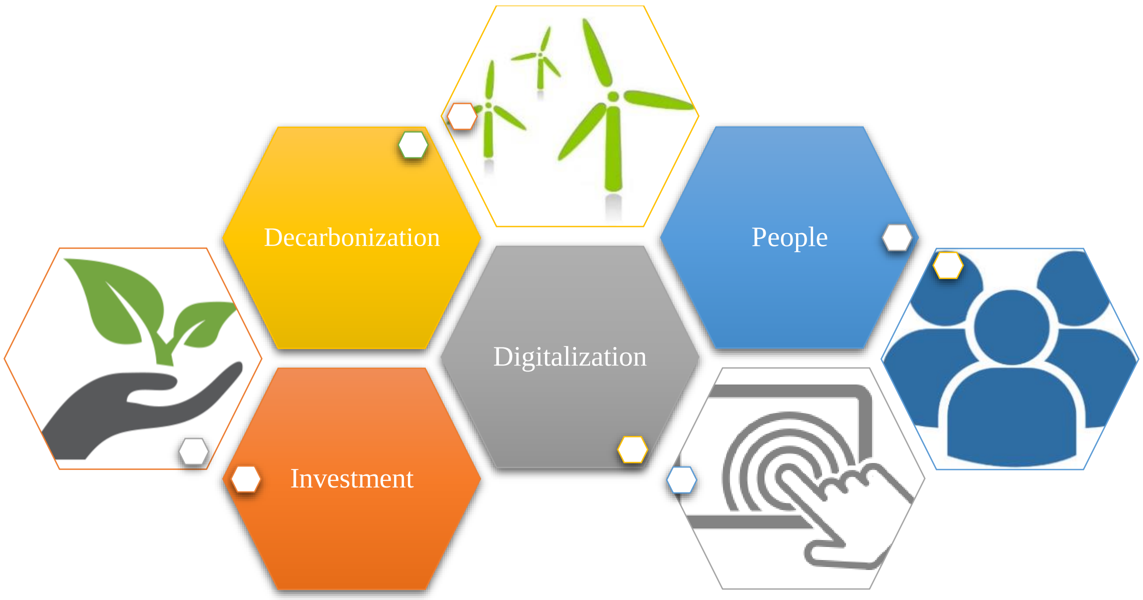


Figure 12: four pillars for the framework

Decarbonization

20% CO_2 Emissions from Transport By 2030

- Global Solutions to Reduce Emissions
- Polluter Pays Principle

Digitalization

Deployment of Connected Vehicles on European Roads By 2019

- Intelligent Transport Systems
- Collaborative Economics
- Drones

Investment

€24 bn. for 2014-2020

- Innovative Financing Mechanisms
- Infrastructure Investment
- Strategic Research and Innovation

People

Halving Road Deaths By 2020

- Safety and Security
- Passenger Rights
- Jobs

Due to the significant impact of urban logistics, EC has allocated specific targets to reach in the future (European Commission, 2017):

- Phase out 50% of conventionally fueled vehicles use in cities by 2040 furthermore completely out of use by 2050.
- Towards “zero emissions” city logistics in major urban centers by 2030

4 Future of EVs

The biggest cost in an electric vehicle is the cost of the battery: when car companies will be able to make batteries cheap enough to put electric vehicles (EV) on par cost-wise with gas ones, they'll finally have a chance to be mainstream in the market (businessinsider, 2016).

Apart from the higher cost, there are other barriers against the diffusion of EVs:

- There is still the lack of charging stations (Schaal, 2015). This problem has been tackled by the authorities to help and give incentives to increase charging stations, as previously stated, but also from private companies like Tesla, which will double the number of Supercharger stations in 2017 (www.cnbc.com , 2017)
- Limited range, which still have strong negative effect on EV market (and it's more evident because of the lack of stations), so customers will face high concern with long trip. For example, a Nissan Leaf can post 84 miles in ideal conditions (Schaal, 2015).
- Dirty power plants: this problem will stand in the way of people who want to make a green impact (Schaal, 2015). The percentage of energy produced from coal, gas and oil is still very high, in China in particular, but also in US and Europe. Hence, "green" customers who pursue better environmental conditions by acquiring EV, would consider their effort for this step as nothing unless they are prosumer and they produce their green electricity from renewables, which make the procedure more complicated and more expensive.

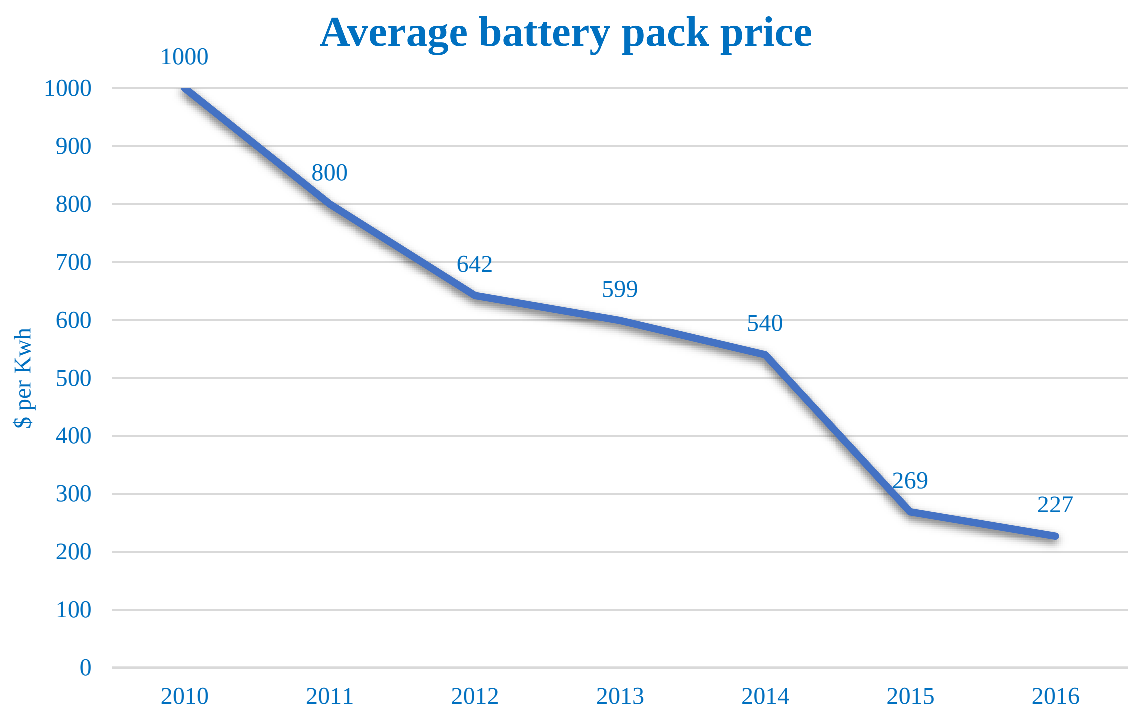


Figure 13:average battery pack cost (electrek.co, 2017)

Regarding the future expected for development of EV, the biggest efforts nowadays are to overcome the high price of the barriers for EV in order to allow the market to grow. Electric vehicles are expected to account for 35 percent of new car sales globally by 2040 (nrdc, 2016) .This may happen because of:

- Battery costs are dropping fast: most EV manufacturers are now trying to exploit economies of scale and build huge factory for producing batteries, such as Tesla's factory called Nevada Gigafactory, which aims at producing cheaper and more powerful batteries (tesla.com, 2014).
- Longer range: most EV manufacturers are focusing on this issue and they achieved some improvements. For example, Tesla and Nissan LEAF, by using plug-in hybrids increased the flexibility for the choice of fuel (electricity or gasoline), allowing to use the latter in case of long trips. Due to the break system which called regenerative braking, this technology is what causes the hybrid engine to regain its electrical charge

(doityourself.com) . Moreover, also batteries have a higher capacity, allowing also BEV to have a longer duration

- More charging stations are coming: utilities and others are moving to increase the number of charging stations at workplaces, apartment complexes, campuses, transit stations and other public gathering places. (nrdc.org, 2016). Moreover, companies from other sectors are entering in this arena, like Google, and Walgreens, which are installing charging stations. Moreover, some EV manufacturers are trying to achieve competitive advantage by offering free charging from many charging stations to gain customer's loyalty such as; Nissan leaf program "no charge to charge" (nissanusa.com, 2017).
- The car industry is embracing EVs: electric vehicles started to attract car makers and make them invest billions of dollars to bring more electric vehicle models to market. This is a signal that they don't want to miss a chance to be involved in the potential electric car market in the future.
- The global awareness to cut carbon pollution and oil dependency: with the increasing concern for climate change issues furthermore, the willingness of many countries to be more independent from traditional energy sources, which come mainly from countries with unstable political situation such as: Russia which is one of the most important suppliers for gas to Europe however after Russian intervention in Ukraine which created a tense relationship between Russia and Europe (haaretz.com, 2014).

4.1 Technologies in the EV market

With high expectation of EV market to spread increasingly worldwide in the future, and not only because of its environmental benefits (especially nowadays most of policies push in the direction of Co2 emission reduction (forbes, 2016)), however also for the potential of significant cost reduction of Electric Vehicle and its cost of ownership in general, makes EV technologies one of the most attracting area for researchers, many companies, and investors as well who expects EV to be the future of the auto market. In this sector, we will go in details for each component in BEV and related technologies and then make comparison between them to try to find out the promising technologies for the future and try to understand how the situation could be changed in the future.

4.2 Comparison Between Gasoline and Electric Vehicle

One of the main advantages of EV market that Electric vehicle has few components plus that there is only one moving component in EV which is electric motor vs. Conventional one which has hundreds of moving parts. Fewer moving parts in the electric vehicle leads to another important difference which is that electric vehicle requires less periodic maintenance and is more reliable. (idaho national laboratory , 2015)

GASOLINE VEHICLE	FUNCTION	ELECTRIC VEHICLE
Gasoline Tank	Gasoline Tank Stores the energy to run the vehicle	Battery
Gasoline Pump	Replaces the energy to run the vehicle Charger	Charger
Gasoline Engine	Provides the force to move the vehicle	Electric Motor
Carburetor	Controls Acceleration and speed	Controller
Alternator	Provides Power to accessories	DC/DC converter
	Converts DC to AC to power AC motor	DC/AC converter
Smog Controls	Lowers the toxicity of exhaust gasses	

Table 3. Comparison between Gasoline and Electric Vehicle (idaho national laboratory , 2015)

From this comparison, it is seen that the main component has strong impact on the EV market is the Battery and in general, Batteries affect the performance and the price of the EV. For the car performance, it has many factors such as speed, power, drive range, recharging time, and life of the battery.

4.2.1 Electric motor

Electric motor uses the energy stored in the battery directly. There are some advantages for electric motor versus the motor used in the conventional vehicles, for example: higher efficiency (an electric vehicle converts around 80 % of the energy it uses to usable power, compared with around 20 % for a conventional vehicle) also electric motor can work as regenerator of electricity and provide it to the battery again while the vehicle is decelerating. Moreover, the electric motor is highly durable, with lower maintenance costs, and less noisy (European Environment Agency, 2016).

4.2.2 Batteries

The battery in an electric vehicle stores electrical energy that the electric motor uses to power the vehicle. Most of EV in the upcoming market will use lithium-ion batteries which has better performance versus the other kind of batteries such as: higher energy storage capacity and longer lifespans. However, currently batteries in the market face some problems like losing capacity over time as a result of ageing and repeated charging cycles (European Environment Agency, 2016). Nowadays, the most used battery technologies in EV market are nickel metal hydride (NiMH) and lithium ion (Li-ion). Hybrid electric vehicle (PHEVs) in the market mainly uses NiMH batteries because it is a mature technology. However, because of the higher energy density, the market of Li-ion is expected to grow fast in EVs market (Kwo Young, 2013). The performance of the battery can be measured by some factors such as:

- Energy density:
  which is the capacity of energy that can be stored per unit volume or mass of the battery. This measurement affects the most important performance of EV which is the driving range: the higher density the longer distances the battery will be able to power the vehicle. In general, it measures by kWh/kg (kilowatt-hour per kilogram) so all companies searching for a solution that can provide more energy content with the same weight or less of the battery with feasible cost
- Power density:
  Which is the measure of power per unit volume which is relevant to the driving performance such as: acceleration and driving speed, and charging time.
- Speed of charging:
  In general, there are three levels of speed to charge your EV: mainly slow, fast charge and rapid charge. Slow charge (up to 3kW) takes 6-8 hours (overnight). Fast Charge (7-22kW) is able to charge some batteries models in 3-4 hours. And finally, Rapid charge, which is able to charge an electric vehicle to 80% in 30 mins (zap-map, 2014)

- Service life

  In EV market, service life is measured by Cycle life which is the number of discharge–charge cycles the battery can handle. (Kwo Young, 2013). One of the advantage of Li-ion batteries that doesn't suffer from "sudden-death" like other kind of batteries, instead with aging or high rate of charge/discharge, Li-ion batteries' performance starts to decrease gradually, and reach end of life when the battery has reduction of 20-30% in its initial capacity. (saftbatteries, 2014).

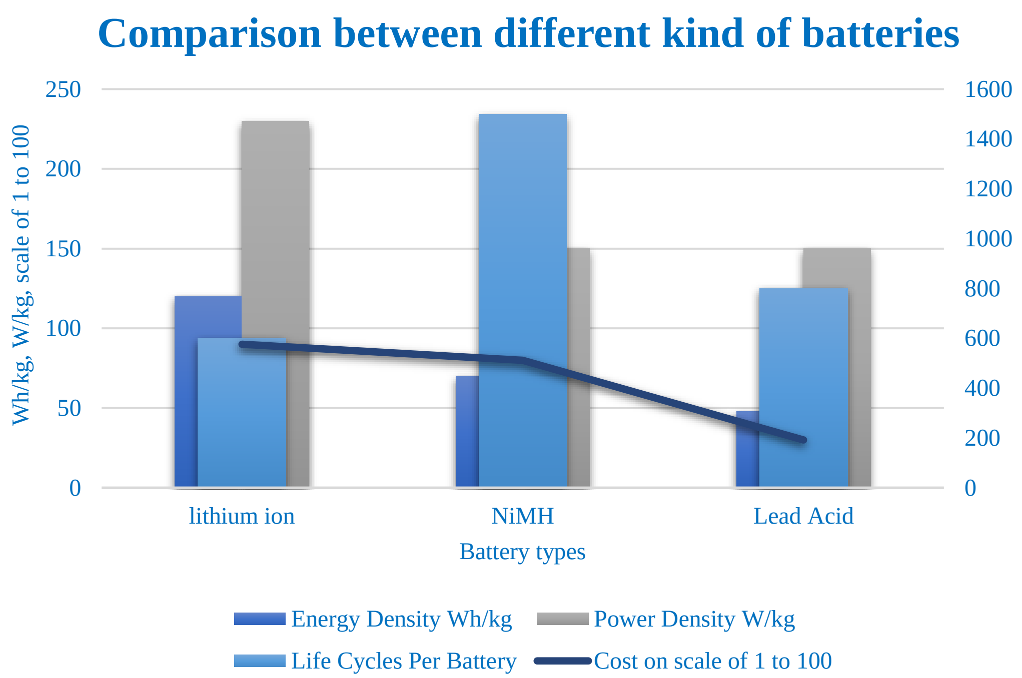
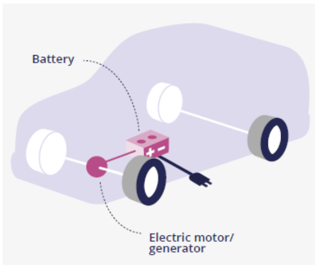


Figure 14. Comparison between different kind of batteries (The University of Tennessee at Chattanooga, 2012)

To conclude, we can see from the graph that performance (energy Density and power density) of Li-ion is higher than other kind of technologies, but the lower life cycle and the higher price of Li-ion could be a barrier. However, with the concentration of R&D nowadays to increase the performance of Li-ion in general, it is expected huge reduction in the cost and increase in the life cycle in the future *(element energy, 2012)*. Even though NIMH has high performance, this kind of technology reached already maturity stage and there is no expecting improvement in the future. That makes Li-ion the most interesting technology and most of researchers and investors as well try to invest to achieve better performance with lower cost to dominate the market in the future.

4.3 Comparison between different kind of EVs

4.3.1 Battery electric vehicles (BEVs):



BEV is powered only by an electric motor using the stored electricity in the battery which must be charged by plugging in the vehicle to a charging station. BEVs have the highest energy efficiency of all kind of vehicles because BEV is able to convert around 80% of the energy stored in the battery into motion mainly because of its electric motor. One of the advantage of the BEV, is zero-emissions vehicle which is great benefit for the environment if the BEVs are powered only from renewables; however, with the current generation mix (renewables and fossil fuels) of electricity there are some emission emitted. With the limited driving range, BEVs need large batteries to maximize the energy storage capacity; however, this large battery will be costly. Most of BEVs have a driving range around 80-100 km. (EEA , 2016)

4.3.2 Hybrid electric vehicles (HEVs):

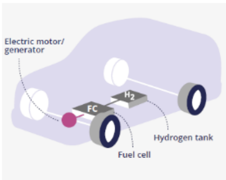
HEV is powered by combination between combustion engine and an electric motor which assists the conventional engine during acceleration; however, some kind of batteries of the HEV cannot be charged from the grid but charged from for example; regenerative braking. So that HEVs are powered mainly by the conventional engine and the electric one just to increase the efficiency and decrease CO2 emissions. The combination between the conventional motor and the electric one differs as there are two ways:

- parallel hybrids, which the convention and electric motors are connected and power the vehicle together.
- power-split hybrids, which they are working separately, mainly the electric motor can power the vehicle alone but in low speeds and short distances. (EEA , 2016)

4.3.3 Range-extended electric vehicles (REEVs):

The situation here is different there are also two kinds of motor conventional and electric, however, the conventional one has no connection to the wheels but working only to generate electricity to electric motor or recharge the battery. So that, the electric motor is the only responsible for powering the vehicle. (EEA , 2016)

4.3.4 Fuel cell electric vehicles (FCEVs):



FCEVs are totally powered by electricity. However, in this case there is no battery to store electricity, but FCEVs have a tank uses hydrogen which is combined with oxygen from the air. The main advantage of the FCEV is that it has longer driving range and faster to refueling similar to a conventional vehicle. FCEVs are better for medium-large vehicles and longer distance. However, because of that this technology is still in the earlier stage of development, so that there are few models of FCEVs in the market and few Hydrogen fueling infrastructure and stations. FCEVs has driving range around 160-500 km. (EEA , 2016)

4.4 Recharging methods

Because of the limited types of electric vehicles, there are limited technologies used to recharges batteries. Consequently, there are mainly three ways for charging: plug-in charging, battery swapping, and wireless charging.

4.4.1 Plug-in charging

Which is used widely by most of EV and other kinds. Batteries of Vehicles can be connected by a cable from the charging station. This station could be wherever: home, public streets, and commercial areas. In general, (slow charging) electric vehicles can be charged at home by domestic socket, however it takes long time around (6-8 hours) because the charging level is 2.3 kW. However, (fast charging) faster plug-in charger or supercharger need special infrastructure.

Currently, most of public stations are normal-faster speed station (EEA , 2016) however there are some drawbacks related to fast charging such as: decrease battery lifetime and lower efficiency because more electricity is lost during transfer. (supercharge) Tesla has stated to carry out its plan to have many worldwide, but still limited amount. (Tesla, 2017).

4.4.2 Battery swapping

Which is replacing the empty battery with fully charged one at special swapping station. This solution is a fast way to recharge the battery such as Tesla swapping system which offers automated system can make the whole operation in 90 seconds (Tesla, 2014). However, there are many barriers to see this solution wide spread worldwide mainly because: first there is no standard type or size of batteries, second not all EVs models have a possibility to swap batteries, third high cost and complex technology of the swapping station and its infrastructure. (EEA , 2016)

4.4.3 Wireless charging

Wireless charging (wireless power transfer) uses electromagnetic fields to transfer electricity from a transmitting source to the battery without using any physical connection (powerbyproxi.com , 2014). Advantages of this technology are mainly reduction of the cost related to the maintenance of the connectors, safe charging device. This technology could be a solution for public parking area like parking spots of famous streets in the downtown where there is no space to put many charging stations with many cables for each vehicle. Another area could be interesting in future, using this technology for “Electrically Charged Highways” (powerbyproxi.com , 2014) which enable charging vehicles in the high way with no need to stop. Nowadays, England is testing the availability of the technology (powerbyproxi.com , 2014).

To sum up this section, we can find out that there are many interesting technologies with high expectation to have more focus from researchers and investors to try to push them in the market and exploit them in feasible way. Mainly, Li-ion is one of the most important technology in which

Tesla is investing significantly, because of its high potential performance of Li-ion batteries especially, higher driving range and thereby high energy density beside faster charging. Tesla has decided to build many huge factories to exploit economies of scale to have strong reduction in the cost of the battery and try to push the Li-ion to be the main stream in the market.

The second main technology is Fuel cell electric vehicles (FCEVs), mainly because it is clean technology with zero emission however, it will be able to overcome the main drawbacks of EV which are long time for charging and short driving range. Indeed, FCEV has quite long driving range around 160-500 km and recharging time like conventional vehicles however with low spread of its charging stations and also this technology is still at the developing stage and needs more time mainly because its complex system.

The third technology which is Wireless charging could have big impact on the EV market in general. Indeed, we can exploit this technology in different phases of charging electric vehicles: for examples during parking time in malls or other open areas without any connectors. Moreover, with the attempt of England to exploit Wireless charging in highway it could be a good solution for short driving range problem which means that customers will be able to travel with their EVs long distance without stops.

4.5 Investments in batteries and charging stations

With the significant growth of EV market and the high expectation for the future, most of investors are looking to invest in EV technologies especially in electric batteries by acquisition or build up batteries plants. Also, EV market benefits that not only electric vehicle manufacturers are interesting in electric batteries, but also many main players in other industries such as; oil and gas

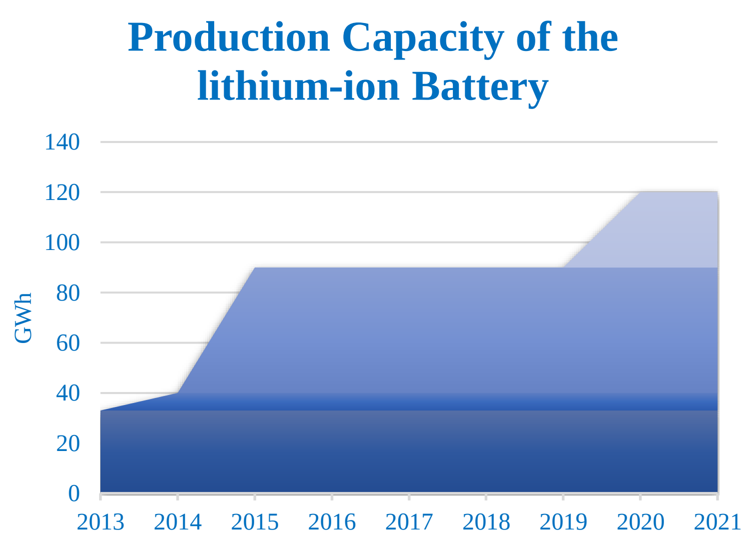


Figure 15: capacity of Lithium-ion Factory (energyandmines.com, 2015)

producer who want to invest more in renewables, also high-speed trains manufacturers and others. Here we can see many case studies of big acquisition and big plants made by main manufactures who are specialized in many industries worldwide. In 2015, production capacity was approximately 35 GWh worldwide. However, it is expected that the total capacity reaches around 122 GWh in 2020 once Tesla's plan for many Gigafactories, LG Chem, Foxconn, BYD, and Boston Power are complete (visualcapitalist, 2015). With more concentration of investment in electric batteries market, the efficiency will increase and cost will decrease by exploiting economies of scale and scope. And in general, because batteries are the most expensive component in the EV will decrease, consequently we expect that EV will compete with conventional vehicle in the future even with lower prices.

4.5.1 Acquisition of start-ups and companies working in electric batteries

1- Saft and Total

Is one of the largest designer and manufacturer of advanced technology batteries. They are working mainly in nickel batteries and also primary lithium batteries. They are operating in 18 countries and have 14 manufacturing sites (idtechex, 2017). Saft has been acquired by oil giant Total for 1.1 Billion $ which has already $4bn Hutchinson subsidiary in vehicle mechanical parts and batteries for electric vehicles.

2- Seeo and Bosch

Seeo is a lithium-ion startup is based in California US, Bosch has acquired it to make a move toward the EV market (forbes, 2015). Seeo is focusing in delivery solutions to EV and PHEV manufacturers by making significant improvement in the performance of the electric battery in terms of energy density and also driving distance with less weight (www.seeo.com, 2017). Seeo is not the first attempt of Bosch to enter the EV market, but there was also a joint venture with Japan's GS Yuasa and Mitsubishi in 2013 to make lithium-ion batteries (forbes, 2015).

3- Magna Steyr and Samsung

Another case that shows how EV attracted a main player from another industry to enter EV market and not only this but also the competition between Samsung and Apple has moved to be in EV market as well Samsung has succeeded to acquired Magna Steyr which was a target for Apple. Magna Steyr is working in many departments for design and build car parts including battery system from electric and hybrid vehicles (businessinsider, 2015).

4- CATL

Now we are talking about China's fastest growing battery maker. CATEL plans to grow its battery capacity by 2020 to 50 GWh which is even more than 35 GWh of Gigafactory of Tesla in Nevada. Here the competition between US and China and who will control the EV market in the future. "We hope by 2020 we can achieve performance and price that lead the world" CEO of CATL (fortune.com, 2016)

As we can see that, electric battery is one of the main technologies which most investors from different industries are interrested to invest and make a move to participate in the EV market in the furture.

4.5.2 Acquisition in charging stations companies

As well as batteries, investors invest also in charging stations because it is one of the main factors for growing the market of EV. The aim of these investment to satisfy the need of the charging stations network and also provide high quality service in terms of speed of charging.

1- EV-Box

EV-Box is a startup which is a supplier of EV charge points with management software and they are working 20 markets including Belgium, Scandinavia, Germany, the UK, and the US, with 40,000 charge stations. EV-Box has been acquired by French electric utility company ENGIE (energy generation and distribution) (tech.eu, 2017).

2- EVgo

They are working in high-power fast charging stations. And they work with ABB to provide the network with incredible speed of charging. The high-power fast charging system has been manufactured by ABB with a maximum charging rate of 150KW. However, they are working to upgrade the system to be 350-400KW which will be the next step in the evolution of EVs. That means that Nissan leaf vehicle with 30kWh battery will need only max 10 mins or less to be fully charged. With the comparing with the max speed in the market of Supercharger of Tesla with max rate 145KW, we can expect huge jump in the world of EV in the future. (ABB, 2017)

3- EZ-CHARGE

With new business model, they have made agreement with Nissan Leaf for "no charge to charge" program. Which allow Nissan Leaf owners to charge their vehicle in EZ-charge stations free for 2 years. (nissanusa, 2017)

4- EVmatch

EV charging startup aims to connect private charging station owners with EV drivers who are looking for a charge to reduce the gap in EV charging infrastructure by providing a platform Mobile APP. With this solution, the host can make money and increase the network stations. (cleantechnica, 2017)

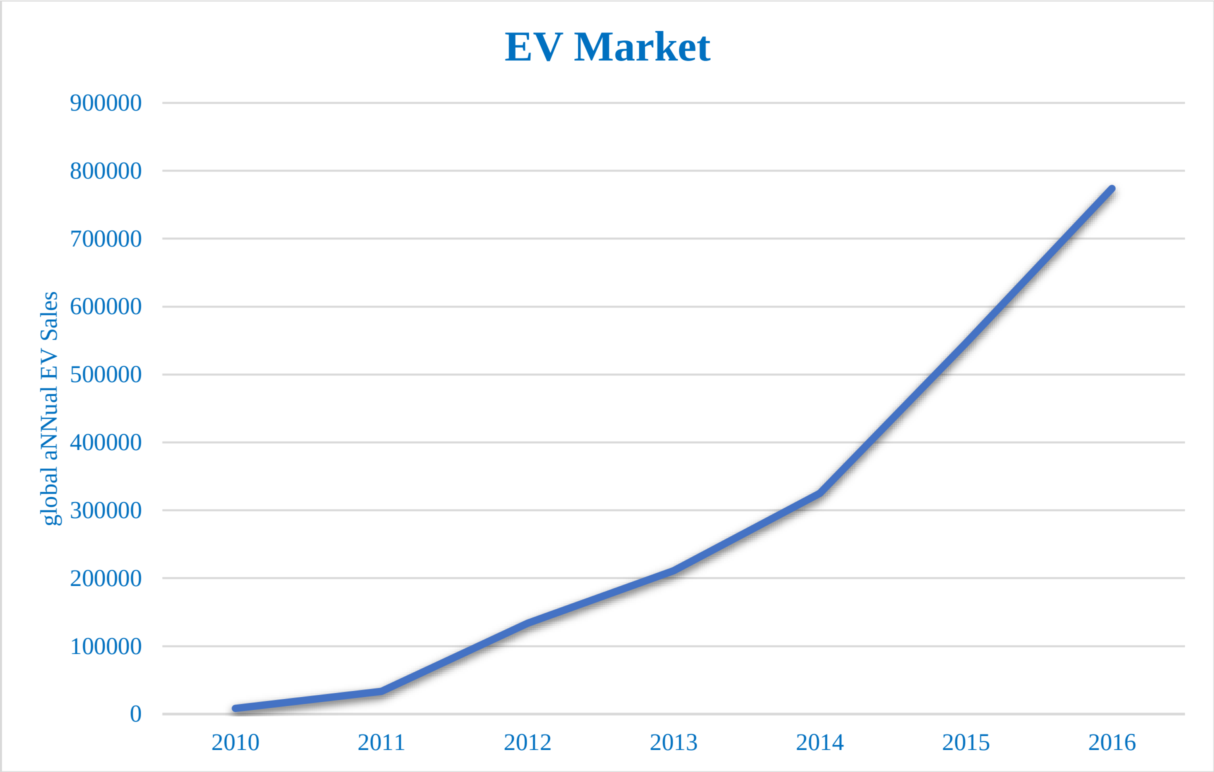


Figure 16: EV Market (cleantechnica, 2017)

Finally, we can imagine this future scenario the customer of EV with very long driving range battery and he/she will be able to charge the battery with less than 10 mins without paying fees and charging stations everywhere. Consequently, with no doubt EV will be the future of auto market. And that is why we can see very fast move from big investors from different countries and different industries toward EV market to ensure participating in the future. In particular, investors, from different industries, are the key actors in batteries investment but mainly carmaker. And for charging stations, the key actors are energy utilities.

5 Total Cost of Ownership model of BEV

5.1 Introduction

We wanted to understand how Electric vehicle can compete conventional one and how using supercharging stations (80% charge of the battery in just 30 minutes, (tesla, 2017)) can be useful without any reduction in the efficiency of BEV respect to diesel vehicle. Moreover, our basic model will be without any shape of Government intervention to be as base line can be applied in any country.

Indeed, we will emphasis the important factors which have strong impact on the competitiveness of BEV. Moreover, we will try to understand how we can achieve breakeven between BEV and Diesel vehicle by making changes in the share of each important factor (i.e. battery cost or diesel price and others) by increasing/reducing the impact of this factor on the cost structure of BEV or Diesel vehicle.

And we will try to understand There is a need for government intervention or not? and if yes, how much does it need to support logistics companies to start adoption of BEV to move to greener environment and higher social welfare. On the other hand, we will try to find solutions to achieve a certain reduction in the Total cost of ownership of BEV to be more competitive and sustainable.

In general, companies are seeking for profit maximization, consequently we applied TCO model to give general idea about the cost structure. And help them to decide what is the optimal situation and time to start investing in BEV for example; when the cost of battery will decrease a certain percentage or when the incentives for adopting BEV will increase and reach a certain percentage.

Generally, the analysis has been made by using average value of the important factors among European countries. The aim of using the average value is that this model can be used as general guideline for all Europe and not for a specific country. Moreover, we have tested the sensitivity analysis of cost of structure of both BEV and Diesel vehicle by making changes in some variances in e-mobility to assess how the situation will change over time. Furthermore, we mainly checked up the results of some assumption for a significant increase performance and reduction in cost of batteries in the future and how the cost structure will be changed. We used in our analysis the most common specification & technical data of light commercial vehicle in the market (Lebeau, 2015) to make our analysis could be used for any vehicle not only for specific kind of vehicle.

Table 4: Vehicle specifications (Lebeau, 2015)

Motor Type	**BEV**	**Diesel**
Average Purchase Price (€)	22457.8	13396.6
Consumption rate	165 WH/km	5.0L / 100 KM
Battery capacity/fuel tank size	24kWh	55 liters
Driving Range	170.59 km	1100 km
CO2 Emissions	0 G / KM	131 – 133 G / KM
Maximum Load Volume	4.2 m³	4.2 m³

5.2 Methodology

5.2.1 Total Cost of Ownership

We used TCO model to consider the associated cost of specific asset along its whole life time which is the purchase price of an asset plus the costs of operation over a limited period of time (investopedia). And try to compare between the full cost of different alternative and evaluate the most profitable one. Hence, the total cost of ownership methodology uses the financial formula of the present discounted value:

$$PV = \mathrm{TCO}_t \frac{1}{(1+I)^t}$$

Where:

- PV: Present value
- I: Real discount rate
- T: Time (expressed in number of years)
- TCO_t: Amount of one-time TCO at a time t

TCO = $TCO = PP_0 - RV_0 + \sum_{t=0}^{T}(FC_t + IC_t + MC_t + BC_t)$

Where:

- PP: purchasing price
- RV: residual value
- FC: feeding cost, in case of EV refers to energy cost while for ICEV refers to fuel cost
- IC: insurance cost
- MC: Maintenance cost
- BC: battery cost (in case of electric vehicle)

5.2.2 Assumptions of the model

the TCO equation can be divided into three variables:

a- the period of time (lifetime of the vehicle)
b- the discount rate applied to future costs to actualize them.
c- the costs of ownership

5.2.2.1 the period of time (lifetime of the vehicle)

we would consider the average of end life of light commercial vehicles in UK as the average for Europe equal to 8 years (statista.com, 2017). Hence, total cost of ownership for both BEV and diesel vehicle will be calculated over 8 years.

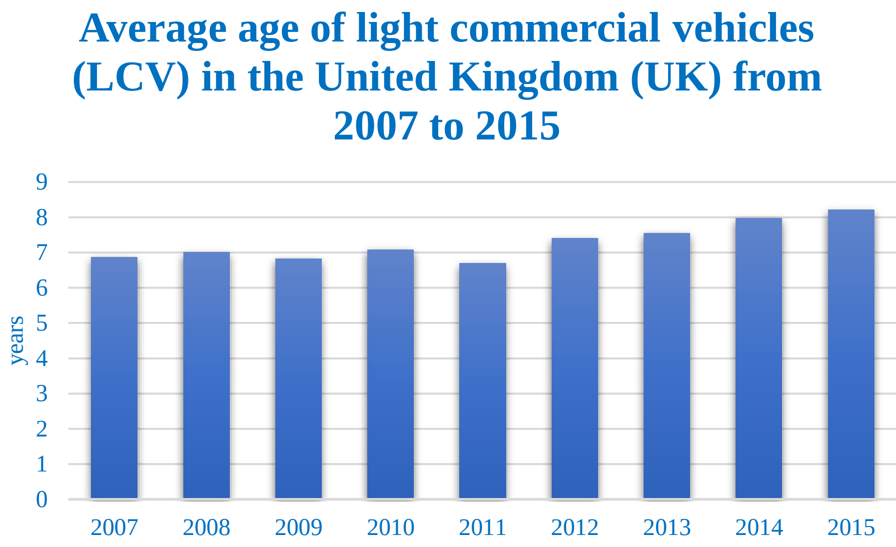


Figure 17: Average age of light commercial vehicles (LCV) (statista.com, 2017)

5.2.2.2 Discount rate

The discount rate is the interest rate which is used to calculate the present value of future cash flows in standard discounted cash flow analysis (propertymetrics, 2013). Many companies calculate their weighted average cost of capital and use it as their discount rate when budgeting for a new project. For this TCO calculation, we used average 10-Year Government Bond Yields for Europe as reference, therefore for the real discount rate is 1.86% (bloomberg.com, 2017). We extract from the interest rate the 1.4% of average expected inflation in Europe (ecb.europa.eu, 2017) to find a real discounted rate of 0.46%.

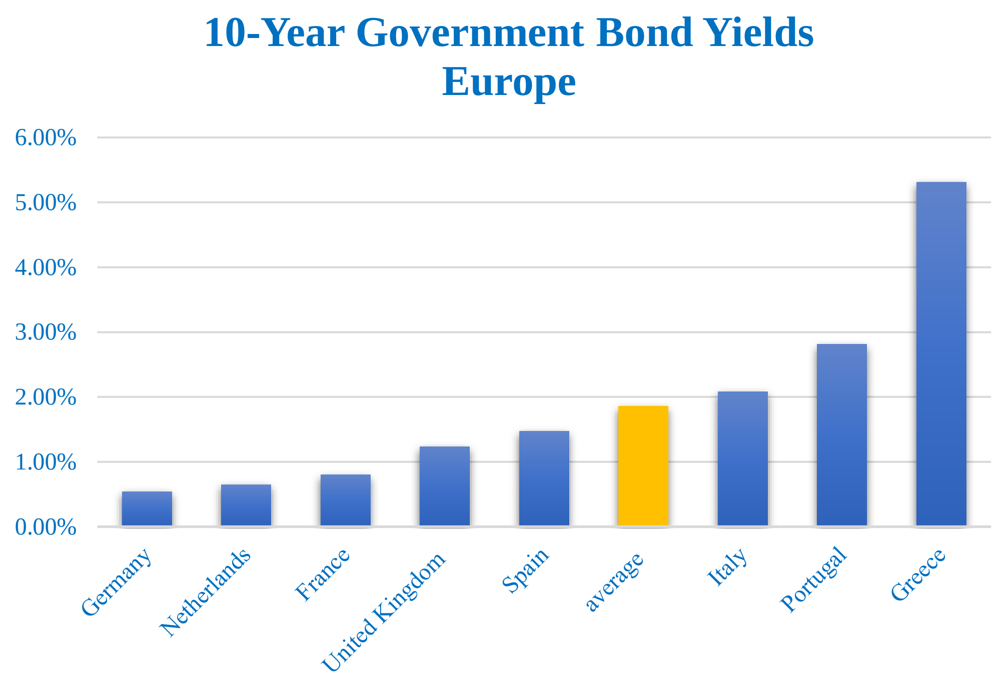


Figure 18: 10-Year Government Bond Yields Europe (ecb.europa.eu, 2017)

5.2.2.3 Cost of ownership

The analysis of the cost of ownership considers every cost associated to the use of the vehicle with excluding road tax (assumed as equal for both), and any government intervention (incentives, tax deduction, and registration fee. Moreover, we did not consider the cost of the infrastructure associated to the supercharging station which will be influenced by the number of electric vehicles will be purchased by the company and there will be a possibility of exploiting economies of scale consequently the cost of the supercharge station will be reduced, with increasing the number of BEVs owned by the company.

5.2.2.3.1 Vehicle purchase cost

We used the average purchasing price of most best-selling light commercial vehicle models in Europe annex 1 (statista.com, 2013). This cost reflects the depreciation of the vehicle during the period of ownership. The depreciation rate is the difference between the initial price and the resell price of a product after a period of time (chron.com). Depreciation is computed by a complex process dependent on factors such as: vehicle features (color, equipment) brand perception, fuel prices, maintenance costs, quality scores, and government regulations. Consequently, we have different depreciation for both BEV and Diesel vehicles (JensHagman, 2016) . Mainly, because of low possibility to resale BEV and less mature market for second hand BEV (Lebeau, 2015).

Table 5: Depreciation rate and average purchasing price of BEV and diesel vehicles (Lebeau P. , 2013)

	depreciation	**Average purchasing price (€)**
Diesel	18.57%	13396.6
BEV	24.43%	22457.8

5.2.2.3.2 Driving distance

One of the most important factors which affects many shares in the cost structure of both BEV and diesel vehicle. In BEV, driving distance can influence many parts in the cost structure, for example; with increasing driving distance, we will need to increase number of charging cycles which we can expect that we will need to substitute more number of batteries during the lifetime of the vehicle which will introduce more cost of the battery share in the cost structure of the BEV. On the other hand, in diesel vehicle, increasing the driving distance will introduce increase in the share of energy cost in the cost structure of diesel vehicle.

In general, driving distance will introduce the utilization rate of the vehicle. According to one of the largest UK parcel delivery carriers, we could find that companies are operating in three categories which are highly-efficient delivery operation, city center-focused, or/and rural areas (the greater distances between drops) (Heriot-Watt University, 2009):

Table 6 different degree of Capacity Utilization (Heriot-Watt University, 2009)

Highly-Efficient Delivery Operation	**City Center-Focused**	**Rural Areas (The Greater Distances Between Drops)**
60-Mile	25-Miles	80-Miles
150 Drops	110 Drops	70 Drops

The higher utilization rate, the higher economic feasibility for E-Vehicle. Consequently, we assume that for one day the vehicle can operate two trips/shifts with the average distance of one trip is 60-mile (around 97 km) equal to the highly-efficient delivery operation so that, the vehicle makes 194 km daily which is more than the maximum distance can be made by one charge for the battery in BEV (24kWh), so that we needed to recharge the E-vehicle between the two trips. Due to the supercharge station, so it will take about 30 mins to charge 80% of the battery (tesla, 2017) however, we can expect that the vehicle could return with a specific percentage of the battery still charged because the vehicle will not operate exactly the maximum distance can be made by one charge therefore, during charging the battery we can expect save time because we will not need to charge the whole battery.

During charging time, it could be used for loading/unloading process in the hub. Therefore, EV and diesel vehicle are equal in terms of time efficiency. Hence, both vehicles can make approximately 50,440kms per year and we will fix this yearly distance for all our analysis as a baseline.

5.2.2.3.3 Insurance cost

For insurance cost, it depends on two different criteria first for vehicle-specific such as: performance, safety ratings, weight, and vehicle value. And second for owner-specific such as: number of accident-free years, age, gender, and address (statefarm.com). However, insurance cost will be different for both BEV and diesel vehicle because of different power of the motors which is lower in the case of BEV. Consequently, in our model we have applied the insurance cost for a last mile logistics company based in Brussels, and operating frequently, with a 30-years driver and no accidents in the last 5 years, we can get average insurance for different vehicle models (Lebeau, 2015):

1- average insurance cost for diesel vehicle: 909.728€/year
2- BEV: 892.9916€/year

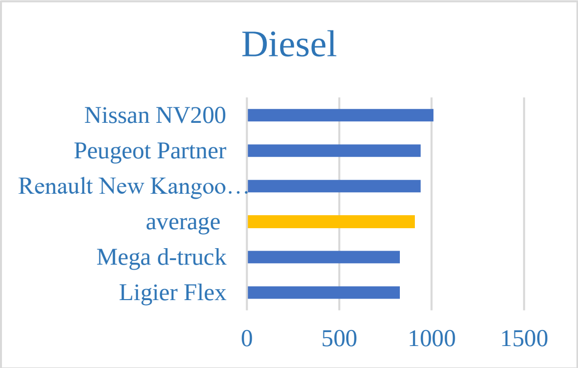


Figure 19: insurance cost of Diesel vehicle

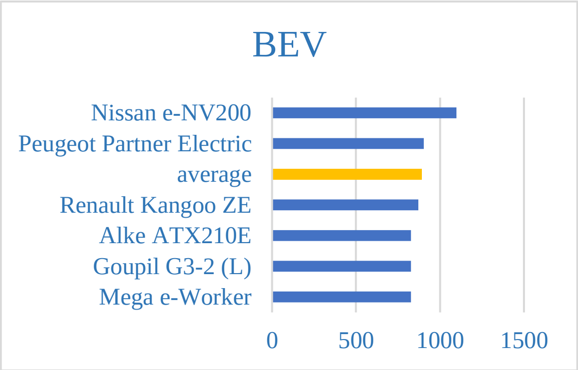


Figure 20: insurance cost of BEV

5.2.2.3.4 Energy costs

For BEV, we have considered the average price of electricity in Europe for industrial sector which is 0.114 €/kWh (ec.europa.eu, 2017). So that with 24 kWh-battery which is able to make approximately 160 km by one charge, the mileage will be: 24: 160 = 0.15 kWh / km. At this point just multiply the two values:

€ / kWh x kWh / km - to get the mileage in euros. Thus, we have got:

$$\text{mileage in euros} = 0.15 \text{ x } 0.114 = 0.0171 \text{ €/km}$$

For diesel price, there are different prices between European countries, hence, we have applied the average price of diesel in Europe in our module.

the mileage in Euros will be (€ / km) = (€ / Liter) x (Liter / km)

mileage in euros = 1.15 x 0.05 = 0.0575 € / km

Table 7: Diesel prices in Euros (drive-alive.co.uk, 2017)

Diesel prices in Euros	**average**	**highest price of Norway**
€ / liter	1.15	1.56
(€ / km) = (€ / Liter) x (Liter / km)	1.15 x 5/100 = 0.0575	1.56 x 5/100 = 0.078

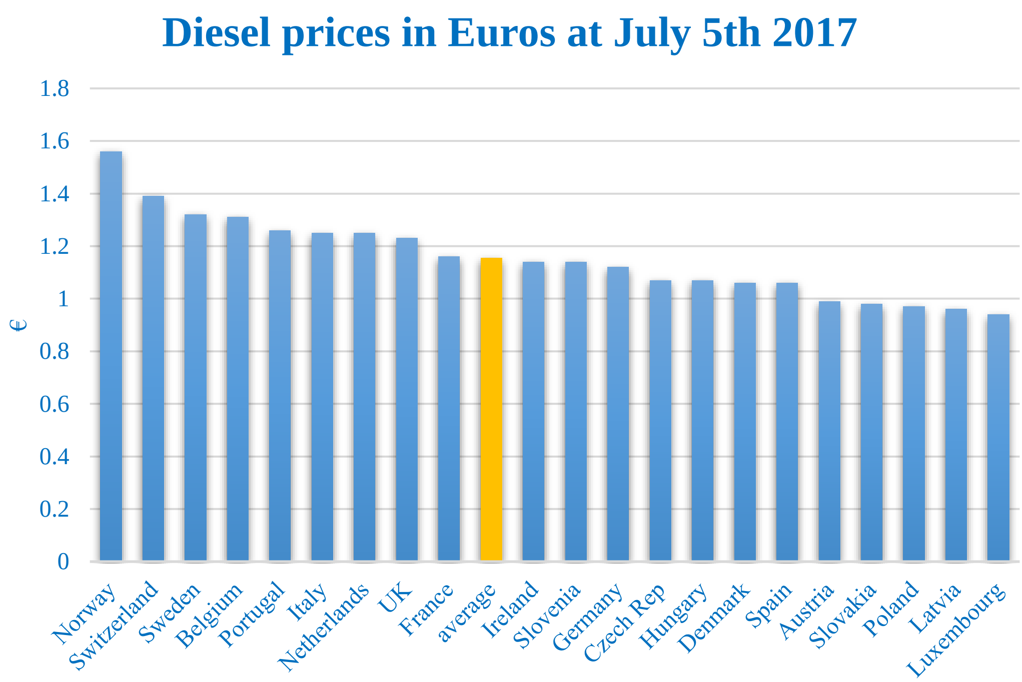


Figure 21: Diesel prices in Euros (drive-alive.co.uk, 2017)

5.2.2.3.5 Maintenance costs

Generally, from the outside, the electric vehicle looks like a diesel one. However, internally, it is a quite different story, 70% of an electric vehicle 's component parts may be different from a diesel-powered vehicle. BEV has several unique components that serve the same function as the more common components in a diesel vehicle.

The significant difference between electric vehicles and diesel vehicles is the number of moving parts. The electric vehicle has one moving part which is the motor. whereas the diesel-powered vehicle has hundreds of moving parts. Fewer moving parts in BEV leads to another important difference. The BEV requires less periodic maintenance and is more reliable. The diesel vehicle requires a wide range of maintenance, from frequent oil changes, filter replacements, periodic tune ups, and exhaust system repairs, to the less frequent component replacement, such as the water pump (Idaho National Laboratory).

Due to less moving parts in BEV and there is no internal combustion engine as well as not need to replace oil and filter. Consequently, maintenance cost of EV is 50% of conventional one. With cost rate 4.3€/100km for conventional vehicle and 2.2€/100km for EV (Lebeau P. , 2013).

5.2.2.3.6 Battery Cost

The cost of batteries is one of the major obstacles standing in the way of widespread use of BEV (iflscience.com). There are many kinds of the batteries in the market such as lithium-ion and lead-acid however we used lithium-ion in our model because li-ion is not mature technology yet hence, there is high expectation to have high performance in terms of long driving range, lifetime, and reduction in the battery cost in the future (smithsonianmag.com, 2017).

In our module, we have carried out our calculation with the average price of lithium-ion in the global market which is $227/kWh (193€/kWh) (electrek.co, 2017). the battery cost is one of the highest shares in the price of the BEV, for this reason, to be more accurate, we have deducted the cost of the battery out of the initial purchase price of the e-vehicle. Furthermore, we separated the battery cost to have more concentration in the analysis. And we will check how the cost structure of BEV will be changing with reducing the battery cost gradually until achieve breakeven between BEV and diesel vehicle.

- 1 Dollar = 0.85 Euro (investing.com, 2017)

Table 8: EV battery pack price (electrek.co, 2017)

	2016	**2020**	**2030**
EV battery pack price	$227/kWh	$190/kWh	$100/kWh
Price of 24 kwh	4607 €/ pack	3856 €/ pack	2040 €/ pack

5.2.2.3.7 The lifetime of the batteries

Service life is measured by Cycle life which is the number of discharge/charge cycles the battery can handle at a specific DOD (normally 80% (Kwo Young, 2013) and DOD is used to describe how deeply the battery is discharged. If we say a battery is 100% fully charged, it means the DOD of this battery is 0% (bestgopower.com). by using Li-ion batteries which have around 600 cycles (The University of Tennessee at Chattanooga, 2012), and with heavy duty two trips per day, for 260 days yearly. Consequently, it is expected to replace a battery pack around 7 times a year and we have used these numbers for the basic scenario. With neglecting any opportunity of replacement by warranty. Indeed, because of the lifetime has a strong effect on the feasibility of BEV, thereofore we will check how the TCO will be changed with increasing the performance of the battery in terms of number of cycles gradually. which is expected to grow in the future for Li-ion with reduction in the cost.

Table 9: The lifetime of the batteries (venividiwiki, 2014)

The lifetime of the batteries (cycles)	**600**	**1500**	**2000**
replacement	around 1 year	around 3 years	around 4 years

5.2.2.3.8 Incentives

In general, there are two types of incentives of BEV either direct incentives or indirect incentives. Direct incentives which are given on the price of the acquisition. One the other hand, indirect incentives which are provided as cost reduction for the usage of vehicles.

In particular, direct incentives for the acquisition may be:

- acquisition facilitation
- VAT deduction
- Tax reduction;

while usage incentives are:

- Road fund license exemption
- Parking/highway payment deduction
- Energy cost reduction

Table 10:Incentives provided for EV. (Energy&Strategy, 2017)

Country	Direct incentive during the acquisition			Incentive for the usage		
Country Region	**acquisition facilitation**	**VAT deduction**	**tax reduction**	**road fund license exemption**	**parking/highway payment deduction**	**energy cost reduction**
Norway						
Germany						
China						
USA						
France						
UK						
Netherlands						
Italy						

Because there are neither standard international subsidies nor tax deduction and mainly depends on the country government and even locally decision, consequently, we will consider that there is no subsidies nor tax deduction for the basic scenario and we will test sensitivity analysis to achieve the breakeven between BEV and diesel vehicle.

5.3 The result

5.3.1 Basic scenario

We applied our model on a highly-efficient delivery operator who can carry out minimum total distance 50,440kms per year which includes 60-mile in 2shifts daily and 150 drops. And we assumed that the vehicle can continue working until the end of its lifetime (8 years) with the same efficiency. We did not introduce any government intervention in this model to make it possible to be applied in any country and any region. Furthermore, to check the situation in which BEV will be able to compete diesel vehicle with the original circumstances which not provide any benefits or barriers (tax) for both BEV and Diesel vehicle. Moreover, we did not apply the highest price of diesel because it will reduce competitiveness of diesel vehicle whereas, we used the average price of diesel in European countries. And we did the same with price of BEV, we did not use the cheapest vehicle however, we used the average price of the main companies in the market and the same with diesel vehicle. Moreover, we integrated the system with supercharging stations and we have checked up how can the new technology of supercharging (80% of the battery in 30mins) can change the competitiveness of BEV. However, we could not merge the cost of these supercharging stations in average cost of BEV because it mainly depends on how many vehicles this company will own. The higher number of vehicle, the lower average cost occurred by the charging station due to exploit economy of scale.

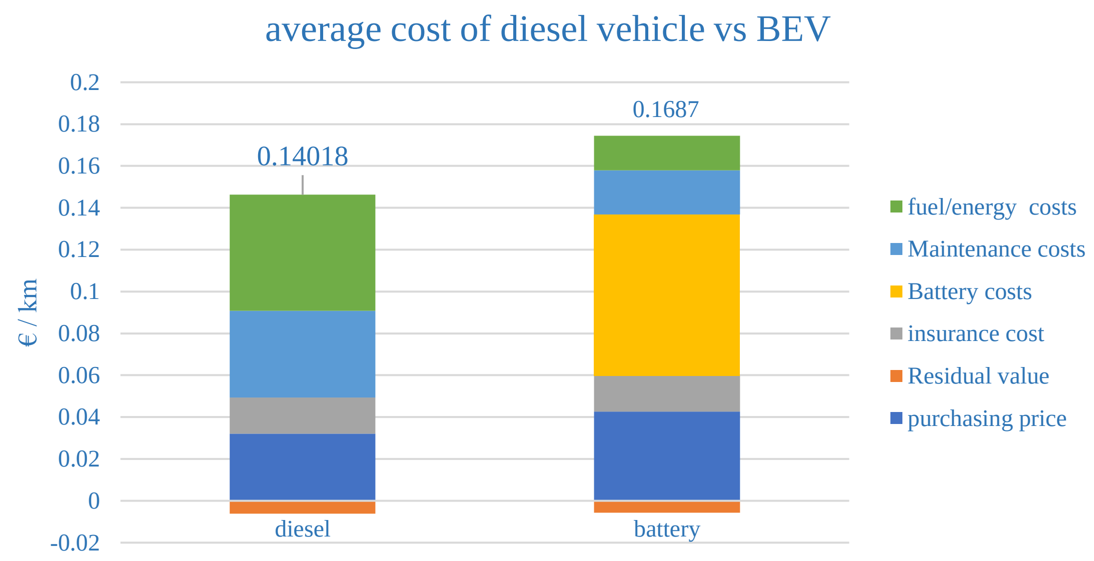


Figure 22: Basic Scenario (average cost of diesel vehicle vs BEV)

As we can see in Figure 22 that with current cost structure of both vehicles and technical features of electric vehicle especially short lifetime of the battery which required to substitute the battery seven times during the lifetime of the vehicle which is very costly. consequently, BEV lost the competition against diesel vehicle, even though the main advantages of BEV which are lower maintenance costs and lower energy costs. Furthermore, this result can make us understand why BEV has very small share in the market of urban logistics. Moreover, BEV cannot be sustainable without the government intervention.

As we can see that Battery cost (4607€ per 24 kWh) has the strongest impact (41%) of the total cost structure of BEV. Because of its current high price which is expected to be lower in the future. Another reason, we applied the model on high-efficient logistics company which need to operate 2 shifts/day and 60miles each. Consequently, we needed to charge the battery two times a day hence, we needed to charge during the whole lifetime of the BEV equal to 4160 times (2-shifts x 260 working days x 8years) which express the total number of cycles (charging/discharging) needed during the whole lifetime of BEV and therefore we needed to replace 7 batteries during the whole life of the vehicle and each battery has 600 cycles (7 batteries = 4160/600 cycles). The need to use 7 batteries increased significantly the average cost of BEV and overcome the advantage of low cost of energy and maintenance cost of BEV against diesel vehicle. So that, the diesel vehicle costs less than the BEV by 11518 €/ 8years.

On the other side, we can observe that the fuel cost and maintenance cost are the biggest shares in the cost structure of diesel vehicle. However, we used a constant maintenance cost during the 8

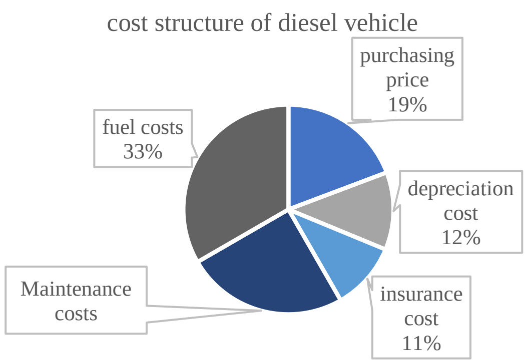


Figure 23: cost structure diesel vehicle

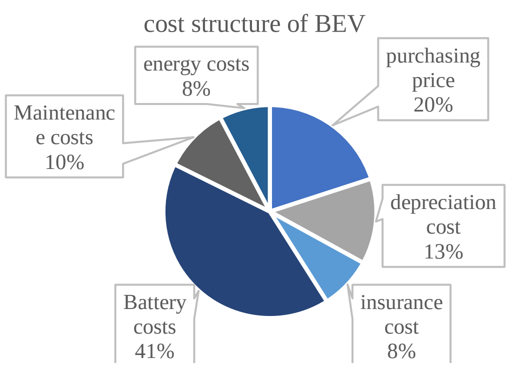


Figure 24: cost structure BEV

years for simplicity, however, it is not too accurate because maintenance cost increasing gradually with aging of the vehicle and increase significantly in the last years of the lifetime of the vehicle. Therefore, we expect that maintenance cost should have bigger share in the cost structure in our model.

5.4 Sensitivity analysis

Sensitivity analysis refers to simulation analysis, which is a way to predict the outcome of a decision given a certain range of variables. By creating a given set of variables, which it will be possible to determine how changes in one variable impact the outcome (investopedia.com).

As we said that we have made our calculations by current number and performance for the basic scenario. Furthermore, we have tested sensitivity analysis to achieve the breakeven between BEV and diesel vehicle. We have created 7 scenarios for set of variables:

1- Distance per trip without using supercharging stations
2- Distance per trip with using supercharging stations
3- lifetime of the battery in terms of number of cycles
4- Price of the battery
5- Combination between price and lifetime of the battery

6- Price of the diesel
7- Government intervention

5.4.1 Comparison between using supercharging station and without

By using supercharging station, which enables us to operate two shifts a day or more. How could be the situation without supercharging station which means that the vehicle will operate only one trip with maximum 170 km and after that it must stay around 6 hours to be full charged again therefore it cannot work another trip at the same day. In this situation and these circumstances, the operator could be better off by using supercharging stations or not? And BEV can reach breakeven with diesel vehicle in terms of cost/km with only one trip?

We made a comparison between two situations:

1- the situation of using supercharging station as basic scenario (two shifts 60 miles each).
2- the situation of operating with normal charging stations therefore we made the model with only one trip with minimum 60miles/trip.

We could observe that the gap between the cost of BEV and the diesel is getting bigger from moving from two trip/day to one trip/day Table 11. Mainly because in two shifts- situation we exploited economies of scale which is higher degree in BEV than diesel so that the fixed cost like initial purchase is distributed on more kilometers so the average cost decreased. However, this gap did not increase so much as expected because when we used only one shift, we decreased the number of charges (cycles) consequently we needed to substitute only 4 batteries during the lifetime of the vehicle instead 7 batteries in two shifts model which is big increase in the cost of the battery and as we could have seen that battery cost is the greatest share in the cost structure of BEV.

Even the cost of both BEV and Diesel vehicle increased by moving from operate two shifts to operate only one shift however, Diesel is still less costly than BEV.

Table 11: comparison between using fast charging station vs. using normal charging station

	Fast charging station (2 shifts 60miles /day)	Normal charging station (1 shift 60miles/day)
BEV (€ / km)	0.168731086	0.233739026
Diesel vehicle (€ / km)	0.140187025	0.183497053
The gap (€ / km)	0.028544	0.050242

however, one of the benefits of using supercharging stations that enables us to have an opportunity to reach breakeven between BEV and diesel vehicle by increase number of shifts/day so more distance-kilometers which we cannot reach breakeven in the case of only one shift even if we operate max distance can be made by one charge of the battery which is 170 km Figure 25. However, we could reach breakeven with two or three shifts and we checked it up in sensitivity analysis on distance with supercharging stations. Moreover, even if the cost of BEV is very close to the cost of Diesel when we have increase equal to 70% in the Figure 25 however, this can happen with maximum capacity of the battery which is decreasing with aging of the battery consequently we cannot rely on the maximum capacity of a new battery.

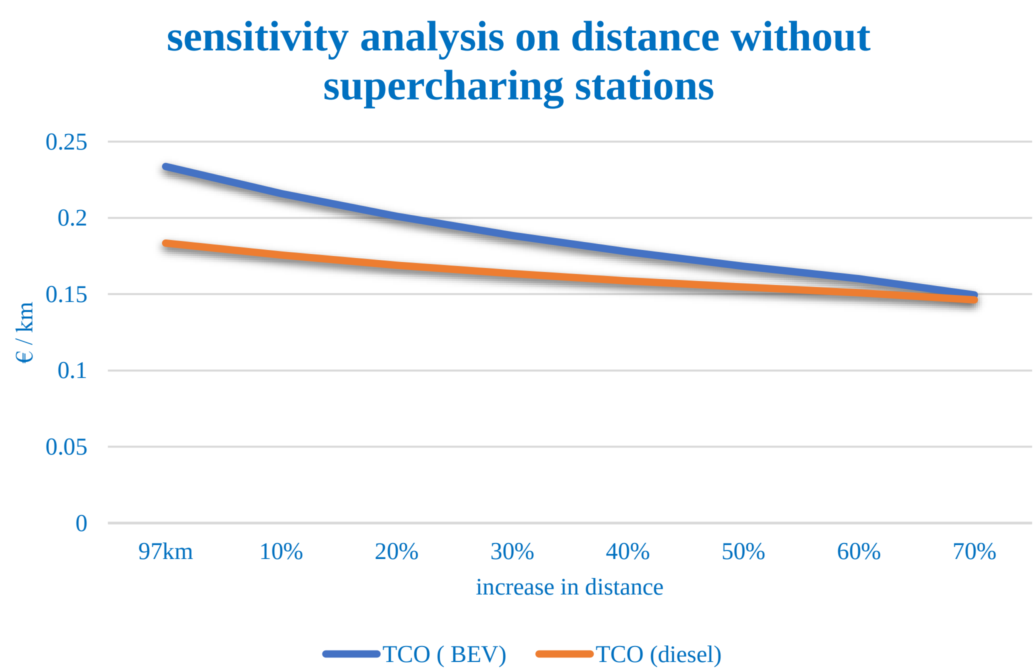


Figure 25:sensitivity analysis on distance without fast charging stations

5.4.2 Sensitivity analysis on the distance per day

As we found that it is necessary to use supercharging stations to achieve breakeven between BEV and Diesel. We started with basic scenario's calculation and supposed that the company can operate 2 shifts/day and 60mile each and from this situation, we started to increase the distance to try to achieve the breakeven. As we can see in Figure 26 that we can increase the distance to exploit economies of scale however after one-point fixed cost will increase significantly hence increase distance will be diseconomies of scale. We could achieve breakeven when the company can operate 143.78km/trip in two shifts however, we could increase efficiency of using BEV by increase distance until we can reach the maximum distance can be made by one charge of battery which is 170km for each shift. And if we need to increase more distance so that we need to move to operate another shift so it will be three shifts/day. However when we operate one additional shift therefore we will increase the number of charging times which affect the lifetime of the battery so that we can see in Figure 26 that when we increase the distance more than 75% , the average cost of BEV increased significantly, because when we started to operate three shifts/day, we will need to substitute the battery 11 times in the whole life of vehicle (8years) which it was only 7 times in case of two shifts which is a big cost which changed the situation from high efficient way to use BEV to very high cost over the cost of diesel. That is why the situation started to be diseconomy of scale. Consequently, we will need more to increase usage rate of the third shift to reduce the average cost to reach the breakeven again. And with the same sequence, we will reach one-point and after this point any increase in the distance will be diseconomy of scale.

With more distance per day, BEV is getting better than diesel vehicle and compete more with less average cost per km without any government intervention or any reduction in price of battery or longer lifetime of the battery. Consequently, BEV could compete Diesel vehicle nowadays with only high exploitation/usage rate of BEV with the current features of battery and average price of diesel in Europe.

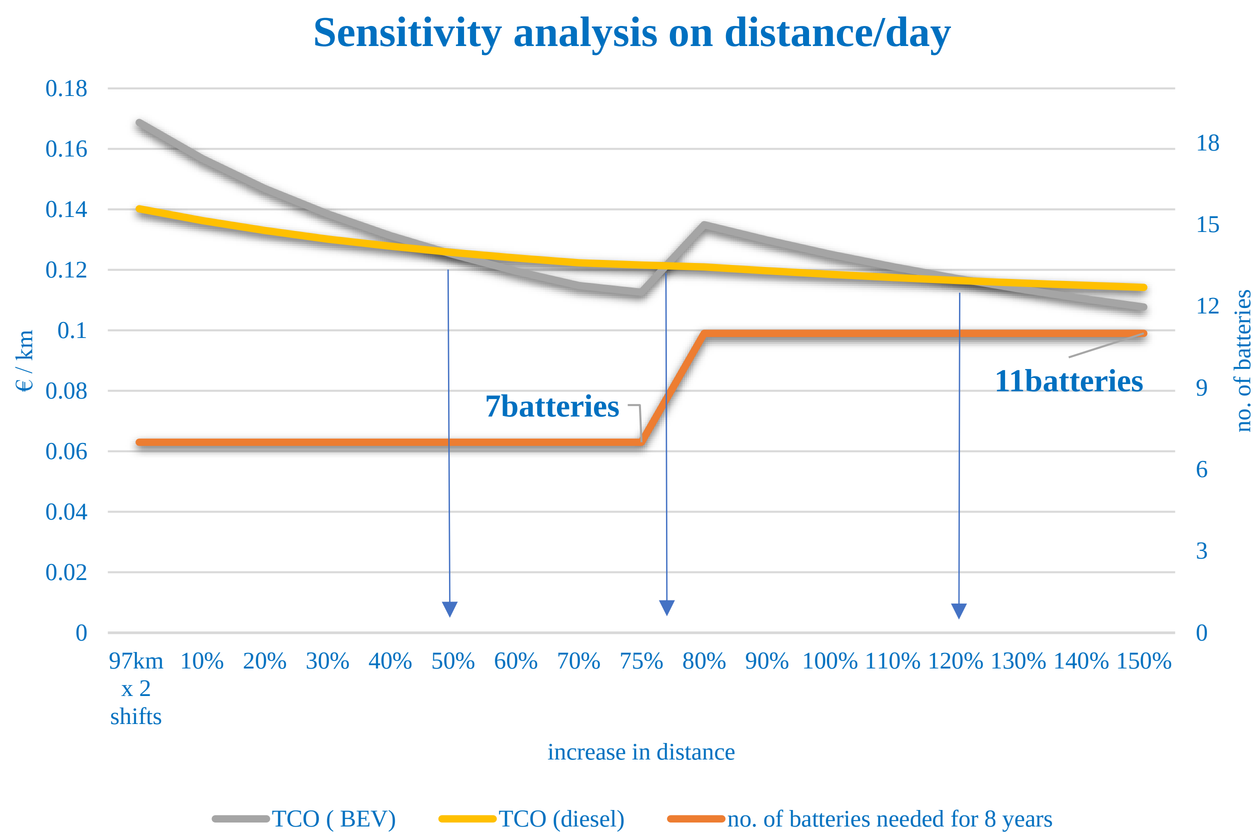


Figure 26: Sensitivity analysis on distance/day

5.4.3 Sensitivity analysis on lifetime of the battery

To make the lifetime of the battery longer with the same work efficiency, therefore it is needed to extend the cycle life which is the number of complete charge/discharge cycles the battery is able to support before that its capacity falls under 80% of it is original capacity (MIT Electric Vehicle Team, 2008). Consequently, if we could double the cycle life of the battery therefore, we will need to reduce substitution number of the battery during the lifetime of the vehicle to the half. Which will reduce the average cost of the BEV significantly. In the sensitivity analysis, we started the calculations with 6oo cycles/battery which is the current performance of Lithium-ion battery and gradually, we increased the number of the cycles to reach breakeven between BEV and diesel vehicle. Indeed, the average cost of diesel vehicle is fixed because it does have this kind of battery. We could achieve the breakeven when the cycles/battery reach 944 cycles consequently, it will be needed to replace the battery 4 times during the whole lifetime of the BEV instead of 7 times with

600 cycles/battery which influences the average cost per km of BEV as we can see in Figure 27 that the two curves of TCO (BEV) and number of batteries, when we introduce more cycles/battery hence, we need less batteries/8years therefore less average cost of BEV.

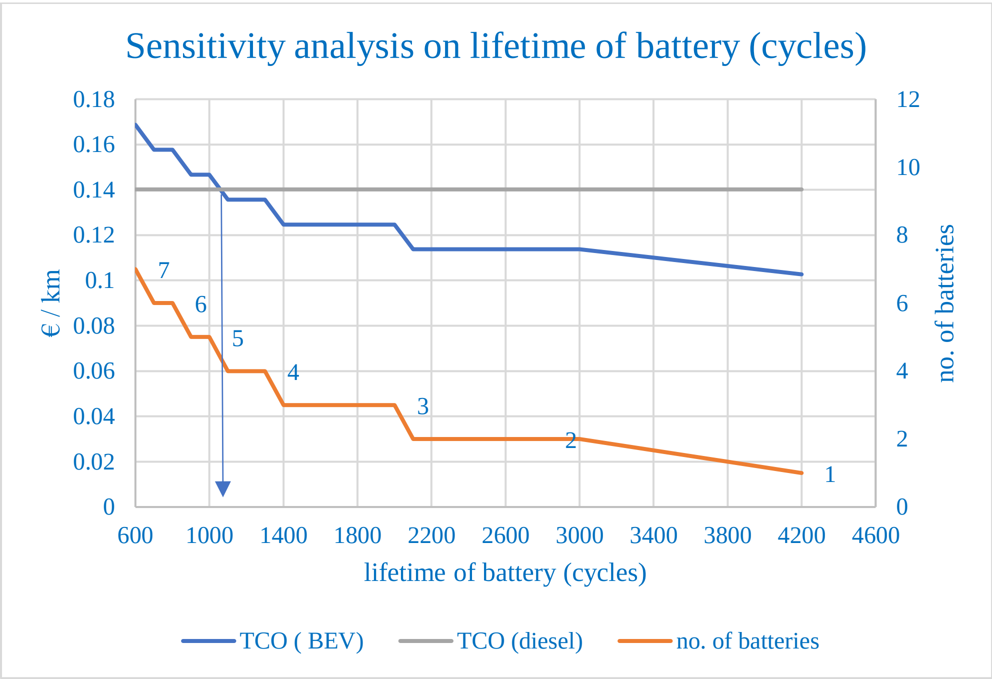


Figure 27:Sensitivity analysis on lifetime of battery (cycles)

5.4.4 Sensitivity analysis on lower price of the battery

As tesla claims that there will be a significant reduction in the price of batteries and it will go down to be $100/kWh in the future. in sensitivity analysis, we started the calculations with the current price of the Lithium-ion battery which is 192.22€/KWh as the basic scenario's price and gradually we decreased the price of the battery to achieve the breakeven which we found it equal to 108.98€/KWh and the average cost of diesel vehicle is fixed because the battery cost does not affect it. Furthermore, we could see in Annex 3 that the cost structure has been changed with the lower price of the battery which enables BEV reach breakeven with diesel vehicle. With this price, battery cost has been decreased from 38% to be only 25% of the total cost of ownership of BEV.

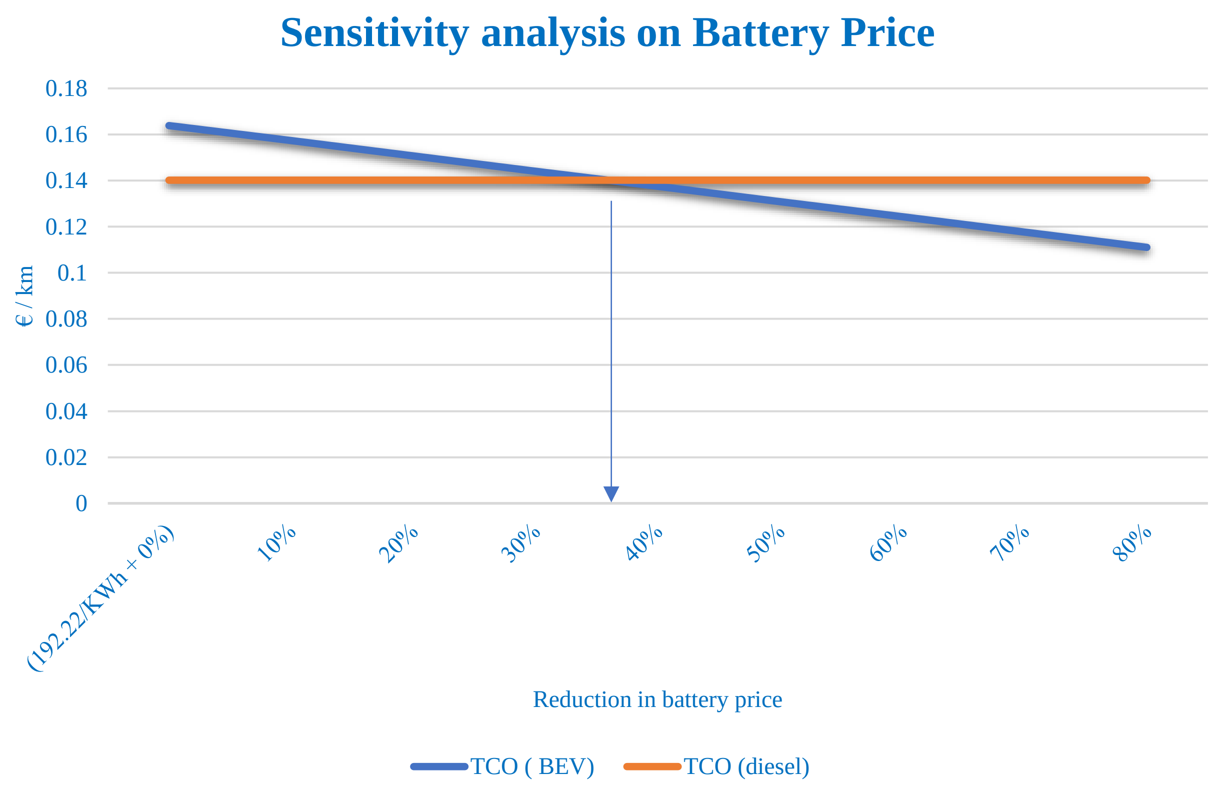


Figure 28: Sensitivity analysis on Battery Price

5.4.5 Sensitivity analysis on combination between lower price and longer lifetime of the battery

As we have seen in the two previous parts, we will need a great reduction almost 43% in price of battery to reach breakeven between BEV and Diesel vehicle and also the same with lifetime of battery, we will need to achieve high performance of the battery to increase the battery’s lifetime by 57.3%. So that, the combination between reduction in the price and increase in number of cycles of the battery will reduce the time needed to achieve the breakeven in the future. and which is closer to the real life because producers of battery are trying to reduce prices and increase the performance of the battery at the same time to be able to continue compete in the market. Consequently, in sensitivity analysis, we applied the model with the current price and the performance of the battery (108.98€/KWh & 600cycles/battery). And gradually, we started to reduce the price and increase the cycles/battery with the same percentage to find out when we can achieve the breakeven with this combination. We found out that we could achieve the breakeven when we can reach price reduction 27% and cycles/battery increase by 27%. We can observe that instead of we need to wait for price reduction by 43% **or** increase in the cycles of the battery by 57.3% to reach breakeven between BEV and diesel vehicle, we will need only to achieve high performance in both of price and cycles/battery by only 27%. And as we see in Figure 29 that we will need to save one battery during the lifetime of the vehicle comparing with basic scenario therefore, we will need to replace 6 batteries in the whole lifetime of the vehicle instead of 7 batteries with the current price and performance of the battery.

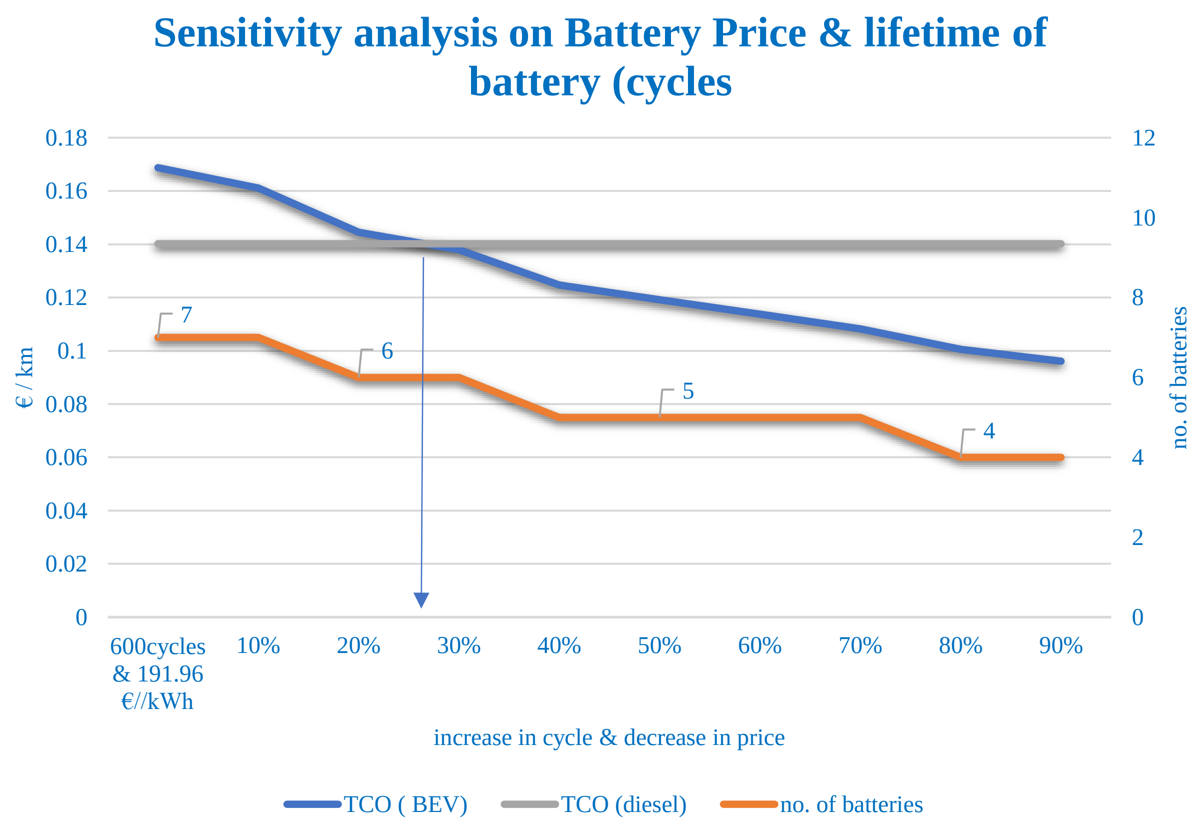


Figure 29: Sensitivity analysis on Battery Price & lifetime of battery (cycles)

5.4.6 Sensitivity analysis on higher price of diesel

Energy cost is the biggest share in the cost structure of the diesel vehicle with 43%. Consequently, if price of diesel will rise which will increase the average cost of diesel, hence BEV will be more competitive. In sensitivity analysis, we started with the average price of diesel in Europe 1.15 € /

liter and increase it gradually to achieve breakeven between BEV and diesel vehicle with the current price and performance of the battery with fixed average cost of BEV. Hence, we found that BEV can reach breakeven with diesel vehicle when price of diesel will reach 1.74€ / liter which is even higher than the highest price of diesel in any European country which is 1.56 € / liter in Norway. So that we expect that price of diesel will not increase by more than 50% of the current price which is needed to reach breakeven. Hence it will be not easy to achieve breakeven in this case. We assumed in our model that increasing the price of diesel will not affect the average cost of BEV which is not accurate because it could affect the cost of production of BEV components which will affect the purchase cost of BEV and also affect the energy price (electricity).

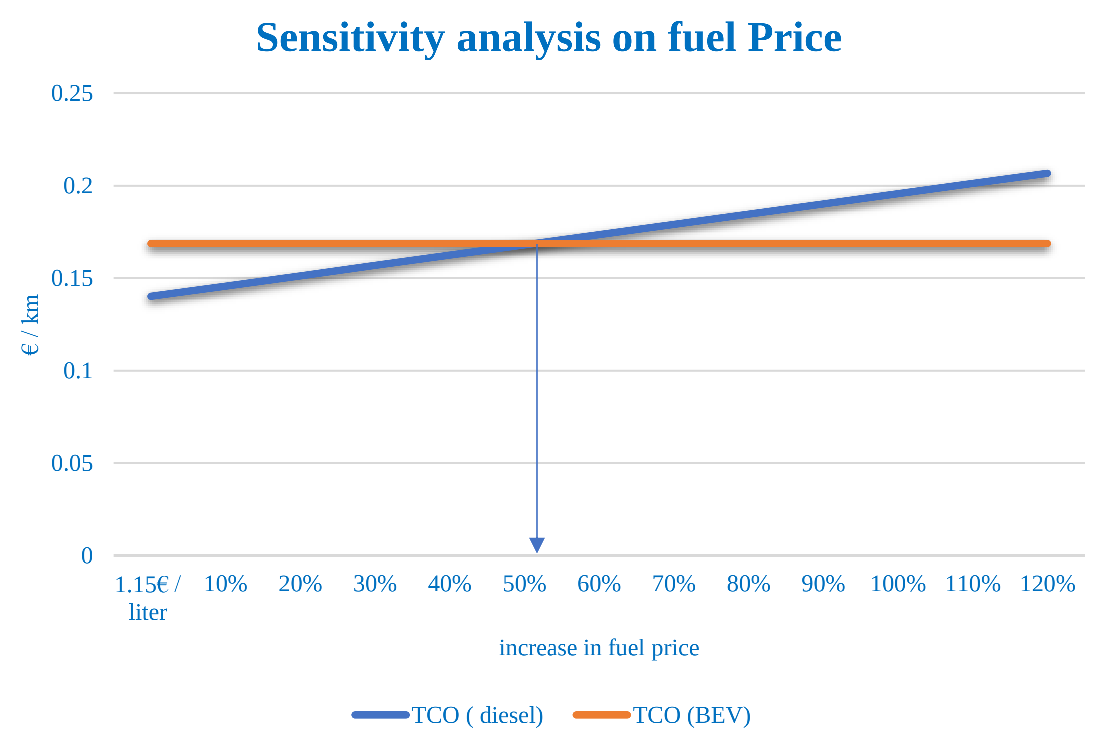


Figure 30: Sensitivity analysis on fuel Price

5.4.7 Sensitivity analysis on Government intervention

Nowadays, it is quite hard to achieve breakeven between BEV and diesel vehicle with the current situation which includes the current price and performance (cycles) of the battery, and the current price of diesel. Unless the operator could carry out two shifts per day with very high utilization rate and could make 143.78km/shift which is more than the high-efficient logistics operator by 48%. Which is not easy to operate this distance per shift and it depends mainly on the features of the city. Consequently, we do need to have government intervention to support using BEV against Diesel vehicle. This intervention can take many shapes for both sides BEV(support) or Diesel vehicle (barrier):

- BEV incentives: subsidies and/or tax deduction
- Conventional vehicle tax: registration fee and co2 emissions.

Thus, in the current situation, to achieve breakeven between BEV and diesel, we will need to increase average cost of diesel vehicle (more tax) or reduce average cost of BEV (incentives) by at least 1493.6€ per year. Consequently, the government should apply either 1493.6€ per year more tax on the diesel vehicle or tax deduction on BEV by the same amount. Why we said at least? because this amount is needed for the highest efficient logistics operator who can make at least 150 drops and 60-mile daily which mainly depends on the feature of the city. So that, incentives/tax should be decided by local authorities. In this model, we applied more tax on the average cost of diesel to achieve the breakeven with fixed average cost of BEV.

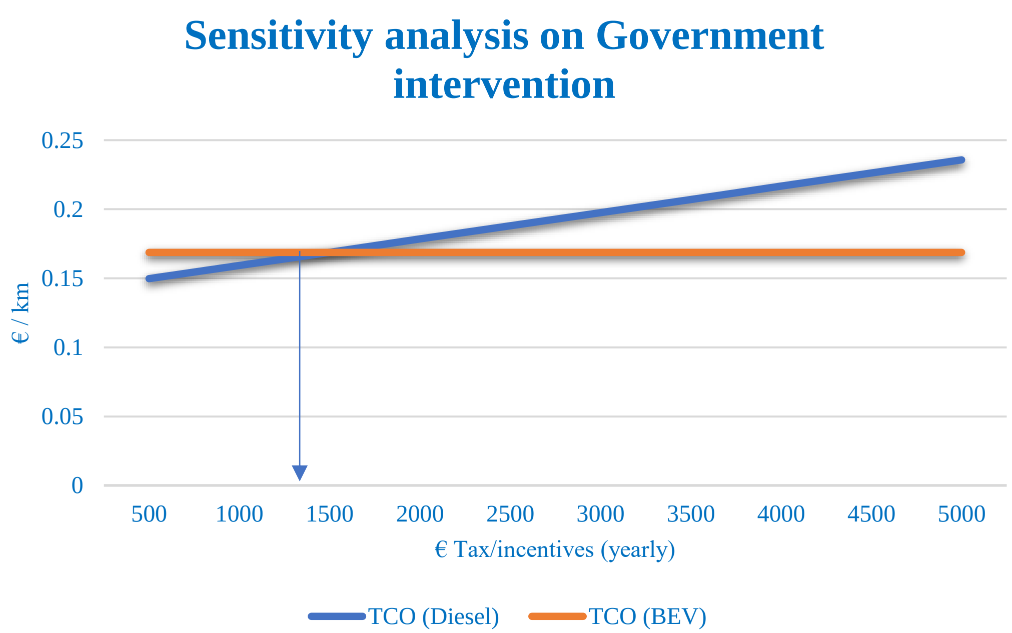


Figure 31: scenario 5- Government intervention

5.5 SWOT

To carry out overview analysis of using BEV in Last-mile delivery, we chose to assess the technology by SWOT analysis.

STREMGTHS

- Clean Technology
- Green Image for logistics companies and E- commerce
- High efficiency of BEV
- Cheap operating cost of BEV

WEAKNESSES

- High cost of battery (high initial investments)
- Limited number of manufacturer companies
- Small market of BEV
- Long charging time, Short driving range
- Few number of supercharging stations

OPPORTUNITIES

- Growing market of e-commerce
- Possible incentives
- Economies of scale and recycling to reduce battery cost
- increase taxes to polluted transportations.
- integration between supercharging stations and renewable energy sources

THREATS

- Reduction in diesel price and purchasing price of conventional vehicles
- Polluted generation mix of electricity used in BEV.
- lithium ion reached its maturity phase.

5.5.1 Strengths

Environmentally-friendly business is profitable business (theguardian, 2013). Nowadays, many policies have been created to enable countries to achieve a significant reduction in the pollution. For instance, 2020 climate & energy package which is a set of obligated legislation to ensure the EU meets its climate and energy targets for the year 2020 (European Commission, 2017). The package sets three key targets:

1- 20% cut in greenhouse gas emissions (from 1990 levels)
2- 20% of EU energy from renewables
3- 20% improvement in energy efficiency

Consequently, the proactive approaches of companies will be encouraging and avoiding any sanctions in the future.

Lower Energy Costs and maintenance cost have strong impact to competitiveness of BEV against Diesel vehicle. As well as high efficient electric motor.

A Better Public Image: one of the most profitable reasons to go green is to enhance company’s image. Consumers want to have choices they can feel good about, and supporting green businesses is something many people prioritize. 66% of consumers say they would pay more for a product they knew was sustainable (engineeringonline, 2016). Sustainable companies are seeing a 4.00% growth rate, compared to 1% growth among non-sustainable organizations. By building a brand image around sustainability, it can add to the company’s business growing number of sustainable consumers (equities.com, 2016).

5.5.2 Opportunities

Growing market of B2C e-commerce: the rapid expansion of the Internet and use of mobile devices in emerging markets is a big part of the reason ecommerce is growing, along with better payment options and advanced shipping (ecommerce-europe.eu, 2017). With the expected growth of E-commerce, it will give an opportunity to last mile delivery companies to operate in efficient way which enables them to touch many delivery points in one trip which will reduce average delivery cost.

Harvesting the Benefits of Government Incentives: many sustainable changes require a large initial investment; however, government incentives can make the investment possible, even for small businesses (equities.com, 2016).

Exploiting economies of scale in battery production: which will bring down the cost of the battery. By building factories with extraordinary size and scale for battery production such as: gigafactory.

Battery recycling instead to discard BEV battery after the end of the lifetime: even recycling is a more economical choice than reuse for applications. Recycling costs are also expected to drop significantly as Li-ion batteries continue to be sold on a larger and larger scale (energy-storage.news, 2017).

Increase taxes for polluted transportations: for example, in UK they are planning to increase diesel taxes to fight pollution (theguardian, 2014). Taxes and other environmental policy instruments in the transportation sector will have a great impact negatively on competitiveness of the polluted vehicles by increasing the average cost.

Integration between charging stations and renewable energy sources (i.e. solar panels and wind farms): with this opportunity, we can expect to drop energy cost consequently, we enhance benefits of using BEV.

5.5.3 Weaknesses

Short Driving Range and Speed: Most of BEVs have range about 50-100 miles and need to be recharged again. It cannot be used for long trips.

Recharge Points: charging stations are still in the development stages. There is still a big shortage of charging stations in some countries, which will be challenging to operate with BEVs. Furthermore, there are few number of supercharging station all over the world hence, companies need to install their private stations which will be additional cost.

High cost of the battery: even with the drop took place in the cost of the battery during last years (nature.com, 2015), however, battery cost is still the highest share in the cost structure of the BEV and consequently, rise the initial investment of owning BEV.

Longer Recharge Time: While it takes couple of minutes to fuel your gasoline powered car, BEV takes about 4-6 hours to get fully charged and even 30 mins with using supercharging stations.

Battery Replacement (short lifetime): Depending on the type and usage of battery, batteries of almost all BEVs are required to be changed every 3-10 years (conserve-energy-future.com).

Some governments do not provide incentives in order to encourage companies to operate with BEVs.

5.5.4 Threats

lithium ion reached its maturity phase: there is high expectation to have reduction in battery cost in the future, however, if this expectation would be not accurate and we are already very close to reach maturity stage of lithium ion battery which means that there is no opportunity to have any increase in the performance of the battery thereby it will impossible to operate with BEVs without government intervention and BEV cannot stand alone against other cheap conventional vehicles.

Polluted generation mix of electricity: the main objective of using BEV by now is that BEV is a clean technology which not produce pollution such as conventional vehicle by using electricity. However, if we would take one step back behind electricity generation, we can observe that most of countries still have a polluted generation mix composed mainly of coal, natural gas, and oil to produce electricity (scientificamerican.com).

Reduction in diesel price: with any reduction in price of diesel and other conventional energy will negatively affect the competitiveness of BEV specially with high cost of electricity in some countries.

6 Conclusion

Regarding the literature review, although there are many scientific papers covered green logistics for last mile delivery in B2C e-commerce however, yet there is no paper considered either the combination between supercharger and BEV, or the integration between electric public transportation (i.e. subway) with automation system. Consequently, our aim for this work is to eliminate this gap and highlight other possible solutions such as: applying sharing economy concept for using drones i.e. present a mobile APP as a platform with the aim is to match between consumers and drones' owners who offer delivery service.

There are high expectations that EV will achieve high performance in terms of longer driving range, shorter time for charging, and lower price. These expectations are based on the high concentration emerged among investors and scholars, resulting either from communities' pressure or the high competition in the auto market.

As we found out by applying Total Cost of Ownership model, BEV cannot compete against diesel vehicle mainly because of high initial capital needed for BEV and especially high price and low performance of electric battery. However, there are many opportunities for BEV to win in the market in the future. For example, exploiting the huge investments in battery industry in many countries such as: China and America which can reduce the price and enhance the performance of the battery. Moreover, nowadays with the increase of the awareness about the pollution problems and the direction to support solutions for environmental issues which forced many companies to be greener, beside that could help to promote the image and reputation of the company among consumers, consequently companies could use the green logistics as a marketing tool and could be a source of additional revenues. Furthermore, there is a general direction in Europe to increase regulation against polluted transportation means by applying more tax and to incentivize clean technologies to support green transportation. Moreover, battery industry attracts many companies from different sectors from the whole world due to the increase in the competition between many companies from Auto sector or from outside, and because of the importance of batteries in many industries and many different products.

7 Limitations and future developments

Green last mile delivery is a complex topic and, at the same time, a relatively new field of application; consequently, there are still several steps to be completed and a lot of aspects to be studied in detail, especially considering that the potential of these schemes is strongly affected by the economic and financial context.

Moreover, the possibility to implement similar solutions depends on the particular features and conditions of the actors involved, which for definition are different from a country to another.

Therefore, it could be useful to develop more detailed analysis focused on a single country, or a group of very similar countries, since there would be the possibility to obtain more specific implications and to reduce the risk of generalizing too much.

Another interesting consideration, we have taken into account that the maintenance cost for both BEV and Diesel vehicles are fixed which is not so accurate. In order to better analyze the competition between BEV and Diesel, the age of the vehicle should be taken in the consideration specially at the end of the lifetime of the vehicle when the maintenance cost rises significantly which can change the shape of competition especially that diesel vehicle will have increasing rate of maintenance cost more than BEV.

In the sensitivity analysis on the battery price to achieve the breakeven between BEV and diesel vehicle, we have used lower prices of the battery which it will be in the future whereas, we have compared these future prices with the current price of the diesel vehicle which it should be changed in the future as well. consequently, for more accurate result and analysis, it would be more precise to consider the reduction rate in the price of the diesel vehicle in the future which will be a negative point for BEV's competitiveness against diesel vehicle.

In the all sensitivity analysis, we did not consider the battery warranty policies which is changed from manufacturer to another. However, this opportunity could bring advantage for BEV and increase its competitiveness versus Diesel vehicle.

One of the most important limitations and there is a need to develop the analysis in the future is that we have not considered the cost of the infrastructure of the supercharging stations for BEV which will have a high negative impact on the competitiveness of BEV. Infrastructure cost will add more cost to BEV which is already higher than diesel vehicle however these costs are expected to fall down in the future due to competitiveness and creation of innovative ideas between companies. Infrastructure costs could be broken down into several categories (cleantechnica.com, 2014):

1- The actual charging station hardware
2- Other hardware and materials
3- Electrician and other labor
4- Mobilization, which we define as time for the electrician and others to get to the worksite (often including an initial on-site consultation).
5- Permitting.

There is an important consideration that these costs should be influenced by the number of vehicles the E-commerce company owns currently and in the future as well, the more BEV vehicles the more exploitation to economies of scale. Furthermore, the infrastructure should have longer lifetime than the vehicle therefore it could be used for many generations of vehicles.

Another important limitation, we considered that time is not a constraint, which it was not so accurate mainly because we assumed that the logistics operator shall work at least two shifts/day to achieve breakeven between BEV and diesel vehicle and this could be not available in a very crowded city which one trip could take all the working time. Therefore, it should be taken into consideration that time as a variable factor which is function in number of the drops can be made in one trip and also which city taken in the analysis and maximum speed can be reach by both vehicles and maximum speed can be reached in the roads of this city.

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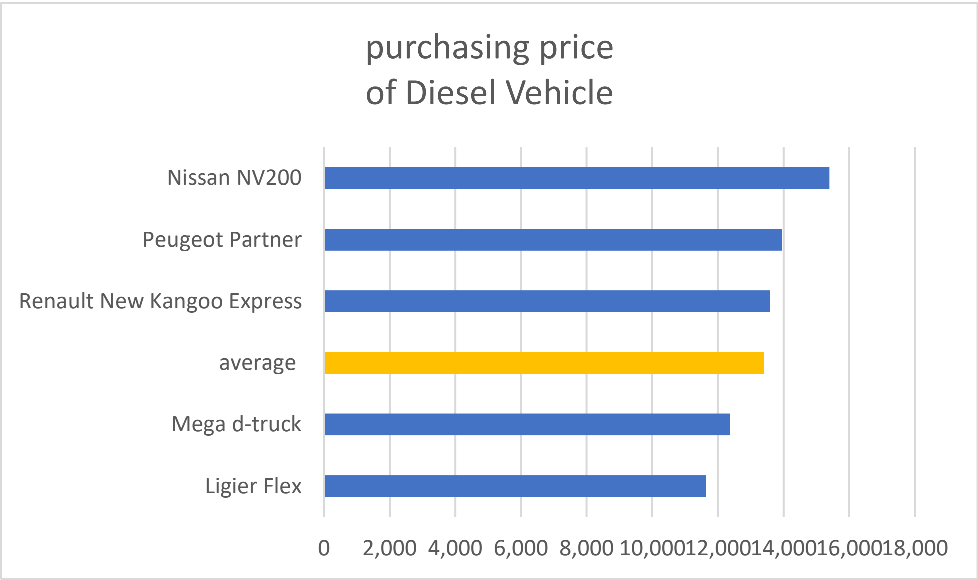
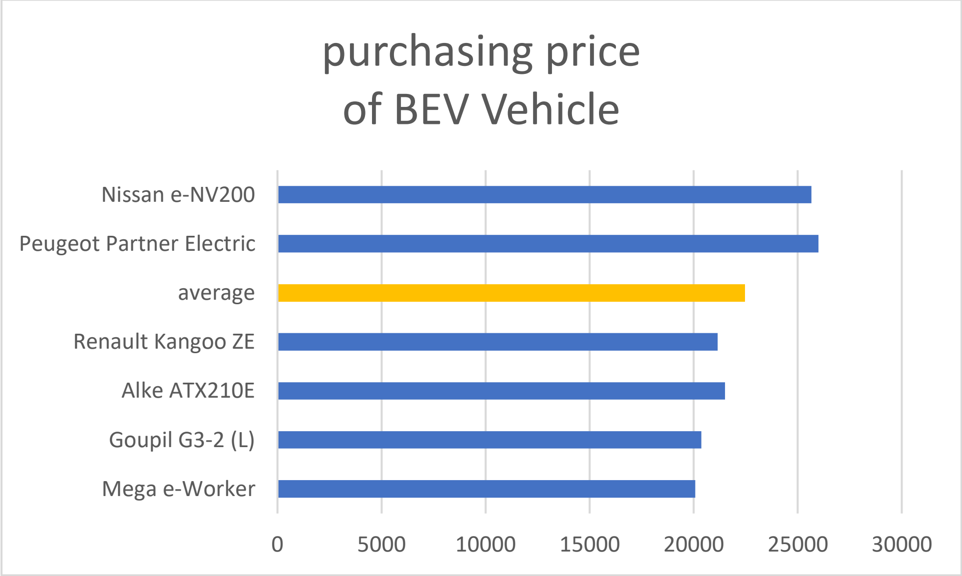
9 ANNEXES

9.1 Annex 1: average purchasing price for both Diesel vehicles and BEV



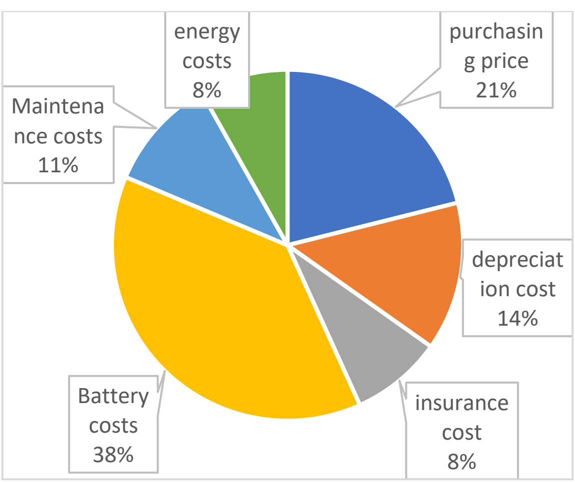


9.2 Annex 2: calculation sheet of Sensitivity analysis on Battery Price & lifetime of battery (cycles

increase in cycle decrease in price	cycles	TCO (BEV)		no. of batteries	€//kWh	battery price	TCO (diesel)	break-even percentage		break-even	no. of batteries
600cycles & 191.96 €//kWh	600	0.16873	6.93333	7	191.958	4606.992	0.140187025	**27%**	cycles	762	6
10%	660	0.16103	6.30303	7	172.7622	4146.2928	0.140187025		price €//kWh	140.12934	
20%	720	0.14452	5.77778	6	153.5664	3685.5936	0.140187025				
30%	780	0.13792	5.33333	6	134.3706	3224.8944	0.140187025				
40%	840	0.12471	4.95238	5	115.1748	2764.1952	0.140187025				
50%	900	0.11921	4.62222	5	95.979	2303.496	0.140187025				
60%	960	0.1137	4.33333	5	76.7832	1842.7968	0.140187025				
70%	1020	0.1082	4.07843	5	57.5874	1382.0976	0.140187025				
80%	1080	0.1005	3.85185	4	38.3916	921.3984	0.140187025				
90%	1140	0.0961	3.64912	4	19.1958	460.6992	0.140187025				
20%	720	0.14452	5.77778	6	153.5664	3685.5936	0.140187025				
21%	726	0.14386	5.73003	6	151.64682	3639.52368	0.140187025				
22%	732	0.1432	5.68306	6	149.72724	3593.45376	0.140187025				
23%	738	0.14254	5.63686	6	147.80766	3547.38384	0.140187025				
24%	744	0.14188	5.5914	6	145.88808	3501.31392	0.140187025				
25%	750	0.14122	5.54667	6	143.9685	3455.244	0.140187025				
26%	756	0.14056	5.50265	6	142.04892	3409.17408	0.140187025				
27%	762	0.1399	5.45932	6	140.12934	3363.10416	0.140187025				
28%	768	0.13924	5.41667	6	138.20976	3317.03424	0.140187025				
29%	774	0.13858	5.37468	6	136.29018	3270.96432	0.140187025				
30%	780	0.13792	5.33333	6	134.3706	3224.8944	0.140187025				

9.3 Annex 3: how the cost structure of BEV changed with lower price of battery to achieve breakeven

Before



After