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Potential users of electric mobility in commercial transport – identification and recommendations

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Abstract

Commercial transport is seen as early adopter of electric mobility. But there is lack of knowledge regarding the use of battery electric vehicles for commercial transportation and potential user groups. We outline a reliable and cost effective methodology to identify vehicles that can be substituted by battery electric vehicles in corporate fleets – technologically and economically efficient. We analyzed statistical data to identify economic sectors that might suit for electric mobility and conducted an online survey with fleet managers of these sectors to gain knowledge about driving patterns and their attitude towards the use of BEV. Furthermore we conducted a GPS data tracking of selected corporate fleets to proof substitution potentials. The analysis was done in Austria and Germany. For fleet management systems designed for mixed and electric fleets we outline a framework and explain algorithmic concepts. Finally, we derive recommendations for stakeholders such as policy makers, vehicle manufacturers, service providers and corporate fleet operators.
The statistical analyses show that highest potentials for battery electric vehicles are according to NACE nomenclature in Wholesale and retail trade, Service and Human health sector. The survey revealed that driving range of battery electric vehicles already comply daily mileage requirements with a high extent within Germany nursing companies and pharmacies. Furthermore, the attitude of the interrogated fleet managers towards the use of BEV is mostly positive but detailed knowledge about BEV and driving patterns of the own vehicles is lacking. Finally, the GPS data tracking could proof high potentials for BEV in these economic sectors.

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Keywords: Commercial transport; electric vehicles; policy recommendations; GPS

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1. Introduction

Sustainable commercial transport solutions are one key factor increasing quality of live in cities and urban areas. Around 75% of the population in Europe already live in urban areas (European Commission, 2014) and thus are affected by urban freight. Commercial transport accounts for 36% of all trips and 27% of kilometers traveled in Germany (Wermuth et al., 2012). The European Commission (EC) aims to decrease negative effects of urban commercial transport on environment and quality of live. Therefore, the EC set the goal of achieving an essentially CO2 free city logistics in major urban centers by 2030 (European Commission, 2011). The strategy of avoid-shift-improve could help to reach that goal: avoiding unnecessary trips by an improved and efficient transport system; shifting transport from the most energy consuming urban transport mode (i.e. road transport) towards more environmental friendly modes; improve vehicle and fuel efficiency as well as optimization of transport infrastructure (Nakamura and Hayashi, 2013). The implementation of electric vehicles is considered as one important step in the improvement of commercial transport in urban areas.

Ambitious goals for the introduction of electric vehicles (EV) have been formulated. Commercial transport is seen as an early adopter of electric mobility. In Germany the goal of one million electric vehicles by 2020 has been set in 2009 (Die Bundesregierung, 2009). Even if growing registration numbers of EVs are observed in recent years (see Figure 1), numbers are fare from realizing this ambitious goal: At the end of the year 2014 there have been 18,948 battery electric vehicles (BEV) and 107,754 hybrid vehicles (HEV) in stock in the Germany vehicle register (KBA, 2015). The number of BEV per capita in Germany amounts to 0.24 vehicles per 1,000 inhabitants. At the same time 3,386 BEV and 12,823 HEV were in stock in the Austria vehicles register (Statistik Austria, 2015). There were 0.40 BEV per 1,000 inhabitants in stock in Austria at the end of 2014. New registrations amount to 12,363 BEV and 33,630 HEV in 2015 in Germany (KBA, 2016).

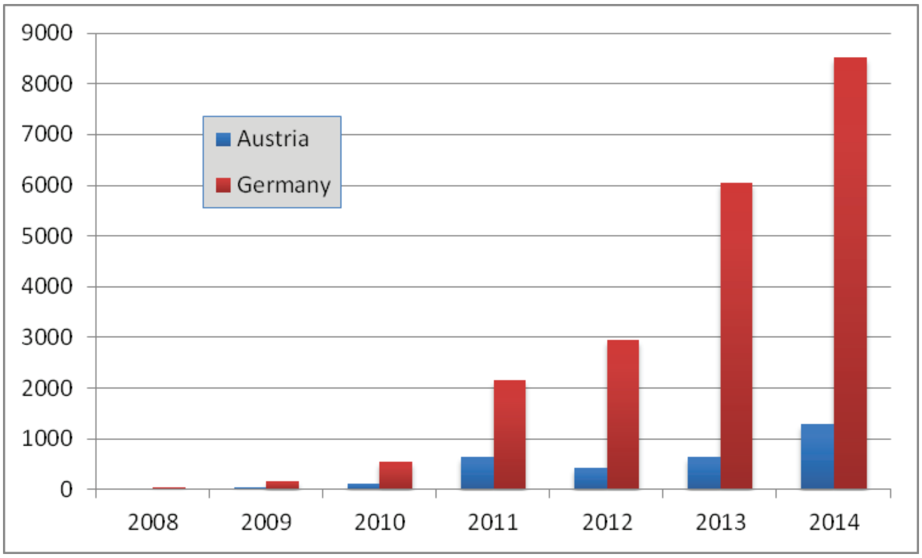

Figure 1: Registration of battery electric vehicles in Austria and Germany 2008-2014

To enhance the use of EV different measures have been taken in Germany. After a series of R+D projects between 2009 and 2015 to improve the performance of the German automotive industry and examine the acceptance within the German population in 2015 the so-called ‘electric mobility act’ was enacted for further EV promotion. It allows the federal states of Germany to grant EV users privileges over other vehicle users when, for example, parking in public spaces or using bus lanes (Deutscher Bundestag, 2014; Trommer et al., 2015). Up to now, there are no policy measures in Germany which influence the purchase price of EVs directly. In some research projects special conditions are offered to people buying EVs (e.g. reduced leasing rates) but incentives for this are given through R&D projects which are funded by the government or the EC.

To lower the operational costs of EVs in Germany the taxation policy for the private use of company cars has been adopted. To minimize disadvantages due to higher list prices of plug-in electric cars private users are allowed to offset the list price with €500 per kilowatt hours of battery size off the monthly rate of 1%, which is treated as taxable income. In general EVs and plug-in hybrid electric vehicles (PHEV) are exempt from the annual vehicle tax for five years. Furthermore, the federal government is considering a special depreciation for zero-emission company cars. Since the beginning of the year 2015 a change in the German driving license regulation allows driving electric vans with a gross vehicle weight (GVW) up to 4.25 tons with a class B driving license. For conventional vehicles the maximum allowance is 3.5 tons GVW with this type of driving license (see BMVI, 2014). Apart from this, different actors demand further measures to improve the attractiveness of electric vehicles. In general, these measures do not differentiate between private and commercial users. We will show a significant potential for the use of EVs in commercial transport. Therefore, we will derive and propose measures to enhance the use of electric vehicles in commercial transport.

Compared to the goal in Germany the Austrian government stated the intention to support the development and integration of the required infrastructure to promote and push e-mobility without mentioning any numbers of registered EVs until a certain date. With the end of 2014 only 0.072% or 3386 cars (2013 0.044% or 2070) of all registered passenger cars were equipped with an electric power-train. This represents an increase of electric driven cars of about 61% in one year. Beside experimental vehicles or vans and lorries for field test there are only a few electric-driven commercial freight cars currently in use in Austria (386 vans and lorries in 2012). Due to the given guidelines for statistical investigations by the national statistical institute of Austria (Statistik Austria) it is not possible to verify the exact number of these types of cars used by companies for commercial transport.

2. Objectives

In the light of the current developments this paper aims at deriving recommendations towards an enhanced use of electric vehicles in commercial transport. For this we will analysis the potential for the use of electric vehicles in commercial transport trying to identify barriers for implementation of electric mobility. Municipal mobility strategies are seen as necessary part in the introduction of cleaner vehicles (Foltyński, 2014). It is obvious that a broader variety of models which suits commercial needs is required to increase registrations of EVs. Therefore, we focus on the technological user needs and on user acceptance.

The results in this paper were derived from the project SELECT (Suitable Electromobility for Commercial Transport), which was supported by national funding in Austria, Denmark and Germany as well as European cofunding under the ERA-NET Electromobility+ scheme. The project investigates how EVs may contribute to an environmentally sustainable alternative to current patterns of urban commercial transport. One central objective of the project is to understand the needs, requirements and attitudes of selected commercial sectors with respect to the use of electric vehicles to fulfil their transportation needs. Out of this investigation recommendations were developed considering different areas and levels of action, as well as the stakeholders in question.

In the following section we describe the methodology of our analysis for the identification of suitable sectors for the use of EVs in commercial transport. This includes the steps of the analysis as well as the description of the data used. Main part of our paper is the presentation of the results of this study. We also propose a framework for the fleet management of EV fleets and mixed fleets, which was developed within the SELECT project. Finally, we finish our paper with a list of recommendations for policy measures to enhance the use of electric vehicles in commercial transport.

3. Methodology

Commercial transport, which is the focus of this paper, is defined as the transport of goods as well as the service related traffic. In the analysis of the potential use of electric vehicles in commercial transport we focus on battery electric vehicles only and their technological capabilities. Our analysis focuses on the countries of Austria and Germany.

To derive recommendations for the best exploitation of potentials of the use of EVs in commercial transport we first analyzed the potentials in the Austria and Germany. We chose a three steps approach to analyze available data on transport and own empirically surveyed data.

At the most general level the commercial transport sector in its variety was analyzed. Questions to be answered include the overall applicability of electric vehicle both qualitatively (e.g. compatible transportation tasks, usage patterns) as well as quantitatively (e.g. potential market shares based on required vehicles). Common as well as diverse requirements were identified. A more detailed analysis was carried out at the mid-level when concentrating on particular sectors that were identified to be of considerable quantitative relevance. Finally, at case study level, specific organizational needs arising from the utilization of electric vehicles gained center stage by looking at the actual practical integration of such vehicles into a particular fleet.

In the first step of our analysis on the most general level we analyzed the daily mileage per economic sector in Austria and Germany. Furthermore the vehicle stock for each economic sector is analyzed. As a result we derive potentials for the use of EVs in commercial sectors. Data sources for the analyses in Germany include publications and statistical data provided by the German Federal Motor Transport Authority (KBA, see http://www.kba.de) as well as empirical survey data from Motor Vehicle Traffic in Germany - Survey of Motor Vehicle Owners 2010 / Kraftfahrzeugverkehr in Deutschland 2010 (KiD 2010, see Wermuth et al., 2012). The survey KiD 2010 funded by the German Federal Ministry of Transport is a nationwide representative survey of vehicle owners on the usage of motor vehicles. The purpose of this study was to record commercial transport, e.g. trip lengths and transported freight. The survey focused commercially registered passenger cars and light duty vehicles/vans with payload up to 3.5 tons. But also heavy duty vehicles and motorbikes were surveyed. The net sample of the survey contains 70.249 recorded vehicle days in total. For this paper the scientific use file of the KiD 2010 could be exploited. The KiD 2010 was a follow up to KiD 2002, the first survey of this kind in Germany.

The analysis in Austria is based on two datasets which were provided by the Austrian Statistics Institute (Statistik Austria) and the Austrian Chamber of Economics (Wirtschaftskammer Österreich). These datasets were merged to provide approximately the same categories as in the German dataset. The Austrian statistics Institute uses categories different from the NACE-Code, since some NACE categories are considered confidential in Austria.

The objective of the second step was to understand the transport needs, related requirements as well as attitudes of particular commercial sectors and involved actors with respect to the use of EVs to fulfil their transportation tasks. The targeted sectors for this analysis were chosen accordingly the results of the first step. The aim was to get a more focused view on these sectors expected to be early adopters for electric mobility. Relevant data for this step was generated by a survey. Its results were used for the further analysis of company-specific trip patterns.

The survey was administered from August to October 2014 among a target group of company representatives involved in fleet decision-making in companies from various economic sectors. This study focused on small and medium size firms because such firms, and in particular entrepreneurial-type businesses, are an ideal focus for early adoption because of their autocratic decision style and high openness to innovative change, risky decisions and government incentives (Nesbitt and Sperling, 2001). In Austria (AT), a company database with 21,300 email addresses led to 206 complete responses. In Germany, three specific economic sectors were chosen: Mobile nursing/homecare (DE: Nursing), pharmacies (DE: Pharma), and courier, express and parcel delivery services (DE: CEP). 24,100 companies were targeted in total and 546 complete responses were collected.

In order to get a comprehensive knowledge of the driving profiles in different economic sectors we use GPS-data in the last step of our analysis. The data were recorded on-board during a period of several weeks. In detail the realized survey was supposed to give evidence regarding the possibility to replace conventional vehicles by electric vehicles in commercial use. The analysis was also based on the results of survey. The GPS-data was examined regarding driving and usage patterns. The analysis also focused on transport demands and the influence of parameters like e.g. time or weekday. We conducted GPS-tracking with commercial fleets on passenger cars and/or light duty vehicles with a permissible maximum weight under 3.5t. The surveys in Austria and Germany were conducted with comparable devices and only slightly different methods. During the survey of different nursery companies in Germany, onboard GPS-tracking devices were used. These devices tracked the position of the cars 24-7 during a period of two to three weeks each. While the vehicle engine was running, GPS-coordinates were logged for each second during the monitoring. Information about the purpose of the trips is not available. The data analysis included single trips analyses, stop detection as well as further statistical analyses. A two minutes stop criteria was applied to separate single legs for a proper stop detection which should only detect stops at patients' homes or company grounds. Traffic related stops at lights or due to congestion should not be detected as a real halt. After returning to the company's premises a new tour was applied.

Last step of the project was the development of recommendations for public policy, decision makers and other stakeholders, e.g. private entities. Basis for this was the outcome of the previous steps described above where barriers for the implementation of electric vehicles in commercial transport were identified.

Parallel to the identification and analysis of potential users for electric vehicles in commercial transport a framework for fleet management systems taking into account the requirements of electric vehicles. The objectives were the translation of the requirements revealed in the analysis of specific economic sectors into specifications for the development of a methodological framework for fleet management systems of fleets with EVs or EVs and conventional cars. On case study level, this framework should be optimized and evaluated by implementing a customized exemplary application.

4. Results

According to our presented method we will describe in the following subsections the results for each step of our analyses. First of all we will show which economic sectors have high shares of the total vehicle stock (high number → high effect) and which economic sectors show daily mileages, which are suitable for the use of EVs. Following this we show how the attitudes of decision makers favor the use of EVs. In the last subsection of the presentation of our results we show to which extend variations in daily travel patterns influence the potential for EVs in commercial applications. The description of our results will lead to the deduction of recommendations for the development of the deployment of EVs in commercial transport.

4.1. Analysis of statistics and studies

The vehicle stock in Austria and Germany is registered in different manners. Thus a direct comparison of both countries is not possible. Nevertheless it is possible to categorize economic sectors in similar ways. This allows identifying similarities and differences.

Table 1 shows that 6.994.485 vehicles including trailers were registered in Austria by end of the year 2012. Our analysis focuses on lorries with a permissible maximum weight of up to 12 tons (359,474 vehicles) and passenger cars (4.584.202 registered vehicles). Passenger cars also include vehicles with commercial owners, but this type of ownership is not specifically highlighted in the available Austrian data.

Figure 2 breaks up the distribution in % of the GVW categories into each economic sector used in the Austrian statistics. Regarding light and heavy duty vehicles, the majority of vehicles have a gross vehicle weight (GVW) between 2 and 3.5 tons in all sectors apart from Transport.

Most of the passenger cars with commercial owner in Germany are registered for the Other service activities sector, roughly 35%. Other important sectors in terms of stock of passenger cars are the Wholesale and retail trade sector and the Manufacturing sector. Concerning the annual registration of passenger cars with commercial owner about every third vehicle is registered for the Wholesale and retail trade sector (G), which also includes Vehicle trade. This means more than 90% of the passenger cars in this sector are newly registered every year. Similar rates of renewing could be seen for the Administrative and support service activities sector (N). In the Manufacturing sector (C) about every second passenger car is a newly registered one each year (see Table 2).

Altogether 35% of the lorries in Germany are registered for private vehicle owners. The sector of Other service activities (S) has a share of 22% in total and even in each vehicle category. Further 9% of the lorries are registered for the Construction sector (F). About 20% of the lorries between 7.5 and 12 tons GVW are registered for the Transportation and storage sector (H) (see Table 2).

Table 1: Vehicles by Permissible Maximum Weight (PMW) and the Austrian economic sectors, due date 2012-12-31

Category	Passenger cars	PMW <= 3.5 t	3.5 < PMW <= 12 t	All vehicles*
Public administration (NACE O)	17,019	3,404	255	32,712
Agriculture (NACE A)	107,869	13,814	568	529,700
Production	76,514	73,278	2,431	205,858
Trading	183,238	72,537	3,819	318,057
Transport	28,890	19,493	2,617	131,458
Hotel and restaurant industry	28,665	5,785	83	46,192
Organisations, associations, etc.)	5,963	870	237	20,239
Other economic sectors	192,915	68,723	2,123	347,620
Employed people	3,943,129	88,493	944	5,362,649
Sum	*4,584,202*	*346,397*	*13,077*	*6,994,485*

* *Including lorries >12 tons, trailers, and other vehicle types. Source: Statistik Austria, 2013*

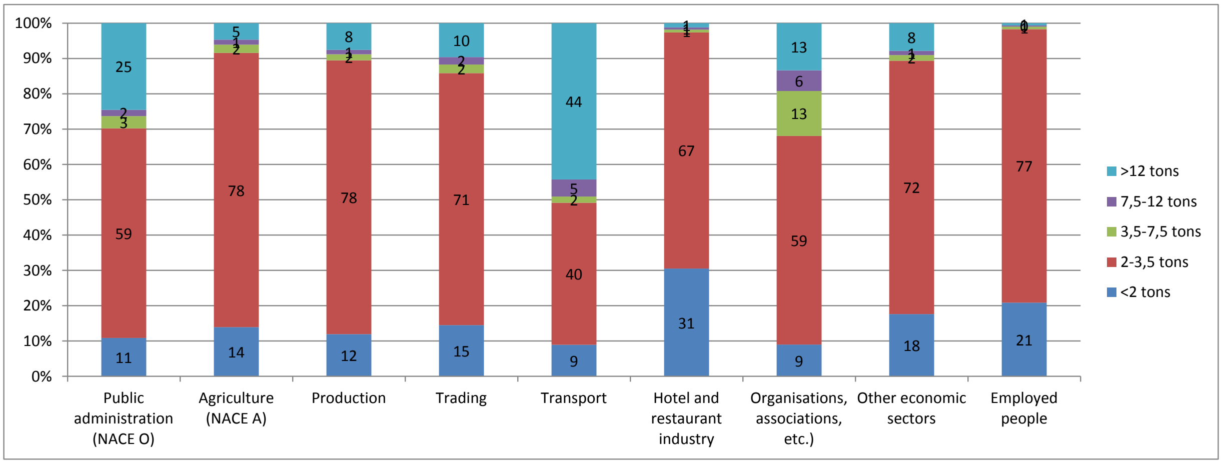

Figure 2: Distribution of vehicle PMW in % in the Austrian sector categories, Source: Statistik Austria, 2013

Data on daily mileages per vehicle are surveyed differently in Austria and Germany: In Austria statistics about the domestic transportation performance is the only source of information. Mean values for daily mileages are calculated based on this statistics. The mean value is 44.2 km for Austria. In Germany the daily mileages are calculated as the sum of all single trips which were reported in KiD 2010 by the respondents at the survey day. The mean value for all vehicles is 36.3 km (Wermuth et al., 2012)

As data on transport in Austria are scarce we can only conclude that based on the collected facts and statistic a closer view on the potential for using electric mobility in Austria should concentrate on commercial vehicles with a PMW under 3,5 tons and which are used in the Production sector and Trading sector (including parcel delivery services). In addition the Health services sector might be analyzed in depth because of its large amount of short trips between home care visits.

The sector based analysis in Germany shows that passenger cars with commercial owner registered for the Human health and social work activities sector (Q) have a share of more than 20% in terms of trips, but only 7.5% in terms of mileage, meaning a very low average trip length of less than 7 km per trip and a relatively high number of average trips per day (9.8). The picture for the Wholesale and retail trade sector (G) is the other way round: A share of nearly 14% in terms of trips and 18% in terms of mileage results in average trip length of roughly 25 km per trip and about four trips a day(see Table 3). When it comes to lorries under 3.5 tons payload, two economic sectors seem to be of specific relevance. The Transportation and Storage sector (H) with its strikingly high number of average trips per day (43.2) accounts for the highest share of the trips (40.92%) but due to a very low average trip length (3.4 km) only for 20.34% of the mileage. The construction sector (F) with average trip lengths of 15.9 km accounts for 28.09% of the mileage even if only 12.89% of all trips are made in this sector.

Table 2: Registered passenger cars and LDV with commercial owner in Germany by economic sector and gross vehicle weight (GVW)

NACE Code	**Passenger cars**	**GVW <= 3.5 t**	**3.5 < GVW <= 12 t**	***All vehicles***
A Agriculture	38,563	20,248	5,736	689,431
B Mining	7,466	3,622	1,215	15,846
C Manufacturing	633,751	127,596	29,585	835,804
D Electricity, gas	36,171	28,802	2,124	71,714
E Water supply	24,897	17,697	5,049	72,879
F Construction	218,417	192,374	32,607	485,814
G Wholesale and retail trade	714,316	135,557	37,762	980,878
H Transportation and storage	150,168	84,763	34,402	470,704
I Accommodation	44,138	7,878	692	55,482
J Information and communication	61,509	10,125	527	73,511
K Financial and insurance activities	62,632	2,195	169	66,345
L Real estate activities	12,788	2,610	238	16,448
M Professional, scientific activities	35,182	2,250	150	38,311
N Administrative and support	411,611	76,931	17,362	536,240
O Public administration	128,959	44,560	13,363	317,205
P Education	9,529	665	126	12,612
Q Human health	175,209	10,346	1,870	196,161
R Arts, entertainment	19,564	2,514	559	26,863
S Other services	1,482,264	430,467	83,808	2,206,240
U Extraterritorial organizations	6,125	1,030	292	9,141
Sum	*4,273,259*	*1,202,230*	*267,636*	*7,168,488*

Source: German Federal Motor Transport Authority (KBA, 2012)

The share of vehicles per sector suitable for a possible substitution by electric vehicles regarding their daily mileage can be seen in Table 4. Besides the private cars (V), it is the human health and social work activities sector (Q) (67.5% less than 50 km and 89.1% less than 100 km), the Agriculture sector (A) (71.8% less than 50 km and 81.4% less than 100 km), and the real estate sector (L) (58.7% less than 50 km and 85.7% less than 100 km) that have considerably high shares of passenger cars with daily mileages below 50 km and below 100 km respectively. Regarding the lorries under 3.5 tons payload it is again the sectors A, L and V and the Public administration sector (O) with highest shares of vehicles with daily mileages less than 50 km and less than 100 km, respectively.

We conclude that for Germany relevant sectors with potential for the use of EVs are the Wholesale and retail trade sector (NACE G), Transportation and storage sector (NACE H) and Human health (NACE Q). Within these sectors specific areas of economic activity were analyzed in detail. For the Wholesale and retail sector we took a deeper look into pharmacy logistics, in the Transportation and storage sector we concentrated on courier, express, parcel services (CEP) and for the Human health sector the mobile nursing services were analyzed in detail.

Table 3: Trips and mileage of passenger car with commercial owner in Germany by stated economic activity in survey year

NACE Code	Passenger cars			Lorries < 3.5 tons pay load		
	Trips per day	Trip length km	Daily mileage km	Trips per day	Trip length in km	Daily mileage km
A Agriculture	4.9	16.4	79.7	8.9	5.2	45.9
B Mining	5.4	22.8	127.5	10.1	7.3	71.4
C Manufacturing	3.8	39.5	149.7	7.7	11.5	88.0
D Electricity, gas	6.8	9.8	66.8	5.6	11.2	63.4
E Water supply	3.1	38.5	122.1	10.7	5.7	60.7
F Construction	3.7	26.5	98.0	4.3	15.9	68.0
G Wholesale and retail trade	4.4	24.4	108.3	10.1	10.8	109.5
H Transportation and storage	11.8	8.8	104.2	43.2	3.6	156.5
I Accommodation	4.8	9.4	45.2	15.0	3.7	56.3
J Information and communication	3.0	36.4	110.6	16.7	4.5	73.9
K Financial and insurance activities	5.0	20.9	103.9	27.1	2.5	67.9
L Real estate activities	4.0	14.9	59.5	8.0	4.6	37.0
M Professional, scientific activities	3.0	45.3	135.7	4.7	24.1	112.9
N Administrative and support	5.5	22.1	122.4	7.8	11.5	90.8
O Public administration	10.1	8.0	81.1	13.0	3.7	47.7
P Education	13.1	7.7	100.6	14.3	5.3	77.3
Q Human health	9.8	6.4	62.1	17.4	4.3	75.9
R Arts, entertainment	3.0	31.3	98.2	10.2	10.6	104.1
S Other services	6.5	19.0	122.5	15.0	6.5	97.4
U Extraterritorial organisations	2.6	23.5	72.6	3.5	n/a	50.5

Source: KiD 2010, own calculation

4.2. Survey results

For the analysis of our survey data it has to be mentioned, that companies from all economic sectors participated the own survey in Austria, while in Germany a sector-specific perspective focusing on three sectors (mobile nursing services, pharmacies, and CEP logistics service providers) was applied.

The number of vehicles used by German nursing services amounts to 5,266, with a mean of 15.8 per firm and 98% of the vehicles being company-owned. The number of vehicles used by German pharmacies is 304 (with a mean of 2.6 per firm and a 95% share of company-owned vehicles, whereas German courier, express or parcel delivery service providers use 6,456 vehicles (with a mean of 66.6 vehicles per firm). In contrast to Nursing and Pharma, 84% of the CEP vehicles are owned by subcontractors. The surveyed firms in Austria sum up to a vehicle fleet of 2,086 (with a mean of 10.1 vehicles per firm an 84% share of company-owned vehicles).

Generally, the sample contains a high share of small enterprises: Every second enterprise has a maximum of 9 employees and a maximum of 4 vehicles, accounting for 6% share of the total sample vehicle fleet. This underlines the importance of understanding decentralized decision-making among small enterprises with little resources for fleet management and vehicle procurement.

Concerning vehicle size, almost only passenger cars are used for German nursing services (97%) or pharmacies (91%) in Germany. Naturally, transport needs of a logistics sector (CEP) differs substantially from these sectors, and consequently only every 5th vehicle used is a passenger car, while every 2nd vehicle is a light duty vehicle with a permissible maximum weight under 3.5t (usually vans). In Austria, 88% of the vehicle fleet used today consists of passenger cars or vans.

Table 4: Daily mileage by stated economic activity and vehicle type

NACE Code	Passenger cars		Lorries under 3.5 tons payload	
	Less than 50 km [%]	**Less than 100 km [%]**	**Less than 50 km [%]**	**Less than 100 km [%]**
A Agriculture	71.8	81.4	73.8	91.7
B Mining	23.7	36.9	53.4	81.4
C Manufacturing	48.8	64.4	50.4	71.0
D Electricity, gas	49.3	81.0	57.3	80.2
E Water supply	38.1	63.9	52.4	84.7
F Construction	55.7	78.7	59.3	79.9
G Wholesale and retail trade	52.9	69.0	41.1	64.6
H Transportation and storage	42.4	56.9	35.6	54.2
I Accommodation	44.9	76.1	62.7	87.7
J Information and communication	36.2	72.0	46.1	71.0
K Financial and insurance activities	33.8	68.0	45.1	67.2
L Real estate activities	58.7	85.7	78.0	90.9
M Professional, scientific activities	43.4	59.8	36.8	59.8
N Administrative and support	34.3	66.1	51.0	71.2
O Public administration	47.5	74.0	68.7	88.6
P Education	28.5	34.5	52.1	77.9
Q Human health	67.5	89.1	52.4	78.1
R Arts, entertainment	55.5	76.2	58.8	75.0
S Other services	50.5	77.1	50.1	68.5
U Extraterritorial organisations	40.3	46.5	28.2	71.9
Sum	*67.7*	*87.9*	*54.8*	*75.6*

Source: KiD 2010, own calculation

The share of EVs among the vehicle fleets of the investigated countries or economic sectors is between one and two per cent. However, already 6% of all enterprises use at least one electric vehicle and 3% at least one hybrid vehicle. Given the nature of the survey, these findings may be biased compared to the complete company landscape.

In order to increase knowledge about vehicle usage in commercial transport, the participating firms where asked whether they consult external experts in this specific sense and if the commercial vehicles are assigned to employees personally or pooled vehicles are available for all employees.

External consultancies regarding fleet decision-making are more likely asked by German nursing services (14% of the companies), followed by the CEP sector (13%) and the pharmacies (8%) in Germany. The contrasting analysis of all economic sectors in Austria showed a smaller degree of fleet consultancy with a mean of 7%.

Within the observed sectors and countries, 36% of the vehicles in German nursing services are used as pooled vehicle fleets, whereas only 9% of the vehicles are assigned to one single employee and the remaining 55% are mixed types. 55-60% of the German pharmacies and companies in Austria assign the vehicles to a specific employee. Within the German CEP sector we found all types of mixed uses, which means that different fleet shares are personally assigned and the rest belongs to an open pool.

The nursing services' high degree of openness towards external consultancy could be a facilitator for an increase in the ECV penetration rate in this sector. Furthermore, nursing services have a high degree of pooled vehicles, which seem to be favorable for electric vehicle usage as spots for charging and parking can more easily be provided centrally at the companies' sites rather than decentral at the employees' places of residence.

Taking a look at daily mileages is useful for assessing the suitability of EVs and their electric range for companies' transport tasks. The results show that the needs of nursing services and pharmacies in Germany can well be satisfied with available state of the art EVs. In contrast, CEP services show a more heterogeneous distribution of range requirements: 39% of daily mileages exceed 200 km which is usually seen beyond the scope of battery electric vehicles. Regarding Austria, more than half of the daily mileages are below 50 km which shows that EVs can be of interest in various economic sectors.

The depicted cross-sectional distribution of daily mileages offers first hints concerning the substantial potential of EVs in commercial transport. It doesn't answer however, whether all transport tasks of a specific company can be satisfied with an electric vehicle. One frequently mentioned barrier towards EV diffusion is the fact that only almost all (and not all) trips and trip profiles would be able to be performed by EVs.

Results show that an electric driving range of 50 km would be suitable for 35% of the German mobile nursing services. A range extension to 100 km would include already 73% of all participating companies in this economic sector. For 2 out of 3 German pharmacies an EV with 50 km range would be suitable for all transport tasks. For CEP logistics purposes however, this range is almost not suitable for any company. Even higher electric ranges can only cover a small share of companies in this sector (11% at a 100 km range and 27% at a 200 km range). Austria shows very similar results: Approximately one third of the participating companies in both countries could cover all distance-depending transport tasks with vehicles offering a 100 km electric driving range.

Furthermore, the survey investigated how strongly firms already consider the procurement of EVs. Most enterprises in Germany (in all three of the selected economic sectors: nursing services, pharmacies and CEP service providers) stated that they were not considering EVs at the moment, but maybe in the future. Together with those firms not considering EVs at all, a majority of companies are therefore not or not yet willing to acquire EVs. In Austria a majority of 55% is more or less willing to procure EVs. In this survey, Austria also shows the highest diffusion rate of EVs to date: one out of ten participating companies has already procured at least one EV. Depending on country or economic sector, approximately 3 to 4 out of 10 companies stated that they were in the process of thinking about EV implementation. This highlights the substantial market potential of commercial EV use.

Besides rational considerations, for instance in how far daily mileages in each firm are suitable for EVs, vehicle-related decisions are also influenced by personal attitudes across business managers, employees and fleet managers. In order to identify possible subjective constraints the respondents were asked to answer numerous preference variables. The responding fleet managers have a high level of personal interest in electric mobility. Two third of the respondents (exception: CEP service providers with only 50%) do not consider electric mobility being a temporary trend. This very positive attitude towards electric mobility might be over-represented, similar to the already high penetration rates of EVs in the company sample that participated at this survey. Nevertheless, the results show that numerous firms are actively dealing with chances and barriers of EVs today.

The (positive) effects of electric vehicles regarding cost savings are assessed more modestly than those towards environmental protection, which are seen positively by three out of four companies. Note that a high percentage of respondents gave neutral answers regarding the effect on cost savings (e.g. 37% of the German CEP firms). This might prove the managers´ proportionally high insecurity in this item. It can be assumed that the decision-makers' ability to give more precise statements concerning cost effects depends on better information about the total cost of ownership of EVs in specific business environments.

Around 7 out of 10 companies in Austria and nursing services and pharmacies in Germany strongly or somewhat agree that an economically viable use of EVs is possible even without direct governmental purchase subsidies. This opinion is less common across the German CEP sector.

Only a minority of the respondents showed a willingness to pay extra for the acquisition of electric vehicles. So even if some companies see advantages in EV use concerning operating costs, the gap in purchase price between EVs and conventional vehicles needs to be reduced continuously.

4.3. Analysis of GPS tracking data

The GPS tracking in Austria and Germany was conducted in companies identified as potential early adopters for electric mobility in the project phases presented above.

In Germany the average number of trips, which were conducted with the vehicles during one day, vary between nine trips per day (company 01) and around 14 trips per day (company 02). Company 01 is the only company of the surveyed four that operates in urban areas. In average all the nursing companies perform eleven stops per day with each car. That means in average nearly twelve single trips are done by each car per day.

The average mileage for each car is about 51 km. Company 01 which operates within densely populated urban areas has a lower average mileage of about 37,6 km per day. Due to the density of the population distances between patients are shorter. More patients can be reached within a shorter radius. Nursing company 02 has the highest mileage to drive: 75 km per day.

When we have a look to the stop duration to assess if recharging could be performed during the halt, we see that in average a single stop is about 50 minutes long. Company 04 shows the shortest stop duration with only 37 minutes.

The mean value of electric mileage of EVs is around 140 km. Therefore, vehicles with a daily mileage below 140 km can be considered as a substitutional potential for EVs. From this limitation the daily mileage of conventional cars may not exceed 140 km per day. The average share of daily mileage above 140 km is 5.2%. The vehicles of company 01 and 04 drive only rarely more than 140 km per day (less than one percent). Approx. ten percent of the vehicles of company 02 and 03 are driven more than 140 km a day.

The means for daily mileage and length of stops show that mobile nursing services have high potential for the use of electric passenger cars. But with the means only hints are given for the potential. Only considering means cannot determine the actual potential. The potential can only be determined with consideration of the maximum daily mileage over a longer period of time.

Furthermore, in order to recharge batteries during a labor day, stops with a minimum length of at least 20 minutes are required to recharge enough energy that the time consuming effort to attach the charging cable is reasonable. Most of the manufacturers proclaim that 20 minutes of fast charging is enough to recharge a battery, i.e. of a Mitsubishi i-MiEV up to 80%. The results of the GPS data show that the mean stop length is around 50 minutes long – time enough to recharge via fast charging method (400 Volts).

The analysis of the key performance indicators in Austria has shown the potential for the use of electric vehicles in specific fleets. The following section illustrates the GPS data analyses for two fleets.

Fleet 1 consists of 27 vehicles operated within a parcel distribution service. Data were collected within 49 days. The analysis shows that in 70% the daily mileage is below 100 km and for 80% the driving kilometers per day of vehicles from Fleet 1 are shorter than 130 km. For 47% of the vehicle days the driving durations per day of vehicles from Fleet 1 are less than 180 min. As thresholds typical driving distance for actual EVs of about 130 km and typical driving duration for the use of an EV of about 180 min is assumed.

Fleet 2 consists of 26 vehicles used in the trading sector. Data was collected within 42 days. With respect to the thresholds mentioned above, the potential for the use of E-Vehicles in Fleet 2 can be summarized as: 32% of the driving kilometers per day of vehicles from Fleet 2 are shorter than 130 km and 20% of driving durations per day of Vehicles from Fleet 2 are less than 180 min. Furthermore 21% of the daily mileage is below 100 km.

The results of Fleet 1 and Fleet 2 show very different potentials for electric vehicles in commercial transport with higher potential in the company conducting parcel delivery and lower potential in the company belonging to the trading sector.

5. Framework for fleet management tool

Nowadays, experts explain the lack of using EVs for mobility needs with the argument of technology-born restrictions represented by too short driving ranges and dependency of the temperature. To reply on these arguments electric mobility shows the perfect supplement of mobility needs in and around urban areas. All short range trips of personal mobility and for delivery purposes can be accomplished with EVs. Looking on commercial fleets, a specific percentage of trips - depending on the needs of each company - can be performed with this innovative propulsion technology. Using a well balanced mix of vehicles with different propulsion technologies in a vehicle pool a huge potential for EVs can be realized. A fleet management framework called DynaTOP (Dynamic Transportation Optimization) was developed within the SELECT project especially to consider all kinds of commercial mobility needs.

This framework uses the implementation of different algorithmic concepts mainly to solve the dynamic vehicle routing problem (VRP) with the special requirements of EV fleets and mixed commercial fleets. The algorithms are based on data of fleet telematics systems such as GPS-based vehicle tracking and the current charging status of vehicle batteries. The framework will provide dynamic tour planning for several VRP classes, as for example the classic VRP or more specific problems like pickup and delivery problems (PDP). However, for all classes, the framework offers the possibility of dynamic tour planning and the possibility of incorporating electric vehicles in mixed fleets. The two main parts of the framework are the simulator which enables the dynamic tour planning and the optimization algorithms providing accurate solution for many problem classes, which are related to the VRP.

The versatile framework, which provides a collection of methods, algorithms and concepts for dealing with fleet management, has a strong focus on dynamic tour planning and on mixed fleet problems.

The recent development in telematics, such as the wide spread use of positioning services (GPS-Tracks) and mobile communication, allows gathering real-time information and exact monitoring of the vehicles. Thus, the development of algorithms, which are able to handle the dynamic nature of VRPs efficiently, is essential. Additionally, the development of software solutions for commercial transport and logistics becomes more and more important in the light of the electrification. Therefore, optimization algorithms incorporating additional constraints and cost factors which consider the characteristics of EVs are necessary. The basic elements for an efficient fleet management nowadays are (1) optimization algorithms, solving the dynamic VRPs and (2) simulation tools for testing and evaluating the algorithms. DynaTOP incorporates these two elements accordingly and offers a useful set of methods and algorithms to make the implementation of dynamic VRPs with the focus on a mixed fleet easy to manage. It provides a possibility of general and modular problem specification, which enables the user to easily apply the existing algorithms and concepts and to extend existing methods as well.

The performance of the framework was tested and evaluated with typical use cases of dynamic VRPs based on real-world data considering to possible events and situations which can arise using a fleet of different vehicle for the purposes of emergency medical service and for a reliable transportation of patients. Besides the requirement of quick decisions for the handling of new events (e.g. vehicle assignment for emergency call) it is necessary to evaluate if or which of the resulting tours can be executed by EVs.

6. Recommendations

In the project SELECT out of the results of the three steps of analysis a list of recommendations for policy measures was derived. Measures implementing these recommendations are considered as a catalyst to increase the market penetration of EVs in commercial transport and thus allow exploiting the identified potential for electric mobility. The following recommendations were deduced:

Companies should get the possibility to test electric vehicles within their fleets.

In the discussion with fleet managers during the GPS tracking period we realized that still resentments against EVs are dominant amongst employees and also amongst fleet managers themselves. Electric mobility projects proofed that as soon as people get in touch with EVs these resentments mostly resolve immediately. We recommend conducting facilitating EV testing schemes with fleet managers and employees before the decision is taken, which kind of propulsion technologies new vehicles should have. Those tests might increase the acceptance of EVs. This measure is easily to apply and cost effective and can be conducted with local car dealers. These testing schemes can also fill the gap of missing knowledge about driving range, recharging time, usability and performance. In parallel, an inner corporate communication campaign can foster a positive attitude amongst employees towards the use of electric vehicle, too. Here the individual experience plays a major role.

Governmental or municipal stimulation programs to promote EVs should be targeted on the most promising economic sectors as identified in SELECT

Stimulation programs fostering commercial EV use should firstly target the identified economic sectors with high potential for the use of EVs. A successful implementation is most promising within these sectors. Thus, measures will have a higher impact and tax money would be applied most reasonably. Such promotion programs should be performed together with the local associations and organizations such as chambers of industry and commerce.

Public authorities should publish and distribute more information about cost advantages to potential users

We also realized that there is still a lack of knowledge regarding possible economic benefits of EVs. Depreciation, tax reductions due to promotion projects, and lower costs in maintenance, insurance, operation etc. can – depending on vehicle miles travelled per year – over-compensate higher leasing or purchasing costs. More information material about costs should be publish e.g. by the ministries to make fleet managers aware of the economic benefits. Still, the fear of economic risks amongst fleet managers persists. With increasing level of information this fear can be minimized.

Analyze use patterns of complete corporate fleets to identify potentials for electric vehicles

Fleet managers should investigate all vehicles within their fleet to identify the potentials for the substitution by EVs. A cost effective measure is the use of GPS-tracking devices to gain knowledge about the actual use patterns of the company's vehicles (Approach described in chapter 2). The potential can be enlarged by tour reorganization and optimization of use patterns. Traditional tours have to be reviewed to fit to the technical constrains of EVs. For this, fleet management systems considering constrains of electric vehicles are required (e.g. vehicle pooling).

Increase of permissible (payload) PMW/GVW of electric delivery vehicles by policy (e.g. 4.25 ton regulation)

As already implemented by the German government a modification of the maximum permissible payload (i.e. increasing the gross vehicle weight up to 4.25 tons) of battery electric vans for type b driving license holders can help to overcome the reduced payload of EVs due to heavy battery weights. The commercial applicability can be increased by this little modification. Due to the actuality of this change in Germany there is no reliable data about the effect of this modified regulation. We recommend applying this regulation in other European countries as well. We also want to address car manufacture: The same effect would be obtained by reducing the weight of chassis and batteries.

Data bases similar to KiD 2010 should be created also in other European countries

The German survey design of KiD 2010 gives a comprehensive overview about travel patterns and user needs in commercial transport. We recommend conducting similar surveys in other European countries. To ensure comparability between different national surveys we recommend harmonizing such surveys. In order to identify the potential for EVs knowledge about the daily driving mileage per vehicle, stop durations, single trip lengths, trip chains and tour patterns should be surveyed.

The list of recommendations reflects a portfolio to foster the commercial use of electric vehicles. For other user groups (e.g. private users) a different set of measures might be needed. The derived recommendations address multiple target groups from the public and the private sector: fleet managers and vehicle users, automotive industry, as well as policy makers and municipalities. The responsibility to implement the measures is assigned to different actors (policy, industry, research, and fleet managers. The measures will have diverse impact requiring different demands of resources.

7. Conclusion

We can conclude that there is a high potential for the use of electric vehicles in commercial transport. But on the one hand this potential is very different in certain economic sectors and on the other hand measures must be taken to exploit this potential. The analysis of statistics and studies has shown that for Austria a closer look on vehicles with a PMW below 3.5 tons which are used in the Production and Trading sector should be taken for potential users of electric vehicles in commercial transport. For Germany the Wholesale and retail trade sector (NACE G), Transportation and storage sector (NACE H) and Human health (NACE Q) are seen as potential early adopters for electric mobility. From the survey among fleet managers we learned that EVs with a range of 100 km are suitable for a high share of Germany nursing companies and pharmacies. Germany CEP companies can cover only small shares of their travel needs with electric vehicles with driving ranges of 100 km. The general analysis for Austria shows that only one third of the companies which took part in the survey could cover all transport tasks with vehicles with an electric range of 100 km. Even the analysis of travel patterns in company fleets via GPS tracking has shown that there is higher potential for nursing companies than for CEP services for the use of electric vehicles with a travel range of 130 km.

Concerning attitudes towards EVs we showed that there is a high level of personal interest in electric mobility. The results show firms are dealing with chances and barriers of EVs. Positive effects are seen for cost savings and environmental advantages.

We demonstrated that the use of fleet management systems which integrate the needs of mixed and electric fleets is seen as one important tool to overcome technology-born restrictions of electric vehicles as they could not cover all travel needs in companies and thus the mixed use of vehicle fleets is needed. Applying algorithmic concepts taking into account special requirements of electric vehicles could enhance the use of electric vehicles in commercial fleets.

As shown in the introduction there are several measures which have been taken in Austria and Germany to enhance the use of electric vehicles. As there is special potential in commercial transport for electric vehicles we recommend using target group specific measures. The results of the three steps of our analysis has lead us in the project to the development of recommendation for stakeholders such as policy makers, vehicle manufacturers, service providers and corporate fleet operators to enhance the use of electric vehicles in commercial transport. We see as central task to give companies the possibility to test EVs and get knowledge about them. This should be complemented by information campaigns. Important is information on cost benefits.

We conclude that the GPS data method is suitable to assess the potential for electric cars. Also it is a very cost efficient method due to the low cost devices and little personnel resources that are needed to perform the data acquisition. In Germany there was no knowledge about the method available at the investigated companies and neither about the hardware. The companies had no information about the suitability of their fleet in regards to electric cars and the economic advantages. Only if the technological feasibility and an economic advantage are proofed companies might be willing to consider procuring EVs in the future.

The results and the experience of SELECT show that there is also a need for the development of powerful algorithms that can optimize and manage tour planning regarding the individual requirements of an increasing number of sectors that will use electric mobility for commercial transport in future. These algorithms have to be able to cope with the complex problems of VPRs respecting the huge number of parameters building the framework of mixed fleets ensuring a very high and flexible applicability as a main success factor for electric mobility in commercial transport in the future.

A further step in the analysis of potentials for the use of EVs in commercial transport is the combination of user acceptance studies and TCO analysis. The last-mentioned was not part of this project.

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