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Investments in Electro Mobility for Freight Traffics in the Field of City Logistics: A Profitability Analysis

Sabrina Gries, Christian Witte, René Föhring and Stephan Zelewski

Abstract

Electro mobility is considered to be a pioneering trend in the field of road traffic to reduce the emissions of greenhouse gases. Because of technical restrictions, which limit the range and loading capacity of vehicles, electro mobility is mostly discussed with regard to passenger cars. However, recent developments raise the question whether electro mobility can be also used promisingly for local freight traffics of the so-called "city logistics". Interesting are especially transports on the "first" and "last mile" of supply chains with combined transports. However, electro mobility has only then potential as a future trend if the profitability of investments can be demonstrated.

The profitability of investments in electro mobility is being examined. The costs of three diesel versus three similar electric commercial vehicles are calculated for a typical case of application in city logistics. The analyses cover three scenarios that represent alternative investment options for the application of electro mobility: the complete purchase of electric commercial vehicles, the partial purchase combined with renting the battery as well as the complete vehicle leasing. Drive-specific features like e.g. the smaller range of electric commercial vehicles compared to diesel commercial vehicles are especially considered. It is shown that already today the regarded electric commercial vehicles prove to be economically attractive in some of the examined scenarios. Moreover, it is elucidated which expectable changes in future within the circumstances of city logistics will promote investments in electro mobility.

Keywords: city logistics, electro mobility, freight traffic, profitability analysis

1. Electro Mobility and City Logistics: an economical challenge

Electro mobility is considered to be a pioneering trend in the field of road traffic to reduce the emissions of greenhouse gases. Because of technical restrictions, which limit the range and loading capacity of vehicles, electro mobility is mostly discussed with regard to passenger cars. However, recent developments raise the question whether electro mobility can be also used promisingly for local freight traffics of the so-called "city logistics". Interesting are especially transports on the "first" and "last mile" of supply chains with combined transports.

In the aforementioned application fields, which in the following will be sub-summed under the term "city logistics" for the sake of convenience, commercial vehicles with electric powertrain (electric commercial vehicles) possess some attractive characteristics towards conventional commercial vehicles with diesel drive (diesel commercial vehicles). Firstly, ecologically harmful emissions of greenhouse gases are being reduced considerably. This applies most of all if the driving power of electric commercial vehicles arises from sustainably produced electric energy like e.g. wind energy or solar energy. Secondly, electric commercial vehicles contribute to a notable reduction of the environmental burden through traffic noise in populous areas, especially in city centers. Thirdly, electric commercial vehicles can receive a privileged access to city centers for reasons of environment protection (e.g. fine dust pollution) or traffic abatement (e.g. at night and in the early hours) if the passing of city centers by diesel commercial vehicles is either principally or at least at definite daytimes forbidden or is significantly increased in price by means of raising an emission dependent city toll. Finally – and fourthly – it can have a positive effect on the reputation of a logistics service provider if it demonstrably realizes the majority of its transports of goods on the road with the help of electric commercial vehicles. From the perspective of the often postulated "green logistics" the logistics service provider can benefit from its contributions to the reduction of emissions of greenhouse gases and from the traffic noise both through additional transport requests

(quantity effect) and through higher transport prices as an eco-premium (price effect).

In the light of such advantages it can surprise on the first glance that electric commercial vehicles are still barely used in business practice. The usual objections against electric commercial vehicles – range is too low (with one battery charge) and the vehicle load capacity is too low (because of the high own weight of the batteries) – do not have an important relevance in the field of city logistics. Especially the range argument cannot convince since the tour distances in city logistics lie beneath 100 km, i.e. a range that can be managed by an electric commercial vehicle with one battery charge without any problems.

Experiences from first pilot applications of electric commercial vehicles and conversations with logistics experts indicate that the main obstacle with regard to the employment of electric commercial vehicles in business practice lies in the widely held preconception that the significant investments in electric commercial vehicles as well as in the necessary infrastructure for running electric commercial vehicles would not pay off from a business point of view. However, it lacks in economically sound profitability analyses in which the technical peculiarities of electric commercial vehicles are being taken into account and in which the different business options for the purchase as well as the usage of electric commercial vehicles is being analyzed.

In order to close this gap in the analyses, this paper will examine with the help of a profitability analysis under which circumstances electric commercial vehicles prove to be advantageous compared to diesel commercial vehicles in the field of city logistics from a business point of view. The focus of the analysis lies in the vehicle cost accounting approach in order to adhere to established specialized literature and also to business practice. In future papers, this cost oriented analysis focus shall be extended by a proceeds perspective for the assessment of e.g. reputation effects.

2. Principles of a profitability analysis on the basis of the vehicle cost accounting

2.1 Overview of the vehicle cost accounting

The vehicle cost accounting constitutes one of the oldest and most widely used calculation instruments in the logistics field. For the vehicle cost accounting a "standardized" calculations schema is being used that also underlies this paper. However, it cannot be fully described here due to the brevity required. Instead, it is referred to a detailed description of the calculation schema in Gries and Zelewski (2013, pp.2–3) that was developed based on Oppenberg and Schimpf (2004, p.83).

The vehicle cost accounting divides into two parts: the variable (kilometer-dependent) and the fixed (time-dependent) vehicle costs. If the entire variable vehicle costs per annum are divided by the annual mileage, one receives the kilometer rate in euro per kilometer. The fixed vehicle costs cover the driving personnel, the fixed vehicle costs and the general expenses per annum. The summation of these three items yields under consideration of the operating days per annum the daily rate in euro per day. At the end of the vehicle cost accounting one receives the total costs of one vehicle per annum from the sum of the variable and fixed costs.

With the kilometer rate, the daily rate and the total costs, a comparison of different commercial vehicles as well as of different purchase and usage options for commercial vehicles can be made. For the sake of convenience, the purchase and usage options for commercial vehicles will be referred to as investments modes in the following.

The details of the following vehicle cost accounting were devised within the framework of the joint project E-Route. They are fully documented in the paper of Gries and Zelewski (2013, pp.3–11 and pp.15–25). Also, there are to be found comprehensive evidences for the numerous assumptions regarding cost influencing variables that are necessary for a realistic vehicle cost accounting. In accordance with a paper giving an overview, only the basic procedure as well as

the key results of the vehicle cost accounting for the use of diesel versus electric commercial vehicles will be presented in the following chapters.

2.2 Basics of a calculation for diesel and electric commercial vehicles

When investing in commercial vehicles, a business managing director has several options. Within the context of this paper the vehicle purchase and the vehicle leasing of diesel as well as similar electric commercial vehicles will be regarded. Additionally, for electric commercial vehicles, the special option of buying a vehicle combined with leasing a battery will be examined. However, when buying an electric commercial vehicle there is still not the possibility to buy each model in any way mentioned. Therefore, for each investment mode one diesel commercial vehicle will be compared with a similar electric commercial vehicle in which case this investment mode is possible.

For the comparison calculation the following similar commercial vehicles will be compared with each other: the diesel model "IVECO Daily box-type van 35S11V" and the electric model "IVECO Daily Electric box-type van 35S", the diesel model "Mercedes-Benz Vito 110 CDI KA/L 3200" and the electric model "Mercedes-Benz Vito E-Cell KA/L" as well as the diesel model "Renault Kangoo Rapid dCi 90" and the electric model "Renault Kangoo Z.E.".

The profitability analysis will be conducted exemplarily for a fictive forwarder that delivers goods for a midsize trading company. The goods are being delivered on two tours per day, on six days a week. For this, an annual mileage of about 40,000 kilometers is necessary. In the case of an annual mileage of 40,000 kilometers and 300 operating days per year, the used vehicles drive about 133 kilometers per day. The electric commercial vehicles chosen for the comparison have a range of 130 to 170 kilometers with a fully charged battery as specified by the "new European driving cycle" (NEDC) according to the manufacturer's data. The actual range depends on the driven speed, the individual way of driving, the vehicle load capacity, the outdoor temperature, the usage of electrical loads and the topography. The charging time takes between 5 and 9 hours when

the battery is fully discharged. In the outlined scenario this is no obstacle for the delivering of goods. The payload of 625 to 850 kilograms and the load volume of 2.4 to 12.0 cubic meters of the here regarded commercial vehicles also suffice for the delivery of customers.

As further calculation data for the vehicle cost accounting the following are taken as a basis: an operating life of the commercial vehicles of 4 years respectively, a leasing term of 24 months respectively as well as a tire mileage of 40,000 kilometers. A fuel price of 1.479 euro per liter and an electricity price of 0.1402 euro per kilowatt hour are being assumed (Gries and Zelewski, 2013, p.5).

The first pool of costs in the vehicle cost accounting is made of the variable vehicle costs. The items amortization, battery leasing and leasing rate will be elaborated on further in the text along with the respective investment mode. In the case of diesel commercial vehicles, the fuel costs are being determined by the consumption in liter per 100 kilometers multiplied with the average diesel fuel price in the year 2012 and are divided by 100 in order to receive the costs in euro per kilometer. The costs for electric commercial vehicles are being determined in the same manner. Here, the consumption of kilowatt hours per 100 kilometers and the average electricity price in the year 2012 are taken as a basis. For lubricants and oils an amount of one percent of the fuel costs is being set for diesel commercial vehicles (Wittenbrink, 2011, p.14). In the case of electric commercial vehicles there are no costs for lubricants and oils as they are not used for these vehicles. Along with the individual commercial vehicles it will be elaborated on the costs for tires. For the maintenance and repair of the vehicles, half of the amount of diesel commercial vehicles will be assumed for electric commercial vehicles since an electric motor with about 300 parts has far fewer components than a combustion engine with about 1,400 parts and thus requires less maintenance (Lienkamp, 2012, p.33; Kampker, Vallée and Schnettler, 2013, p.47). The calculation basis is made up by the vehicle specific maintenance and repair costs that are to be expected on average in the case of an annual mileage of about 40,000 kilometers.

Any other operating costs are also counted among the variable vehicle costs. These include all further costs that are directly ascribable to the vehicle and that depend on the covered kilometers. In the case of an annual mileage of about 40,000 kilometers, a lump sum of 200 euro per year is being set for other operating costs for all vehicles.

The next pool of costs is made of the fixed i.e. the time-dependent vehicle costs. This pool of costs is divided into driving personnel costs, fixed vehicle costs and general expenses.

The driving personnel costs are being calculated for all vehicle types with the same amounts as they are not vehicle specific. The driver wage is assumed to be 20,000 euro gross per year since in many cases temporary drivers are employed in the field of city logistics (Wittenbrink, 2011, p.58). 500 euro per year is assumed as Christmas bonus. An addition of 20 percent on the gross wage is made for social costs. It is assumed that per vehicle costs arise for only one driver.

For the fixed vehicle costs, the motor vehicle tax for diesel commercial vehicles has been calculated with the help of the online tool "Kfz-Steuerrechner" of the federal ministry (<http://www.bundesfinanzministerium.de/SiteGlobals/Functions/KfzRechner/cartax.html>, Stand: 2013-07-02). Vehicles with a purely electric drive and a registration date between the 18th of May 2011 and the 31st of December 2015 are exempted from the motor vehicle tax for 10 years. In the case of a later registration date until the 31st of December 2020 an exemption from the motor vehicle tax of 5 years applies. After that, the motor vehicle tax is being calculated on the basis of the admissible total weight like for other light commercial vehicles. However, it is to be noted that this sum is being abated by half.

The costs for the motor car insurance have been determined in the best possible way. Nevertheless, these costs may lead to a distortion of the calculation results since not all electric commercial vehicles are listed with the insurances and thus have to be calculated with similar values of diesel commercial vehicles.

In Germany, only heavy commercial vehicles have to pay a freeway toll. Thus, the freeway toll does not need to be considered for the here regarded light

commercial vehicles for distribution transports on the "first" and "last mile" in the field of city logistics.

It will be elaborated on further costs, which make up the fixed vehicle costs, along with the alternative investment modes.

Among the general expenses are above all the administration costs. The costs for the administration of the vehicles, which especially covers the disposal of the vehicle operation, have to be divided on all vehicles in the car pool. This happens through a fixed percentage of the vehicle operating costs. The vehicle operating costs are made up of the kilometer-dependent (variable) costs as well as the time-dependent (fixed) driver personnel costs and the fixed vehicle costs. For the calculation of the general expenses, 16 percent of the vehicle operating costs are being set.

2.3 Options for the purchase and usage of commercial vehicles

For the pure vehicle purchase, the IVECO Daily box-type van 35S11V (diesel commercial vehicle) and the IVECO Daily Electric box-type van 35S (electric commercial vehicle) will be compared with each other. The model-specific calculation data are compiled in table 1 and will be explained briefly further on.

In the case of the vehicle purchase, the net purchase price without tires, the net purchase price of the tires, the circulating assets and the necessary operating capital are being used for the determination of the capital binding. The net purchase price of the vehicle is needed in order to calculate the amortization amount. Here, the net purchase price without tires and without value added tax is set, because the tires normally feature another operating life than the vehicle and because the value added tax in business practice is mostly treated as a "continuous" item that is not relevant to the calculation. For the tires a net purchase price of 200 euro per tire is being assumed.

Using the circulating assets, the financial advanced payment of the forwarder is being considered before the payment of a trading company for the transport services come about. For this item, a lump sum of 200 euro per ton of admissible

total weight of the vehicle is being set as fixed circulating assets averaged per year (Fiedler, 2007, p.75).

The operating assets are the capital fixed by the company of a vehicle. It is compiled by the averaged fixed capital assets and the averaged fixed circulating assets. For the averaged fixed capital assets, half of the net purchase price including the tires is being set. For the interest of the operating assets a rate of 7.5 percent is being assumed.

In order to calculate the amortization amount, the net purchase price without tires is being divided by the planned operating life (amortization period) in accordance with an easy, thus transparent linear amortization. This amount is being divided into the variable and fixed vehicle costs. In the case of commercial vehicles for the local traffic, a high percentage of 70 is being ascribed to the fixed i.e. time-dependent vehicle costs as a "devaluation", and a smaller percentage of 30 to the variable vehicle costs (Fiedler, 2007, p.77).

Independent variables	IVECO Daily box-type van 35S11V	IVECO Daily Electric box-type van 35S
Net purchase price without tires	30,230 euro	80,200 euro
Net purchase price of tires	800 euro	800 euro
Circulating assets	700 euro	700 euro
Operating assets	15,865 euro	40,850 euro

Tab. 1: Capital binding of the vehicle purchase

For the vehicle purchase with battery leasing, the Renault Kangoo Rapid dCi 90 (diesel commercial vehicle) and the Renault Kangoo Z.E. (electric commercial vehicle) will be compared with each other. The battery, however, can be only leased for the electric model. In the case of the diesel commercial vehicle it

concerns a normal vehicle purchase. The model-specific calculation data are compiled in table 2 and will be explained briefly hereafter.

In the case of this investment mode, the same information is necessary in order to determine the capital binding for the diesel and the electric commercial vehicles as for the vehicle purchase. However, in case of the electric commercial vehicle information on the battery is added. The battery leasing is completely classified with the fixed i.e. time-dependent vehicle costs. For the tires a net purchase price of 200 euro per tire is once again being assumed.

Independent variables	Renault Kangoo Rapid dCi 90	Renault Kangoo Z.E.
Independent variables	17,610.52 euro	21,956.48 euro
Net purchase price without tires	800.00 euro	800.00 euro
Net purchase price of tires	387.20 euro	425.20 euro
Circulating assets	9,398.86 euro	11,590.84 euro
Operating assets	0.00 euro	2,513.28 euro

Tab. 2: Capital binding of the vehicle purchase with battery leasing in case of the electric commercial vehicle

For the vehicle leasing, the Renault Kangoo Rapid dCi 90 (diesel commercial vehicle) and the Renault Kangoo Z.E. (electric commercial vehicle) as well as the Mercedes-Benz Vito 110 CDI KA/L 3200 (diesel commercial vehicle) and the Mercedes-Benz Vito E-Cell KA/L (electric commercial vehicle) will be compared with each other. The model-specific calculation data are compiled in table 3 and will be explained briefly hereafter.

In the case of the vehicle leasing, only the leasing costs are being set regarding the capital costs. These costs are being ascribed to a hundred percent to the time-dependent vehicle costs and thus increase the fixed vehicle costs and the consequent daily rate of a vehicle (Wittenbrink, 2011, p.49). In return, the variable vehicle costs decrease in case of this investment mode.

Vehicle	Leasing rate (euro/month)	Battery leasing (euro/month)
Renault Kangoo Rapid dCi 90	598.28	0.00
Renault Kangoo Z.E.	724.39	209.44
Mercedes-Benz Vito 110 CDI KA/L 3200	455.86	0.00
Mercedes-Benz Vito E-Cell KA/L	999.00	0.00

Tab. 3: Capital binding of the vehicle leasing

3. Results of the profitability analysis

For the profitability analysis of the vehicle cost accounting, the kilometer rate, the daily rate and the total costs of the vehicles are depicted in the following table 4. For the above described fictive forwarder, the Renault Kangoo Z.E. with a battery leasing of 43,794.03 euro of total costs per year is most cost-effective for a vehicle purchase from a financial point of view. The Mercedes-Benz Vito E-Cell KA/L is the most cost-effective commercial vehicle with 0.0403 euro per kilometer regarding the kilometer-dependent costs. This advantage becomes important when a company needs a commercial vehicle that has to manage an infinite deal more than the annual mileage of 40.000 kilometers per year as assumed here. In the case of the disposal of the vehicle, however, it has to be taken into account that the Mercedes-Benz Vito E-Cell KA/L has a range of only 130 kilometer with a fully charged battery according to the NEDC and after that has to be charged for at least five hours in order to restore the full battery capacity. With a daily rate of 124.43 euro the Renault Kangoo Rapid dCi 90 is the most cost-effective commercial vehicle regarding the time-dependent costs when buying a vehicle.

Vehicle	Investment mode	Kilometer rate (euro/km)	Daily rate (euro/day)	Total costs (euro/year)
IVECO Daily box-type van 35S11V	Vehicle purchase	0.2590	139.13	52,096.65
IVECO Daily Electric box-type van 35S	Vehicle purchase	0.2683	170.60	61,911.98
Mercedes-Benz Vito 110 CDI KA/L 3200	Vehicle leasing	0.1514	127.34	44,260.24
Mercedes-Benz Vito E-Cell KA/L	Vehicle leasing	0.0403	145.58	45,287.81
Renault Kangoo Rapid dCi 90	Vehicle purchase	0.1762	124.43	44,377.34
Renault Kangoo Z.E.	Vehicle purchase battery leasing	0.1066	131.76	43,794.03
Renault Kangoo Rapid dCi 90	Vehicle leasing	0.1232	136.42	45,852.65
Renault Kangoo Z.E.	Vehicle leasing	0.0455	145.85	45,573.76

Tab. 4: Results of the profitability analyses on the basis of a vehicle cost accounting

Even if the profitability analysis was conducted exemplary with the help of the vehicle cost accounting only for a fictive forwarder, it is still shown rather obviously that the currently still high battery costs and the higher acquisition costs

(purchasing prices partly including, partly excluding the battery) of electric commercial vehicles affect the profitability of the electric models negatively as opposed to a diesel model.

When buying a vehicle, the battery costs as a component of the clearly higher acquisition costs have an effect on the kilometer-dependent (variable) as well as on the time-dependent (fixed) vehicle costs due to the amortization of the acquisition costs. This means that the kilometer and the daily rate as well as the total costs are higher with an electric commercial vehicle than with a similar diesel commercial vehicle.

When leasing a vehicle, whereby the leasing costs affect only the time-dependent vehicle costs, the electric commercial vehicle has a cost advantage towards a similar diesel commercial vehicle because of the lower kilometer-dependent costs. However, it has a cost disadvantage because of the higher time-dependent costs. The high battery costs of the electric commercial vehicle are covered here in the leasing rate that has only an effect on the time-dependent costs as a special "cost-pusher". The effects working in opposite directions in the case of the vehicle leasing – relatively low kilometer-dependent and relatively high time-dependent costs for the electric model compared to the similar diesel model – lead to the fact that no general statement of advantageousness in favor of the electric or the diesel model is possible. For the investment mode of the vehicle leasing regarding the ultimately deciding total costs, table 4 shows in an exemplary way that the electric model is once inferior (case „Mercedes-Benz“), but proves to be superior in another case (case „Renault Kangoo“).

If one does not take into account the battery costs in case of the electric model, acquisition costs emerge for both kinds of commercial vehicles that do not differ greatly from each other. In case of the investment mode of the vehicle purchase with battery leasing for the electric model, this advantage is being taken. As a consequence, the electric model in case of "Renault Kangoo" regarding the ultimately deciding costs proves to be economically advantageous if the commercial vehicle is being acquired excluding the battery and the battery is being leased while the similar diesel model is being fully purchased in a

conventional way. Moreover, the forwarder has the advantage of not having to bear the usage risk of the battery on their own.

4. Conclusion and outlook

The profitability analysis based on the vehicle cost accounting has shown that the use of electric commercial vehicles in the field of city logistics – contrary to the widely held prejudice – by no means proves to be an economically disadvantageous investment in general. It rather depends on the situational operating conditions of the respective individual case to be analyzed whether the diesel or alternatively the electric commercial vehicle proves to be economically superior. For the here exemplarily regarded, fictive individual cases of a forwarder it becomes apparent that electric commercial vehicles lead to clearly higher as well as to approximately the same, under favorable terms even to lower investment costs than diesel commercial vehicles depending on the respective investment mode.

Especially noteworthy is that in case of the investment mode of the vehicle purchase with battery leasing for the electric commercial vehicle, the cost advantages with the variable vehicle costs can have a positive impact without the cost disadvantages of the high battery costs completely compensating these cost advantages. Therefore, it is desirable that more vehicle manufacturer of electric commercial vehicles offer this investment mode. However, this applies only as long as the climate change policy and the transport political objectives are being shared, and if as many transports of goods of transportation with climate-damaging emissions of greenhouse gases as possible, like e.g. diesel commercial vehicles, are redeployed onto other means of transportation without emissions, like e.g. electric commercial vehicles (or also railways or inland vessels).

In future, the here portrayed profitability analysis based on the vehicle cost accounting shall be further developed along three main lines.

Firstly, the "static" comparative cost calculation should be expanded by a "dynamic" investment calculation in the sense of the "life cycle costing". With this, an adjustment from "calculated" costs to "real" payments has to come along in order to capture economically correctly especially interest effects within multiannual investment and planning periods.

Secondly, next to costs or payments as negative performance indicators also proceeds as positive performance indicators should be taken into account. This applies above all to additional proceeds that may result from the quantity and the price effects of an enhanced reputation based on "green logistics". Furthermore, additional proceeds may be generated if an integration of electric commercial vehicles into the "vehicle-to-grid concept" (Bretzke and Barkawi, 2012, pp.141–142; Fournier, et al., 2014, pp.67–76) is successful. Here, the batteries of the vehicles serve as a temporary storage for electricity from renewable energies, like e.g. from wind power plants. This concept supports the expansion of renewable energies since wind and solar farms have to be partially shut down at the present time because they produce more electricity than can be fed into the electricity grid. By taking the positive performance indicators into account, an extension of the profitability analysis to a determination of the "total value of ownership" happens.

Finally – and thirdly – an extension of the profitability analysis by a non-monetary determinant of the economic success should be considered. Thereby, it can concern reputational effects that can admittedly be measured with the help of a reputation survey, but are only very hard to convert into additional proceeds ("monetize"). But also other non-monetary effects come into consideration, like e.g. the basic or the depending on the time of day accessibility of inner cities for the delivery of customers. In order to factor such effects in, in an economically convincing way, it needs further analysis methods "beyond" the established investment calculation. A promising approach in this direction presents the method PROMETHEE that is currently being looked into regarding its applicability for an extended profitability analysis in another research project (Cinibulak and Zelewski, 2014).

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