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Less range as a possible solution for the market success of electric vehicles in commercial fleets

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Abstract

This study analyses the real-world usage of electric vehicles (EVs) in the French-German border region in commercial fleets in a field operational test with more than 100 EVs. Android smartphones are employed as data loggers in the vehicles for GPS data and additional trip data. It is shown from the analysis of about 3,000 trips that the EVs are as pool vehicles dominantly chosen for short trips with mostly only one person and few payload in a small local area. They show a daily mobility far below their maximum range with long parking hours at night. Likewise there is no need for fast-charging. The data suggests that about 90 % of the mobile days could be covered with an EV range of 60 km and nightly recharging. A model calculation indicates that an accordingly specified EV would have significantly lower battery costs. In a total cost of ownership (TCO) perspective this might even lead to a cost advantage in comparison to a conventional car. This would form a working business case for electric vehicles in commercial fleets and remove a major obstacle for their market success. Furthermore the market potential in commercial fleets is pointed out based mobility studies and the German fleet structure.

Keywords: BEV (battery electric vehicle), commercial, fleet, market, range

1 Introduction

The main obstruction for the market success of the current generation of electric vehicles (EVs) is found in the high acquisition costs [1] [2]. Even the lower operating expenses during the lifetime do not compensate this cost gap in comparison to a similar car with internal combustion engine (ICE). In commercial fleets EVs also provide the benefit that they can have a positive effect on the image of the company which brings an additional value for the company that is hard to quantify. But nevertheless the gap in the total cost of ownership (TCO) between an EV and an ICE should remain small if at all existent for a real market success. A survey among fleet managers in Berlin showed that almost 40 % are not willing to accept any TCO increase for EVs and 1/3 would only accept up to 5 % [3]. Currently the TCO gap for business users is seen between 2,200 and 5,300 Euro [4]. One main determinant of the EV's acquisition costs is the battery capacity. For that reason it is absolutely crucial for a market success to have a clear insight in the actual demand of range of customers to build EVs with the cheapest battery capacity possible to fulfill the needs of the user. Simultaneously in reducing the gross weight of the car this measure would increase the overall efficiency as well.

Therefore we will present results from the real-world usage of EVs in commercial fleets and deduct their actual demand of range. Based on these figures we will give an estimation for the cost advantage potential of an accordingly designed vehicle to meet that range demand and give an outlook on the potential market.

2 Study Design

One prime goal of the study is to identify the specifics in the usage of EVs in commercial fleets to derive the actual demand of range according to the usage patterns. These results can be used for a demand-orientated dimensioning of cheaper EVs for a future market success. Therefore a field operational test (FOT) has been implemented in the French-German border region with more than 100 EVs that have been distributed to business customers on both sides of the border. The majority of the vehicles are used in a multi-user scenario as part of a small commercial fleet of public authorities or midsize companies. The project-fleet includes seven different car types from four European car manufacturers. The corpus of the fleet is equipped with data loggers to monitor certain conditions of the vehicle. One main interest is in the GPS data which is used as a basis for the mobility analysis. GPS provides accurate information about time, position, speed and distance. In addition to the analysis of technical data the users are also interrogated directly with several questionnaires to collect background information about companies and users as well as subjective data like satisfaction with the cars (results available in [5]).

2.1 Measurement system

2.1.1 Measurement device

A big part of the fleet had to be retrofitted with GPS data loggers after the cars have already been delivered to customers. As the fleet is spread over a large area in France and Germany the data loggers also need to be able to transfer the acquired data wirelessly. This is why Android smartphones type Samsung i5500 GT were chosen as GPS data loggers.

2.1.2 Application

A special application has been programmed to acquire data with the smartphones. The application starts with the identification of car and driver via unique ID. Afterwards a short optional questionnaire gives the opportunity to collect additional data about the trip via multiple choice-input (e.g. number of passengers on board or payload). During the trip the GPS signal is recorded at a sample rate of 1 Hz including the following data: Longitude, latitude, altitude, speed, accuracy, bearing and time. Additionally the device records orientation information and accelerations at a rate of 10 Hz. At the end of the trip the application checks for a network connection and if available the data is transferred via the GSM interface in an SSL-encrypted text upload. If no signal can be found the trip record is kept to be uploaded after the next trip. This method enables a continuous evaluation of data during the FOT without the need for a manual readout or the exchange of a removable storage medium.

2.1.3 Data storage and post processing

The upload is received by a server connected to a large SQL database where the mobility data is stored. For post processing and analysis the data is exported trip wise in CSV-files to be imported into MATLAB. All further calculation an analysis is performed in this programming environment.

3 Situation in commercial fleets

Commercial fleets offer the big advantage in comparison to private households that there is often a larger pool of cars. In those pools it is unproblematic that even EVs with 100+ km operating distance are unable of providing range for every possible trip [6]. For long trips large and comfortable cars or alternative means of transport like trains are often preferred anyway. In spite a small and efficient EV for short trips that only covers a share of all trips would help to increase the overall efficiency of the fleet. Furthermore many fleet vehicles are used at companies or local authorities that only cover a rather small circumference with their business. Therefore there is also only a very limited demand of range for business trips. Examples are craftsmen with regional customers or nursing services. Another important field of application for short-range vehicles is postal delivery. DHL's delivery vehicles are used for an average daily range below 40 km [7] and FedEx delivery vehicles [8] are even only driven 24-32 km per day. In Germany 80 % of all commercial vehicles are used less than 80 km per day [3].

This shows that there is a huge potential demand for EVs that are optimized for short to middle distances. Additionally companies using EVs perceive a positive effect on their image what could monetarily be evaluated similar to regular advertisement. Nevertheless a vehicle acquirement usually has to be judged in a TCO comparison with alternatives where most companies accept only a small extra charge for an EV if at all [3]. Initially EVs were often bought or leased by companies and in many cases in the framework of a research project. With the beginning market ramp-up we now see a trend that companies and local authorities are only responsible for 1/3 of sales of certain EVs [9] what is presumably a result of the higher price sensitivity of commercial users.

4 Key findings

The analysis of ca. 3,000 trips with almost 30,000 km shows that the EVs are mainly used for short trips (Fig.1) with 1.2 passengers on average and in 94 % less than 5 kg of luggage. It has to be mentioned that a large part of the fleet has only two seats what might have an influence on the passenger number. But business cars are only very rarely used for more than two persons and the average number of passengers found here is also confirmed by other studies [10].

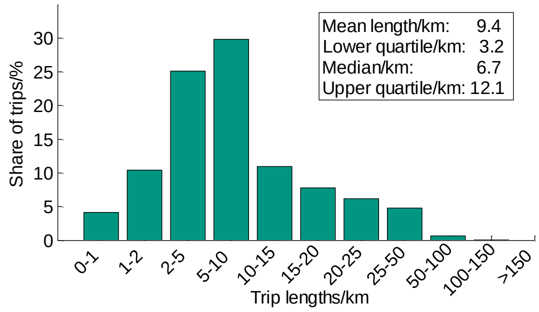

Figure 1: Trips with EVs classed by length

The mean trip distance is 9.4 km and the median 6.7 km. This is slightly below the average French and German trip lengths of 11 km [11] and 11.5 km [10]. In [7] 7.3 km was found as the average trip length in a combined analysis of commercially and privately used EVs. Less than one per cent of the trips exceed 50 km despite having cars in the study with 255 km range in the New European Driving Cycle (NEDC). Three quarters of the trips are 12.1 kilometres long or shorter. This shows a strong focus on short distances for individual trips what can also be seen in the fact that arithmetic mean and median are only 2.7 km apart from each other. When taken into account that there should be no need to recharge the EV during the day the total mobility for mobile days has to be viewed (Fig. 2).

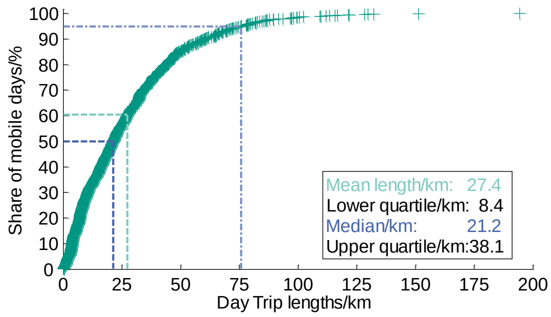

Figure 2: Cumulated trip lengths for mobile days

Also in this perspective the mean length for all trips on a mobile day is still below 30 km and the upper quartile is 38.1 km. This pattern is comparable to privately used passenger cars in Germany with an average of 30,9 km/d (week average) but less than average commercially used cars with 58.5 km/d (week average) [12]. The low average results from the lack of long distance trips.

Table 1: Movement spaces

	Median	Mean value	Upper quartile
Radius per trip in km	1.6	2.9	3.7
Radius for all trips per car in km	13.5	17.1	24.9

Table 1 indicates regionally limited usage in an average radius of 2.9 km around the centre of the trip. The cumulated analysis for each car shows that 75% of the EVs have only been moved in an area with a radius below 25 kilometres for all of the recorded trips. It has to be noted that the centre of the movement space here is not necessarily the base of the vehicle as it is calculated on basis of all locations that have been recorded for the vehicle. The local concentration is higher than for conventional German cars with 60 % solely used in a radius of 50 km or below around the user's home base [12].

The trip speed distribution (Fig.2) suggests a predominant urban use. Defining 60 km/h as maximum city speed (50 km/h as urban speed limit + 10 km/h tolerance) almost three quarters of the trips show an in-city-share of 80 % or higher.

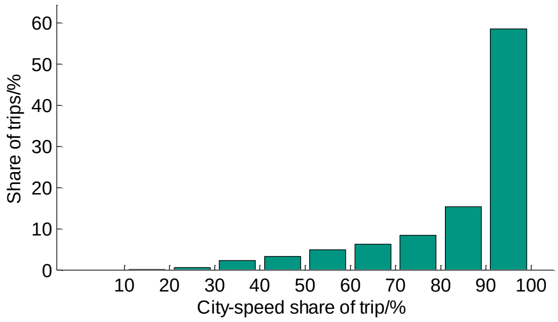

Figure 3: City-speed share of trips

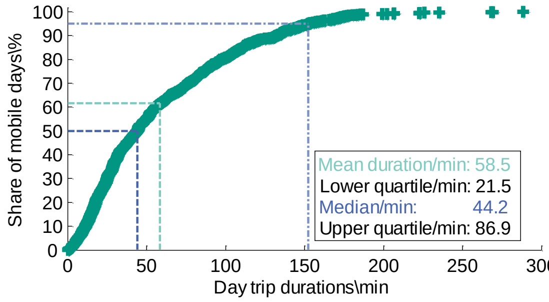

Figure 5: Daily trip duration

Similar to conventional business cars [12] the EVs are mostly used during the regular business hours of their users with slight peaks in the morning and in the afternoon. Only a negligible share of trips happens between 21 and 6 o'clock. This offers the potential for regular nightly recharging.

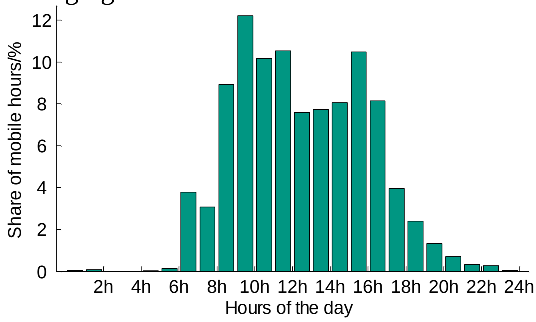

Figure 4: Mobility distribution across the day

Keeping the average daily trip length of 27.4 km in mind it is clear that usually only few energy needs to be recharged. Even at a slow charge with 3 kW normal EVs should be recharged in less than two hours. Likewise there is a big potential for load shifting to the night or very early morning to phases with lower energy prices or even the possibility of net balancing in the evening hours when most of the EVs are plugged-in already.

The average daily usage time of the EVs is 58.5 min and the median is 44.2 min (Fig. 5). This corresponds to the daily trip lengths of 27.4 km (arithmetic mean) and 21.2 km (median) and the high in-city share at comparably low average speeds.

The daily trip times consist of 3/4 actual movement time and 1/4 of phases with zero speed at traffic lights for example.

4.1 Round up

Based on the recorded trips it can be shown that the EVs are mainly used for short trips below 10 km and even the combined mobility for a whole day is far below the vehicles' maximum range. The cars are mostly used by only one person with very few luggage in an urban environment in a rather small area around the company. We see over-night parking times of nine hours or more on the companies' parking lots. This leads to the conclusion that for today's use of EVs with limited ranges, the range that is offered and requested is too high and too expensive for the actual demand. Having the ability to switch to other means of transport for longer trips, the commercial fleet users mainly take the EV for short in-city trips. Accordingly the vehicles properties should be optimized for a short range scenario to give an advantage in costs and overall efficiency.

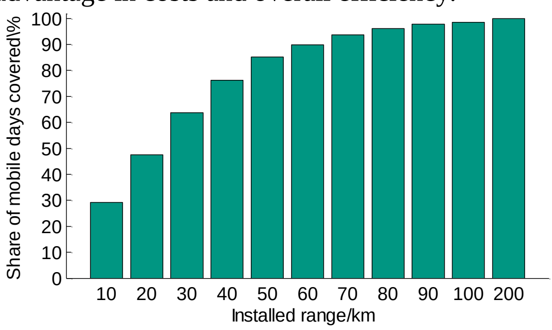

Figure 6: Share of mobile days covered per installed range with solely nightly recharging

Setting the installed range on the mean value for mobile days (27.4 km) about 60 % of all mobile days could be executed. But on the other hand this means that the user would have to adopt his mobility to the specifics of the car on 40 % of the days. This is would be a big obstruction for the acceptance of the vehicle. Fig. 6 shows that the lion's share of all mobile days (90 %) can be covered with an installed range of only 60 km without any recharging during the day. To cover the last 10 % more than three times the range would be necessary. Therefore it is meaningful to focus a vehicle design on those 90 % and achieve an enormous cost reduction with the adjusted battery size. From an overall perspective a positive perception from the user is expected as he gets a large cost advantage for a comparably small demand for increased planning of vehicle usage.

5 Use-based specification and cost advantages

To show the financial potential of an optimized short-distance EV we compare it to a typical EV with 135 km NEDC-range, 16.5 kWh battery capacity and 8 h charging time [13]. The actual costs for current lithium battery systems (battery plus power electronics) are hard to determine. They are found in the range between 700 €/kWh [14] and 1,000 €/kWh [1]. For further calculation we assume 800 €/kWh what results here in battery costs of 13,200 €.

About 90 % of the recorded mobile days can be covered with 60 km range. The parking times at night are long enough for a complete recharge of the battery system even when only charging with Mode 1 at a maximum of 3.6 kW. The data suggests that in this scenario there is no need for expensive fast-charging technology. The few remaining mobile days with longer total trip distance can be covered with conventional cars from the fleet, other means of transport or even with the short distance EV when it is (partly) recharged during the day. Even the day with the longest movement duration in the record still offers more than 19 hours of parking time for potential recharging. Without considering efficiency improvements through battery weight reduction a battery capacity of 7.3 kWh can be deduced from the original specification to give enough range for 60 km in the NEDC. This generates in comparison a cost reduction of more than 7,300 € by reducing the installed capacity to 44 % of its original size. The usual TCO gap in commercial fleets versus an ICE [2] is seen between 5,800 € and 2,200 €. This gap is turned here into a cost advantage between roughly 1,500 € and 5,000 €. So the EV would actually be cheaper than the ICE in a combined view of acquirement and operation costs. Of course it has to be kept in mind that the development and production costs for the vehicle manufacturers and accordingly the prices of the vehicles might rise with a diversification for special range needs. But for current EV designs it can be observed that high battery capacities are often achieved with a parallel connection of several e.g. two [15] or three [16] identical batteries that each run on the final voltage level. Those modular topologies suggest easy variations of EVs with half or third ranges or other fractions in comparison to the standard specification without additional development costs. In terms of economy of scale a positive effect for all EVs using battery system based on those modules can be expected. When the production number of the short range EV rises the number of produced battery modules will rise as well what can lead to a price reduction of the modules an well as of all battery variations based on the modules.

A specification purely based on the NEDC might be insufficient in real usage throughout the whole year as the NEDC does not include auxiliary energy demand. The auxiliary energy has to be stored in the battery as well. The overall city-consumption for an average EV including heating and climatisation under realistic conditions from winter to summer can be assumed as 22.8 kWh/100 km [10]. This increases the battery capacity for 60 kilometres range including auxiliary power demand to 13.7 kWh with a remaining cost advantage of ca. 2,200 € to the stock specification. Those additional 6.4 kWh on top of the NEDC-based design can also be viewed as a buffer for unanticipated events. As 13.7 kWh are sufficient energy for the mobility and comfort demand like heating and climatisation the driver can decide to cut auxiliary energy if necessary and get a significant range increase for total trip lengths far beyond 60 kilometres. In fact it was shown from the summary of certain fleet trials in Germany with over 350 vehicles [7] that the average consumption for small and middle class vehicles is only around 17 kWh/100 km. That would enable the here specified EV for an operating radius of 80 km without recharging what is equivalent to a range buffer of 1/3 of the installed range. Depending on the actual TCO gap in the given range, the vehicle still reaches TCO equality with an ICE or is at least significantly less negative than the original specification. Hereby a major obstacle for the market success of EVs in commercial fleets is removed. It also has to be kept in mind that the positive effect on the image of the company through using an EV has not been evaluated monetarily at this point.

This approach of focussing the range on the lion's share of the mobility demand cannot be applied on all vehicles of course. For companies or households with only one vehicle it would need a significant change in mobility if another means of transport had to be employed on statistically every 10^{th} day. Still car sharing and public transport could probably fill the gap in numerous cases.

But it has also been shown [17] that not only fleets offer a large potential for EVs that are optimized for short distances. So called "hybrid households" also have more than one car where one of them is dominantly used for short ranges. This car might as well be replaced with a short-distance EV without forcing the users of the household to noteworthy compromises. In [18] more than 1/3 of all household that owns passenger cars stated to have two or more vehicles. Here we also find a large market potential for optimized EVs.

5.1 Market Potential in commercial fleets

Research on the commercial usage of passenger cars [19] shows that 20 % of all commercial trips are performed with passenger cars of commercial car owners. Commercial trips are responsible for 14,995 Billion trips in Germany per year. Likewise about 3 Billion trips are made with commercially owned passenger cars every year. In total more than 4 million commercially owned passenger cars are registered in Germany what is about 10 % of all German passenger cars. The average age for German cars is 8.7 years [20]. Despite the fact that commercially used cars are probably in average younger than private cars we can choose this figure as minimum. This would mean that every year in Germany at least about 460,000 new commercially used passenger cars are sold what shows the big market potential for electric vehicles in commercial fleets. The use-case for short range vehicles can be seen from the fact that 30 % of all commercially used vehicles are utilised in the city of the company and 50 % in the surroundings [12] (multiple answers were possible).

6 Conclusion

The public discussion about a potential market success of EVs usually tends towards more installed range as many users fear limitations in their operation [21]. In commercial fleets the situation is different as many companies use a pool of cars where there is no need for every individual car to be able to provide range for every possible trip. Here it is possible to build up a portfolio of vehicles that are optimised for certain fields of the total mobility demand of the company to achieve an overall efficiency improvement. In those fleets the TCO gap is the dominant obstacle for the introduction of electric vehicles. Similar situations can be found in hybrid households with two or more cars where one vehicle is in many cases dominantly used for short ranges.

This paper gives an overview of the everyday usage of the current generation of EVs in commercial fleets. Through the analysis of ca. 3,000 datasets we showed that EVs in commercial fleets are mainly used for short trips with mostly one person in a small local area far below their maximum range. Even when combining the trips of mobile days per vehicle the majority stays far below the maximum range of the EVs. Therefore a possible solution would be to offer small EVs with an installed real-world range of 60 km which could still provide enough range without recharging during the day for ca. 90 % of all the mobile days we have seen with fully equipped EVs. The reduced battery expenses could turn the current TCO gap between EVs and ICEs into a TCO advantage and form a working business case for EVs in commercial fleets.

7 Outlook

Battery size and operating range are a major field of research for the future development of EVs. Especially private users are very focused on that topic. The goal is to achieve significant range improvements in the near future. Nevertheless increasing battery capacity is still equivalent to increasing acquisition costs what is another main area of interest. To fill the gap until battery prices have dropped significantly and to support a market ramp up we recommend a modular battery strategy that enables manufacturers to offer different ranges at different price levels. Commercial fleets with a professional fleet management could adopt those short range variants in high numbers if the cost structure was comparable to a conventional car. This demand would support the production ramp up and help to reduce vehicle costs for all specifications.

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