E-Vehicles in the Last-Mile Distribution

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Abstract

The objective of this research paper is to identify changes in costs and operational processes caused by the use of electric vehicles in the last-mile distribution of retail and logistics companies. Based on action research in three companies in Germany we provide managerial insights in processes and cost accounting schemes that have to be adjusted. Furthermore, we show a process model and a cost accounting scheme for electric vehicles in logistics.

Keywords: Operations and cost management, sustainability, e-mobility

Introduction

Fossil fuels vehicles "are polluting the world´s cities, dumping increasing amounts of carbon dioxide and other climatering greenhouse gases into the atmosphere, and consuming vast quantities of petroleum" (Sperling, 1995, p. 1). Nevertheless, oil demand is increasing and will exceed production by 2035. This will have an impact on fuel availability as well as on cost of fuel (Charles et al., 2014). However, accomplishment of travel reduction or transportation of goods will be difficult therefore sustainable energy and transportation systems are needed to be established. "The focus on sustainable development motivates companies [in particular logistics companies] to integrate the increasing ecological demand in their services and product cycles" (Klumpp, 2014, p.4). According to this, the use of electric vehicles in the delivery process would be an opportunity to decrease the economic and ecological key driver fuel. Another advantage would be decreasing noises and reducing carbon emission. In the logistics industry, for example Deutsche Post DHL has integrated electric vehicles in their fleet pool for urban delivery (Deutsche Post DHL, 2014). To enhance the use of electric vehicles different research efforts have been driven by different disciplines such as engineering, economic or business science research fields. However, one research project namely E-Route funded by the state of North-Rhine Westphalia as well as the EU ERDF focus on the evaluation of the process changes as well as cost management by the use of electric vehicles in the last mile distribution. The Project members are FOM University of Applied Sciences, University Duisburg-Essen, Noweda, and Zentek in Germany. In this research paper, the investigation on cost and operations management by using electric vehicles in the last-mile distribution is provided. Based on action research in three companies in Germany we provide managerial insights which processes have to be adjusted as well as a process model and cost accounting scheme.

This study is structured in five sections. After a brief introduction, section 2 presents a status quo on vehicles in Germany as well as the impact of electric vehicles in German industries. Section 3 presents the research method. Before concluding in section 5, section 4 describes the operations and cost management by using electric vehicles in the last-mile distribution.

Status Quo

At the beginning of 2014 almost 53 million motor vehicles were officially registered in Germany (Kraftfahrt-Bundesamt 2014a). Currently, more than one billion motor vehicles exist worldwide (Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit, 2014a). It is being forecasted that the number of worldwide motor vehicles will have doubled by the year 2030 at the latest. Hereby, the emissions of carbon dioxide (CO_2), other pollutants and noise caused by traffic will have increased. There are also the increasing dependency of oil imports and the shortage of this resource. Especially in the field of urban economic transport (last-mile distribution) alternative motor systems like electric motors for used vehicles become more and more important (Bundesregierung, 2009; Bundesregierung, 2011). The use of electric vehicles is an important contribution to support the reduction of environmental pollution affected by traffic. Electric vehicles run without fossil fuels and do not produce any CO_2 if they are charged with sustainably produced electricity.

Companies in the field of urban economic transactions are careful in using electric vehicles due to three main reasons. The first reason is that the companies do not have any experience on the use of electric vehicles and they do not know which processes have to be adjusted in case of implementing electric vehicles. The second reason deals with the investment because due to the lack of experience the return on investment (ROI) remains unclear. The third reason is that the companies do not clearly know the impacts on the business in case of integrating electric vehicles. The German Federal Government set the objective: one million electric commercial vehicles shall be registered in Germany until the year 2020. Currently, there are 21,324 motor vehicles with an electric drive altogether (Kraftfahrt-Bundesamt, 2014b). As a small incentive to buy an electric vehicle no motor vehicle tax has to be currently paid for up to ten years (Bundesministerium der Finanzen, 2014). An electromobility law has agreed at the end of September 2014 to encourage the integration of electric vehicles in German industries. This law makes it possible for local communities to promote electromobility in the most reasonable manner (Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit, 2014b). In the electromobility law it is regulated how an electric vehicle has to be defined and how the marking of such vehicles via licence tag has to be executed. Furthermore, parking and retaining regulations, the usage of bus lanes and the lifting of access restrictions for electric vehicles are regulated too.

Research Approach

To address our research purpose a research project team within the E-Route project has been built. The team consists of six researchers from two different universities as well as a practitioner team from the companies Noweda and Zentek in Germany. Noweda is wholesale and distributes medicines to more than 8,600 pharmacies in Germany. Its turnover from 2012/2013 was more than 4.6 Billion Euro. Zentek is a medium-sized waste disposal company and provides all waste disposal solutions for each sector. Within this research project, we had the possibility to test the electric vehicles, to adjust processes, to develop a cost accounting scheme as well as to gain managerial insights in the use of electric vehicles in the last-mile distribution at Noweda and Zentek. Moreover, we achieved to test the electric vehicles at a food and non-food wholesale industry too. Implemented action research has been divided in two main stages.

The first stage focused on the adjustment of processes. It dealt with capturing empirical data based on semi-structured interviews, documents, observations as well as surveys. The survey (60 respondents) focused on the understanding as well as knowledge of the practitioner participants on electric vehicles generally as well as on last-mile distribution. Furthermore, we conducted 14 interviews with the employees from the logistics group as well as drivers of diesel engine vehicles in the timeframe from December 2012 until July 2014. The semi-structured interviews had been executed in the German language. The interviews had been transcribed, coded and analyzed. Based on observations and different internal documents from the companies the logistics processes had been analyzed in the period of January 2014 until October 2014. To ensure the quality of the action research within the companies three senior researchers joined the research work and approved the transcribed semi-structured interviews.

The second part of capturing empirical data is based on testing the electric vehicle in the last-mile distribution in each of the above-mentioned companies. The testing of the electric vehicle at the first company was from 2013 September 2nd until September 13th and December 2nd until December 6st, at the second company from 2014 June 23rd until July 2nd and finally at the third company from 2014 July 9th until July 18th. The electric vehicle namely Vito E-Cell had been rent from Mercedes Benz in North Rhine Westphalia. The measurement of the vehicle is 5008 mm x1895 mm x 3200 mm (Length x height x width). The battery capacity is approx. 36 kWh. The gross vehicle weight is 3050 kg, the kerb weight is approx. 2200 kg and the payload is 775 kg. The range (NEDC) is 80 miles. The charge time of 400 V/230 V battery is between 5 h and 10 h. However, this stage is classified in three steps. The first step included the presentation of the electric vehicle and its technical capacity as well as driver instruction to the employees within the company. The second step dealt with testing the electric vehicle. For each tour, we have placed a GPS module to ensure a follow up of the tour. Furthermore based on a developed protocol by the researchers we documented different factors such as starting time, battery capacity of the vehicle, shipment, if the heater had been used or if the driver had used the windshield wipers etc. This documentation allowed us to collect data about the electric consumption and to analyze if it has any effect on the battery capacity of the electric vehicle. In the third step, three other interviews had been conducted to get a feedback about the use of the electric vehicle in the last-mile distribution. The target was to understand the differences between the use of electric vehicles and the use of diesel engine vehicles in the logistics industry. In addition to investigate if, other adjustment towards education and training of drivers and administration staff towards the use of electric vehicles have to be made. Further electric vehicle testing are planned for winter 2015 for further adjustments of operations.

The second stage deals with the development of an accounting scheme for electric vehicles. For the vehicle cost accounting, a “standardized” calculation scheme is used in this research study.[1] The vehicle cost accounting is divided into two parts: the variable (kilometer-dependent) and the fixed (time-dependent) vehicle costs. In order to calculate the variable average costs in Euro per kilometer (“kilometer rate”) the total variable vehicle costs per annum have to be divided by the annual mileage. The fixed vehicle costs include the salary of the driver, fixed charges of the vehicle and general overhead expenses per annum. The sum of the mentioned fixed vehicle costs divided by 300 working days indicate the daily rate in Euro of the vehicle. The sum of the variable and fixed costs indicate the vehicle total costs per annum. The total costs of a vehicle per annum allow for a cost-oriented comparison between the profitability of electric vehicle and diesel engine vehicles as well as hybrid vehicle based on a full cost accounting. The variable average costs per kilometer and the fixed average costs per day serve as additional information for the cost management regarding the comparison of different vehicle deployment scenarios. In case of other deployment scenario (than described in this research study below), the calculation of vehicle total cost per annum other number of mileages or number of days can be applied. Within the context of the research project E-Route a first vehicle cost accounting for diesel and electric engine vehicles was generated in 2013 (i.e. Gries and Zelewski, 2013). In Gries and Zelewski (2013) the general structure of the vehicle cost accounting is explained. In the following, we provide how a vehicle cost accounting for diesel and electric engine vehicles have been conducted. In addition, we show the modification that have been executed based on the first vehicle cost accounting of 2013. However, on the one hand we have chosen other vehicles for providing a better comparison between the different vehicle types. On the other hand, we have just considered the purchase of the different vehicles. On the forthcoming research study, different purchase types such as leasing will be analyzed.

Management of E-Vehicles in the Last-Mile Distribution

Operations Management

In our research study, we observed the main processes within these industries using the diesel engine vehicle as well as using the electric vehicle. For example in the food and non-food wholesale industry the main processes are order management, warehouse management, specific commissioning of products, loading the vehicles, routing planning and delivery to customer. The wholesale trade company delivers different food and non-food goods to different catering trades in Cologne in Germany and its neighbourhood. The weight of the delivered goods to approximately 20 customers is between 150 and 500 kilograms. Nevertheless, after evaluation the correctness of the incoming orders the order management division forwards the incoming orders to the logistics and transport division. The logistics division is responsible for the inventory as well as warehouse management. Hereby specific commissioning of incoming orders based on customer requirement are considered. The transport planning is responsible of the vehicle to distribute the goods to the customers. Based on decisive criteria such as opening times of customer, number of goods, location of customer, unloading ramps, capacity of vehicle etc. the dispatch planner starts the routing planning. The responsible drive starts loading the shipment into the last-mile distribution vehicle and deliver the goods to the customers. We have to take into account managing the last-mile distribution using electric vehicle the technical features of an elec-

[1] Detailed description of the calculation scheme is in Gries and Zelewski (2013). The cost accounting calculation scheme was developed based on Oppenberg and Schimpf (2004).

tric vehicle as well as the related process have to be reflected. As we compared the processes, we analyzed the technical features of an electric vehicle. Therefore, diesel engine vehicles as well as electric vehicles had been used in the summer, winter as well as autumn. The purpose was to see the effect of the weather on the battery capacity of the electric vehicle - as one of the main decisive criteria in routing planning is the vehicle capacity in form of space as well as kilometer/miles range. These are crucial because cost management of last-mile distribution depends on these criteria in all these industries.

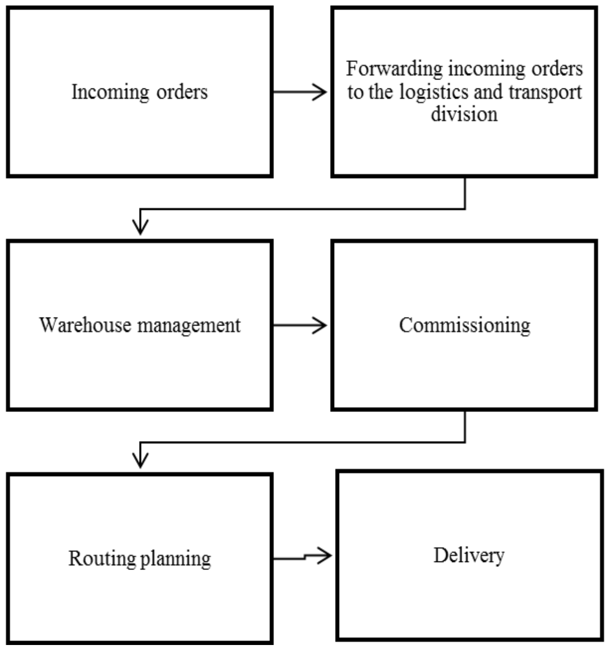

Figure 1: Main activities in the last-mile distribution

For example in some cases due to the dependence on the battery capacity of the electric vehicle the dispatch planner has reduced the tour of delivery 10-12 customers per day using diesel engine vehicle to 5-6 customers per day using electric vehicle. Managing the routing planning within these industries (pharmaceutical, food and non-food as well as recycling) remains the focal process that have to be adjusted in case of using electric vehicles. After a working day between (6 a.m. and 4 p.m.), the drivers claimed that driving with electric vehicle is more comfortable and easier to use than diesel engine vehicle but the insecurity of the battery capacity as well as the technical handling remain a challenge. Due to the innovative and technical components of electric vehicles, the drivers are not allowed to touch or to start repairing the electric vehicle in case of a breakdown. The industries have to focus on how to plan the distribution of goods to the customers under consideration of the restriction of the range of electric vehicles as well as how to deal with an electric vehicle in case of car breakdowns. Nevertheless, there is a significant need to develop and to integrate education and training seminars of drivers as well as administration staff towards the use of electric vehicles and management of last-mile distribution in this sector.

Cost Management

In this research paper the vehicle cost accounting for vehicles listed in table 1 are considered. For this cost analysis, we used a realistic operational deployment scenario based on fictive data. Our operational deployment scenario consists of exemplarily a forwarder agency that delivers goods for a middle-sized trading company on the "last-mile" in the field of city logistics. The good are dispatched in two tours per day and on six days per week. The annual mileage is about 40,000 kilometers. According to the annual mileage and 300 operational days per annum, the employed vehicle drives about 133 kilometers per day. The electric vehicles chosen for the comparison have a maximum range of 170 kilometers with a fully charged battery according to the data of manufacturer´s, which is in compliance with the "new European driving cycle" (NEDC). Therefore, this nominal range would be sufficient for a one-day trip with an additional contingency battery charge. However, the actual range depends on driven speed, individual driving behaviour, load, outside temperature, usage of other electric devices and topography of the area. The charging time for a complete discharged battery varies between 6 and 15 hours. The load capacity of 460 to 770 kilograms and the load volume of 3,7 m^3 to 4,6 m^3 is sufficient for the delivery to the customers. A 4 years operating life of vehicles respectively as well as a tire mileage of 40,000 kilometers are taken as a basis in the vehicle cost accounting.

Table 1: Vehicles

Diesel models	**Electric models**
Citroën Berlingo box-type van HDi90 (L2)	Citroën Berlingo Electric box-type van (L2)
Renault Kangoo Rapid Maxi Extra dCi 90	Renault Kangoo Maxi Z.E.
Peugeot Partner box-type an HDi 90 (L2)	Peugeot Partner box-type van Electric (L2)
Nissan NV200 box-type van 1.5 dci90 DPF PRO	Nissan e-NV200 box-type van PRO

The first part of costs in the vehicle cost accounting consist of the variable vehicle costs. The amortization will be elaborated later in this paper. The fuel costs of diesel vehicles are determined by multiplying the consumption in liters per 100 kilometers with the average diesel price of about 1.376 Euro per liter and divided by 100. The costs for electric vehicles are determined in an equivalent way. The consumption of kilowatt hours per 100 kilometers and the average electricity price of 0.1537 Euro per kilowatt hour are taken as a basis. For lubricants and oils a share of one percent of the fuel costs is set for diesel vehicles (Wittenbrink, 2014). In case of electric vehicles, no costs for lubricants and oils are incurred as they are not used for these vehicles. We assumed 65 percent of the maintenance and repair costs of diesel vehicles in calculating the maintenance and repair costs of the electric vehicles. We point out that the maintenance costs of electric vehicles are 35 percent lower than those for diesel vehicles do (Institut für Automobilwirtschaft an der Hochschule für Wirtschaft und Umwelt (HfWU) Nürtingen-Geislingen, 2012). The lower costs can be explained among other things by the fact that an electric engine with about 200 parts consists of less components than a combustion engine with about 1.400 parts (Lienkamp, 2012; Kampker, Vallée and Schnettler, 2013). For maintenance and repair costs 0,004 Euro per kilometer are being included for diesel vehicles and 65 percent thereof, i.e. 0,026 Euro per kilometer, for electric vehicles. Other general expenses also belong to the variable vehicle costs. These include all further costs that can be directly attributed to the vehicle and that depend on the driven kilometers. For all vehicles 200 Euro per annum are being included as other operating costs for vehicles with an annual mileage of about 40,000 kilometers.

The second part of costs is the fixed, i.e. time-dependent vehicle costs. This part of costs is divided into fixed charges of the vehicle and general overhead expenses per annum. The costs for drivers are being calculated for all vehicles with the same amount, as they are not vehicle specific. For the driver salary 20,000 Euro gross per annum are included as in the field of city logistics, temporary drivers are often employed. For the fixed vehicle costs, the motor vehicle tax for diesel vehicles are calculated using the online tool "car tax calculator" of the Federal Ministry of Finance (Bundesministerium, 2015). Vehicles with only an electric drive are exempted from the car tax for ten years in case of a registration date between May 18th 2011 and December 31st 2015. In case of a later registration date until December 31st 2020, a car tax exemption of five years is applied. . To determine the costs for vehicle insurances, the online comparison portal tarif24 was used (www.tarif24.de). As electric vehicles are still not listed in the well-known insurance companies, the insurance rates calculator on the internet site emover24 is used for determining the vehicle insurance (www.emc24.com). The general expenses are mostly administration costs, which especially extend to the planning of vehicle employment. The vehicle employment costs consist of the kilometer-dependent (variable) costs as well as the time-dependent (fixed) driver costs and the standing charges for vehicles. For the calculation of the general expenses, 16 percent of the vehicle employment costs have been set. For determination of the capital binding the net purchase price of the vehicle without tires, the net purchase price of the tires, the circulating assets and the necessary operating capital are used (see table 2).

Table 2: Capital binding in case of the vehicle purchase

Vehicle	Vehicle type	Net purchase price without tires	Circulating assets	Operating assets
Citroën Berlingo box-type van HDi90 (L2)	Diesel	16,550.00 €	428.00 €	8,789.00 €
Citroën Berlingo Electric box –type van (L2)	Electric	26,450.00 €	436.00 €	13,743.00 €
Renault Kangoo Rapid Maxi Extra dCi 90	Diesel	16,500.00 €	440.00 €	8,770.00 €
Renault Kangoo Maxi Z.E.	Electric	20,900.00 € + 209,44 €/month battery rent	435.00 €	10,967.50 €
Peugeot Partner box-type van HDi 90 (L2)	Diesel	16,950.00 €	428.00 €	8,989.00 €
Peugeot Partner box-type van Electric (L2)	Electric	25,550.00 €	436.00 €	13,293.00 €
Nissan NV200 box-type van 1.5 dci90 DPF PRO	Diesel	15,390.00 €	410.00 €	8,200.00 €
Nissan e-NV200 box-type van PRO	Electric	24,457.98 €	450.00 €	12,753.99 €

The net purchase price of the vehicle is needed in order to calculate the amortization amount. For the tires a net purchase price of 150 euro per tire is assumed. In the circulating assets we considered the financial advance payment of the executed transport services made by the forwarder. For this a sum of 200 Euro per ton of total weight of the vehicle is being set as fixed circulating assets on average per year (Fiedler, 2007). The asset required for operation is the capital bound by the employment of a vehicle. It consists of the average bound capital assets and the average bound circulating assets. For the average bound capital assets, half of the net purchase price including tires is being estimated. For the interest of the operating necessary capital a rate of 7.5 percent is being estimated. For the evaluation of the vehicle cost accounting, the kilometer rate, the daily rate and the total costs per annum are depicted in table 3 for the listed vehicles. The detailed calculations for the eight alternative vehicles are documented in Gries and Zelewski, 2015. For the above described operational deployment scenario of this research study, the Nissan e-

NV200 box-type van PRO with a total costs per annum of 40,687.54 Euro has proven to be the most economically and reasonable choice in a full cost analysis from the perspective of cost management. Moreover, this electric vehicle shows the lowest daily rates of 120 Euro fixed average costs. The Renault Kangoo Z.E. with 0.1090 Euro of variable average costs per kilometer is the most cost-effective vehicle regarding the kilometer-dependent costs. This advantage becomes important when a company needs a commercial vehicle that has to manage more than the annual mileage of 40.000 kilometers per year as assumed here.

Table 3: Results of the vehicle cost accounting

Vehicle	Vehicle type	Kilometer rate (€/km)	Daily rate (€/days)	Total costs (€/annum)
Citroën Berlingo box-type van HDi90 (L2)	Diesel	0.1675 €	122.74 €	43,521.44 €
Citroën Berlingo Electric box-type van (L2)	Electric	0.1228 €	121.75 €	41,436.85 €
Renault Kangoo Rapid Maxi Extra dCi 90	Diesel	0.1604 €	122.41 €	43,141.11 €
Renault Kangoo Maxi Z.E	Electric	**0.1090 €**	126.61 €	42,344.39 €
Peugeot Partner box-type van HDi 90 (L2)	Diesel	0.1682 €	122.99 €	43,625.50 €
Peugeot Partner box-type van Electric (L2)	Electric	0.1211 €	120.97 €	41,136.70 €
Nissan NV200 box-type van 1.5 dci90 DPF PRO	Diesel	0.1570 €	122.24 €	42,949.02 €
Nissan e-NV200 box-type van PRO	Electric	0.1172 €	**120.00 €**	**40,687.54 €**

In case of the planning of vehicle, it has to be taken into account that the Renault Kangoo Maxi Z.E. has a maximum range of 170 kilometers with a fully charged battery according to the NEDC. Its actual range is between 80 and 125 kilometers according to the manufacturer (depending on the outside temperature and the driving profile). After the deployment of the vehicle, the battery has to be charged for at least six hours in order to restore the full battery capacity. The economic superiority of electric vehicles is a surprising result of the presented cost analysis, because up to now the prejudice prevails in practical logistics, that the employment of electric vehicles cannot be economically justified due to their high purchasing costs (with or without battery). The vehicle cost accounting shows that – at least for the realistic operation scenario of a forwarder as presented here – this prejudice is economically unwarranted. For electric vehicles, the costs of amortization on purchase costs and on speculative interest rates on the capital bound in assets required for operation outweigh the related costs for similar diesel-powered vehicles. However, these costs are being overcompensated by a – partly considerable – reduction of the maintenance costs. These are incurred for electric vehicles as the counterpart diesel vehicles in case of the employment costs with regard to electricity costs instead of fuel costs, costs for lubricants and oils as well as repair and maintenance costs and also in case of the fixed vehicle costs regarding the car tax and the vehicle insurances. Even if the cost analysis has been performed in this research study with the help of the vehicle cost accounting for only a realistic operational deployment scenario with fictive data it nevertheless shows very distinctly that electric vehicles prove to be already today. Despite the higher acquisition costs of electric vehicle, it is economically more advantageous from a cost perspective compared to diesel vehicles because maintenance costs are lower.

Conclusion

This research contribution has shown for the limited application area of last-mile distribution logistics that electric vehicles may be economically the best choice – besides the obvious ecological advantages of zero local emissions as well as reduced noise and resource use in the long run. This is due to a significant lower level of marginal – running – cost effects with the electric vehicles compared to diesel engine vehicles, a calculation which has been grossly overlooked due to recent focus towards private use of electric drive concepts. In addition, the routing planning have to be managed under consideration of the battery capacity of electric vehicles and the adjustment of education and training of human resources towards the use of electric vehicles and last-mile distribution in the regarded sector have to be executed. Therefore, it can be stated that especially also public policy should consider these results as existing research and incentive programs in order to foster electric vehicles have a huge bias towards private use – though larger benefits for users as well as for society may stem from their use in logistics and other corporate environments. Consequently, also further research should concentrate on verifying these results with additional data and business context samples as the results currently only apply for Germany and are based on three corporations with high-use logistics demands.

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