Strategies to Increase the Profitability of Electric Vehicles in Urban Freight Transport

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Abstract Electric vehicles (EVs) address the challenges global megatrends impose on freight transporting companies in urban areas. EVs decouple transport costs from depleting oil reserves and are free of tailpipe emissions. They are, technically, suitable for urban transport tasks which are often characterized by short, pre-planned tours and enable battery charging—or changing—at the depot. Despite these promising potentials, electric urban freight transport is still a niche market. The literature suggests the main obstacle for mass usage is the high purchase price, since profitability is considered the most important factor by nearly all companies. A descriptive statistical analysis of urban freight initiatives deploying EVs in the European North Sea Region identifies two current trends, and clusters profitability concepts of good practice examples in Europe. The study suggests that one trend is to deploy slow and light electric vehicles such as electric cargo bikes, scooters or heavy quadricycles, often combined with micro-consolidation hubs. In the second trend, medium heavy electric trucks substitute conventional vehicles in last mile logistics. Here, concepts that fully exploit the strengths of EVs to increase their productivity reach profitable operations. These include: (i) reducing the capital investment for EVs, (ii) increasing the kilometre range to benefit from low operational costs, (iii) capitalizing on the vehicles' sustainable image and (iv) exploiting of new business opportunities. The findings have implications for policy makers and companies, and they encourage the use of EVs in freight transport to abate freight transport-related emissions.

Keywords Urban freight · Electric vehicles · Profitability · Sustainable logistics

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1 Introduction: Significance of Electric Vehicles in Urban Freight Transport

Passenger electric vehicles (EVs) are currently favourites with the media and shareholders of some companies. At the same time, commercial electric vehicles have reached, for instance in Germany, with much less media attention, a share four times higher within the licensed vehicle stock than passenger vehicles (KBA 2014). Deploying zero emission vehicles will become even more important in the future, especially in urban freight transport: The amount of inland freight ton kilometres grows (European Commission 2013), while the number of private car-owners is declining in urban centres (Kenworthy 2013). Accordingly, last mile distribution, which is carried out mainly on roads, increases (European Commission 2011). Utilizing freight EVs holds a potential for all relevant stakeholders—national and regional governments, municipalities representing the urban population, freight transporting companies, their EV drivers and customers:

- Reducing transport-related greenhouse gas emissions is of particular importance to European Member State and European Free Trade Area governments. Greenhouse gas emissions of the transport sector rose by 20 % between 1990 and 2010, while at the same time, emissions from all other sectors decreased (European Environment Agency 2012). Within the transport sector, road transport is responsible for 70 % of the greenhouse gas emissions, thus it is the main contributor by far (ibidem). This development counteracts the efforts of the EU Member States to reduce overall greenhouse gas emissions by at least 20 % by 2020, compared to the base year 1990 (European Parliament 2009). Moreover, the current Transport White Paper specifies the objective of a carbon-free city logistics in larger urban areas by 2030 (European Commission 2011). Hence, supporting electric mobility is an important measure for the Member State governments to adhere to the EU agreed and self-set climate goals.
- At a regional and local level, potential noise and air pollutant reductions of electric commercial vehicles are significant to municipalities. Especially in densely populated urban areas, fossil-fuel-based transportation-related air pollution is a serious concern for public health (Woodcock et al. 2007; World Health Organization 2013). Exemplary data from Hamburg shows that freight vehicles are emitting over 45 % of the city's traffic nitrogen dioxide (Böhm and Wahler 2012) and are the main contributors to noise (Ohm et al. 2012). While medium-sized commercial vehicles up to 12 tonnes emit around 100 times more nitrogen dioxide than a reference passenger car in Amsterdam (Verbeek et al. 2011), their electric counterparts operate locally tailpipe emissions free. Furthermore, they are more silent up to a speed of 50 km/h (Umweltbundesamt 2013), and this means nearly in the whole city area.

- Companies transporting freight in urban areas are increasingly facing the consequences of global megatrends. According to Altenkirch et al. (2011), urbanization and the demographic changes lead to a rising transport demand in e-commerce and growing home care and services. They suggest that at the same time, sustainability, another global megatrend, leads to a customer request for environmentally sound transportation. The necessity for companies to explore alternative urban transport solutions is enhanced by increasing fuel prices due to limited fossil resources, and through both the EU, national government and local public authorities tightening emission policies for vehicles and restricting the number of vehicles entering urban areas, the latter the prerogative of local public authorities.
- User acceptance of drivers and the attitude of shift managers towards freight EVs were "very positive over all", despite current limitations, such as the range and comparable high levels of investment, in a multi-agent empirical study of user needs by Ehrler and Hebes (2012). The positive feedback was complemented by customers and neighbours, who especially appreciated the reduction in noise and exhaust emissions. The city logistics study accessed user expectations and acceptance via interviews, questionnaires with shift managers, drivers, customers and neighbours in Berlin. The authors' recommendations include carrying out more quantitative studies of benefits as well as studies over a longer time span.

Raising freight EV numbers is significant for all stakeholder groups. Hence, projects at European, transnational, national and regional levels support battery electric freight vehicles.

Examples for European projects are the EGVI,[1] which researches alternative powertrains, including light and heavy commercial vehicles. The project BESTFACT[2] collects and provides the best practice examples for freight transport, with electric urban freight as one of three best practice categories. ELTIS[3] is a further website which facilitates the exchange of knowledge and contains European case studies on urban freight and city logistics, among other mobility topics. FREVUE[4] runs urban freight EV demonstration projects in major European cities. The fourth edition of the CIVITAS initiative (Citivas Plus II) improves urban mobility by integrating clean vehicles like EVs for personal, collective and freight transportation in the project 2MOVE2.[5] The ICT services developed in the

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[1]EGVI "European Green Vehicles Initiative" (2014–2020) funded by the Horizon 2020 Framework Programme: www.egvi.eu/. The project followed on from the European Green Cars Initiative (2009–2013) funded by 7th Framework Programme.

[2]Bestfact (2012–2015) funded by the 7th Framework: http://www.bestfact.net/.

[3]ELTIS funded by the Intelligent Energy– Europe (IEE) programme: http://www.eltis.org.

[4]FREVUE "Freight Electric Vehicles in Urban Europe" (2013–2017) funded by the 7th Framework Programme: www.frevue.eu.

[5]2MOVE2 "New forms of sustainable urban transport and mobility" (2012–2016) funded by the CIVITAS PLUS II Programme: http://www.civitas.eu/content/2move2.

European EV pilot projects sm@rtCEM,[6] MOLECULES,[7] and ICT4EVEU[8] include services for vans or freight distribution. In the project ENCLOSE,[9] city logistics services for small and medium-size European Historic Towns are derived. The project CityLog[10] tested off-hours transportation of pre-packed mobile compartments ('BentoBox') by EVs and hybrids with partners in 6 European countries. The project SELECT[11] investigates the potential of electric mobility in the commercial transport. An electric MicroCarrier was tested in a city logistics concept in the EU project FiDEUS.[12] The EU funded project cyclelogistics[13] researches the potential to replace motorized freight transporting vehicles with cargo bikes and electrically supported cargo bikes.

Examples for transnational initiatives are the Interreg IVB projects E-Mobility NSR,[14] which integrates a freight dimension in promoting e-Mobility solutions *with a platform for knowledge exchange* (*CUFLOS*); and ENEVATE,[15] which includes research on light commercial vehicles in the European North West Region.

An overview of programmes and projects at national or regional level is provided in a project report of the "European Electro-mobility Observatory" (EEO 2013). However, the report states, it only provides a first overview; i.e. in Germany only the names of the most important national funding programmes are listed: the electric mobility pilot regions, the showcase programme and the clean energy initiative. Table 1 gives an overview of projects under the German national schemes, which fund electric freight mobility projects.

Despite the support in demonstration and research projects, and high potential for stakeholders, interested companies still often decide against deploying EVs for urban freight transport tasks. Only about one in a thousand commercial vehicles in Germany was an EV on 1 January 2014 (KBA 2014). The main obstacle for mass usage is the lack of profitability of utilizing the EVs, since profitability is considered

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[6]sm@rtCEM (2012–2014) funded by the ICT Policy Support Programme: http://www.smartcem-project.eu.

[7]MOLECULES (2012–2014) funded by the ICT Policy Support Programme: http://www.molecules-project.eu.

[8]ICT4EVEU (2012–2014) funded by the ICT Policy Support Programme: http://www.ict4eveu.eu.

[9]ENCLOSE "ENergy efficiency in City LOgistics Services" (2012–2014) funded by the Intelligent Energy– Europe (IEE) programme: http://www.enclose.eu/content.php.

[10]CITYLOG (2010–2012) funded by 7th Framework Programme: http://www.city-log.eu/.

[11]SELECT (2013–2015) funded by 7th Framework Programme and national funding: http://www.select-project.eu/select.

[12]FiDEUS "Freight innovative Delivery of goods in European Urban Spaces" (2005–2008) funded by the 6th Framework Programme: http://www.2020-horizon.com/FIDEUS-FREIGHT-INNOVATIVE-DELIVERY-IN-EUROPEAN-URBAN-SPACE%28FIDEUS%29-s30333.html.

[13]Cyclelogistics "Moving Europe foreward" (2011–2014) funded by the Intelligent Energy Europe Programme: http://www.cyclelogistics.eu.

[14]E-Mobility NSR "North Sea Region Electric Mobility Network" (2011–2014) funded by the Interreg IVB North Sea Region Programme: www.e-mobility-nsr.eu.

[15]ENEVATE "European Network of Electric Vehicles and Transferring Expertise" (2010–2012) funded by the Interreg IVB North West Europe Programme: http://www.enevate.eu/.

Table 1 German national projects supporting battery electric freight transport

Electric mobility pilot regions[a]		
Region	Project name	Project runtime
Berlin/Potsdam	BeMobility 2.0	2012–2013
	E-City Logistik	2010–2011
Bremen/Oldenburg	UI ELMO	2012–2015
	PMC-Modul 3	2010–2011
Hamburg	hh = pure	2010–2011
	hh = wise	2010–2011
	Wirtschaft am Strom	2012–2015
Rhein-Main	E-LIFT	2012–2015
	EMIO	2012–2015
	Flottenversuch elektrisch betriebene Nutzfahrzeuge	2010–2011
Rhein-Ruhr	colognE-mobil	2009–2011
	colognE-mobil II	2012–2015
	E-Aix. Teilprojekte: Nutzfahrzeuge	2009–2011
	ELMO	2012–2015
	E-mobil NRW	2009–2011
Stuttgart	EleNa	2010–2011
	Elena II	2012–2013
	IKONE	2010–2011
Electric mobility showcase programme[b]		
Baden-Württemberg	e-fleet	2012–2016
	Get eReady	2013–2015
	Landesfuhrpark	2012–2015
Berlin-Brandenburg	DisLog	2013–2016
	KV-E-CHAIN	2013–2016
	NANU!	2013–2015
Bayern-Sachsen	Elektromobilität in Bereichen der Abfallwirtschaft der Landeshauptstadt Dresden	2013–2015
	E-Lieferungen im Allgäu	2012–2014
Others programmes		
Clean Energy Initiative	Ich ersetze ein Auto[c]	2012–2014
Erneuerbar Mobil	CO_2-neutrale Zustellung in Bonn[d]	2012–2016
Forschungsprogramme Stadtverkehr	komDRIVE[e]	2013–2015
	WIV-RAD[f]	2013–2015

[a]http://www.now-gmbh.de/de/projektfinder.html
[b]http://www.schaufenster-elektromobilitaet.org/programm/das-schaufensterprogramm-im-ueberblick
[c]http://www.ich-ersetze-ein-auto.de/
[d]http://www.erneuerbar-mobil.de/de/projekte/foerderung-von-vorhaben-im-bereich-der-elektromobilitaet-ab-2012/markteinfuehrung-mit-oekologischen-standards/erprobung-von-e-mobilitaet-im-flottenbetrieb-co2-freie-zustellung-in-bonn
[e]http://www.komdrive.de/
[f]http://www.dlr.de/vf/desktopdefault.aspx/tabid-2974/1445_read-39657/

the most important factor by companies (Fraunhofer IAO 2011). Since the capital investment for EVs is double to triple the price of conventional diesel vehicles (Taefi et al. 2015), but exemplary operational costs are about 50 % lower (Pommerenke 2014), a total costs of ownership calculation (TCO) is necessary to compare the costs. Hacker et al. (2011) have modelled a scheme to calculate the TCO for small passenger EVs and estimated the market potential of electric commercial vehicles, but they do not discuss the freight dimension. Element Energy (2012) outlines the total cost of ownership of low and ultra-low emission plug-in vans (fully electric, hybrid, hydrogen under 3.5 tonnes gross weight). Lee et al. (2013) compare the TCO of medium duty 7.49 tonnes electric and diesel trucks for different drive cycles and under various conditions. They exclude subsidies and regulatory effects and conclude that the TCO of the EV can be lower than that of a diesel truck, especially when EVs reach a high average daily mileage on an urban drive cycle with frequent stops and a low average speed. Feng and Figliozzi (2013) developed a deterministic TCO model and calculated break-even points for different scenarios for electric commercial vehicles. Davis and Figliozzi (2013) developed the model further and integrated internal and external factors, such as speed profiles, energy consumption, routing constrains and TCO into a competitiveness model for electrical trucks. Some web-based TCO calculators differentiate between private customers and companies.[16] Altenkirch et al. (2011) researched improved vehicle design and logistic processes for future strategies and services for electric commercial transportation. Suggestions in their report are based on possible technical innovations for future EVs, e.g. redesigned cargo compartments, but are not based on the vehicles available today. Kley et al. (2011) outline a methodology to derive business models for selling EVs or electric mobility services. The instrument can be utilized at a strategic level, but has no implications on the daily operation of EVs at freight transporting companies.

Some studies take a broader view of urban logistics and suggest further types of electric or electrically supported vehicles for road freight transport tasks: The baseline study of the EU funded cyclelogistics project calculated that 31 % of motorized professional urban goods transport in freight and service could be shifted to (electric) cargo cycles in European cities (Reiter and Wrighton 2013). Advantages of cargo cycles compared to motorized vehicles include the reduced space for kerbside loading space and overnight storage, an emission-free and very low noise operation, lower purchase and operational costs, and positive public perception (Leonardi et al. 2012). Results from a German project testing cargo cycles in courier services, in 7 of the 15 biggest German cities, show a substantial demand for transport services by electric cargo cycles (Gruber et al. 2014). The majority of interviewed car and bicycle messengers regarded the tested cargo cycles as “highly competitive for delivery tasks in their specific urban surroundings”, but voiced concerns about the electric range and purchase price (ibidem). A simulation

[16] I.e. http://www.elbiler.nu/index.php/elbil-okonomi/oekonom-og-co2-beregner; http://www.gronnbil.no/calculator.

of energy, environmental and traffic impacts in the city of Porto (Portugal) showed that small electric vehicles, such as electric cargo cycles, improved traffic and environmental effects at a market penetration of 10 % and when utilized at street level (Melo et al. 2014). At the same time, the authors expressed reservations with regard to operational issues—such as the reduced travel distance and capacity to carry cargo weight and volume, which implies the use of an urban consolidation centre—and financial issues, such as higher vehicle purchase costs (ibidem). Two ex-ante studies of urban consolidation centres with electric delivery vans and tricycles in London and with electric quads with trailers (the Cargohopper) in Amsterdam proved successful with regard to the reduction of the total distance travelled (19 and 20 % reduction), CO_2-equivalents per parcel (at least 90 % reduction) and operational costs (Browne et al. 2011; Duin et al. 2013).

In summary, the current literature expresses the need for solutions to overcome the gap in the TCO, especially for electric vans and trucks. The available literature highlights single factors that positively influence the TCO calculation, but does not discuss a systematic approach to improve the profitability of freight EVs. Slow and light EVs, such as electric cargo cycles or electric quads with trailers are suggested —in some examples in conjunction with urban consolidation centres—as a viable alternative in certain transport cases, but their profitability remains disputed.

This leads to the research question explored in this paper: What measures are companies taking today, at an operational level, to increase the profitability of EVs in urban freight transport? To fill the perceived gap, this contribution discusses the current trends in deploying EVs for freight transport tasks. It builds on a comprehensive database and compilation report of 57 EV freight transport cases studies from the North Sea Region (E-Mobility-NSR 2013) and thus offers a transnational angle on the topic. Moreover, this article analyses successful concepts which the companies carry out to reach a profitable operation. In this way, the paper adds good practice examples of sound business models to the scarce literature. Finally, it includes guidance for policy makers, as well as highlighting gaps for further research and pilot projects. As a consequence, this paper provides insights for practitioners as well as the research community and policy makers at all levels and can serve as an inspiration to increase the share of EVs and reduce emissions in urban freight transport.

2 Methodology

This research study focuses on battery electric vehicles utilized in urban freight transport. Thus, hybrid vehicles or electric vehicles powered by fuel cells are excluded, as they do not fall under the definition of a battery electric vehicle. For better discussion of the current trends, the field of urban freight transport is divided into the following four segments:

- Commercial transport—The main business model of a freight forwarding company is to transport goods for another party. Examples are logistic providers such as mail-, courier-, express- and parcel transports or haulage.
- Transport on own-account—A company transports their own goods, within or between their own subsidiaries, with their own vehicles as a part of their value creation process. The transport is not for hire or rewarded (OECD 2002). One example is a bakery, which produces bread in a central bakery and transports it to various outlets for the product to be sold.
- Service—A company is providing a service at a customer's location which involves the transport or pick up of goods. Examples are craftsmen transporting tools and spare parts for repair, a fast food company delivering pizza, or a removal company picking up furniture.
- Municipal services—This includes fleets belonging to the municipality or private companies providing municipal services. Examples are municipal waste removal or foliage removal in public parks.

The explanatory research question demanded a qualitative, exploratory approach. A two-step research design was chosen (cf. Table 2):

Study A, see Sect. 3: Profitability concepts of 15 cases of urban freight with EVs in Germany were analysed in-depth. The cases where identified through a keyword search in the literature. The identified cases were only included if road legal EVs were tested or planned to be tested over a period longer than 1 year. This restriction was applied, since tests only provide realistic values on energy efficiency and thus profitability of EVs when deploying the vehicles for a full calendar year. The EVs' range is influenced by weather conditions: practical tests showed that at very low temperatures, the range of EVs can be halved (Taefi et al. 2015). This impacts the usability of EVs and decreases the savings from low operational costs per kilometre.

Table 2 Overview over the research process

	Study A: Profitability concepts	Study B: Trends and profitability measures
Region	Germany	European North Sea Region
# Cases	15 cases	72 cases
Research questions	1. Are freight EVs profitable?	1. Who uses freight EVs and how?
	2. How so, or why not?	2. How is EV productivity being improved?
Methodology	1. Literature review	Descriptive statistical analysis of freight EV state-of-the-art report
	2. Qualitative interviews	
Goals	Identify profitability strategy and concepts	1. Trends in freight EV usage
		2. Confirm profitability concepts and identify underlying measures
		3. Good practice portfolio

The data for each case were collected by semi-structured guideline-based expert interviews at company level in the period between May 2012 and April 2013. Questions included the company's objective on EV utilization, problems encountered, success factors, whether the EVs are profitable and how profitability is determined. Interviews were carried out face-to-face when possible or by telephone, due to a limited budget and time constraints. The negative impact of utilizing two different methodologies was reduced since the interviews were carried out by the same researcher. Furthermore, the succession and wording of the questions was kept, regardless of the interview method. Findings derived from a content analysis (Mayring 2010) were clustered in a matrix to detect a general profitability strategy and different concepts companies followed when deploying their EVs.

A deeper understanding of motivations and concepts can be gained through semi-structured interviews. However, the relatively small sample size of the resource intensive interviews is a potential weakness (Denscombe 2007). Thus, a second study (study B) verified profitability concepts and described single measures:

Study B, see Sect. 4: A descriptive statistical analysis examined a state-of-the-art database containing 57 case studies of urban road freight transport with electric vehicles.

The state-of-the-art case study was carried out within an EU funded project, *North Sea Region Electric Mobility Network*, during the year 2012. It included seven countries of the North Sea Region; Belgium, Denmark, the UK, Germany, The Netherlands, Norway and Sweden. Typical drawbacks of cross-country studies —such as different contexts and language barriers (Yin 2009)—were avoided, since the involved researchers utilized a common analytic framework and were based in the country of the respective case study (with one exception). The relatively small number of cases per country reflected the fact that utilizing EVs for urban freight transport tasks was still in its infancy. Case descriptions were detailed in the project report (E-Mobility-NSR 2013). The German companies questioned were a subset of companies in study A. However, the research focus of this set of interviews was different: Apart from case study descriptions, for each single case, the number of utilized freight EVs and enablers and barriers in deploying freight EVs were identified. Common enablers and barriers were identified and clustered (Taefi et al. 2015). The study confirmed profitability as being one of the most important barriers for companies in deploying freight EVs.

Through the descriptive statistical analysis, this paper adds a new perspective to the case studies by examining current trends in freight EV usage. Furthermore, this research confirms the suggested profitability concepts of study A. Through establishing measures increasing the profitability of freight EVs, good practice cases are identified and described. One possible limitation of the statistical analysis is the fact that the data were extracted from existing case studies; no new interviews were conducted. Since profitability measures for electric urban freight transport are newly defined in this article, the researchers conducting the interviews might have not have detected or recorded all relevant information. Future research might further enhance concepts and measures.

The four identified profitability concepts and their underlying measures serve three purposes:

1. To demonstrate how companies which consider deploying freight EVs can increase the vehicles profitability and thus reduce the perceived financial barrier.
2. To establish indicators for policy makers to support freight EVs.
3. To highlight gaps for future research projects.

3 Study A: Profitability Concepts of Freight EV Users in Germany

Even though the low quality of after-sales services was an obstacle, electric vehicles were often found, technically, suitable for urban freight transport tasks and welcomed by most stakeholders along the transport chain (Taefi et al. 2015). However, companies argue that vehicles are seldom profitable compared to diesel vehicles (ibidem). A study of 15 cases analyses the motivation of companies to deploy freight EVs and examines whether and how the EVs can be operated profitably. Table 3 gives an overview of the researched cases. An earlier publication provides detailed case descriptions (Taefi et al. 2013).

The 79 EVs in the study ranged from electric quad/trailer combinations and electric scooters, to light and heavy trucks up to 12 tonnes. The identified cases fell into three transport segments, commercial transport, transport on own-account and services. An emphasis on commercial transport was found. In Germany, the majority (62 %) of utilized EVs were vans between 3 and 3.49 tonnes, apparently due to a focus of local manufacturers on this weight class.

In nearly half the cases (7/15) the companies claimed or expected (if the test had only recently started) that usage of the EVs for freight transport is profitable. Each company factored in different variables to calculate the profitability of their EVs. Calculations ranged from a rough comparison of the higher capital investment against fuel savings in small companies to elaborate TCO calculations in larger companies, including deprecation time, residual value of the vehicle, costs for insurance, maintenance, taxes, price increases, etc. Though the methods of calculation were not comparable, in this study the relevant point is the fact that companies rated their EVs as profitable (or not) and, thus, might decide on this basis whether to invest in further EVs.

A cross-case synthesis of the case studies showed that profitability was not dependent on the geographical location, the type of vehicles used, the type of cargo or the transport segment. A correlation was found, however, between the profitability, the year the vehicles were acquired and the motivation to utilize EVs in urban freight transport. An exception is one case from 2000 which developed from an earlier city logistic project in the 1990s. In 2010 and 2011, practical freight EVs tests started in the German electric mobility pilot regions. Under this scheme, the

Table 3 Overview of profitability study cases and results

No.	City	Cargo	Year	Electric vehicles			Main purpose	Profitable	Profitability concepts			
				No.	Type	Gross weight			1	2	3	4
Commercial transport												
1	Stuttgart, etc.	Parcels	2011	7	Van	3 tonnes	Test EVs	No	x			
2	Nürnberg	Parcels	2000	2	Quad-trailer	3.5 tonnes	Cost reduction	Yes				x
3	Bonn, etc.	Parcels	2011	13	Van	3.5 tonnes	Test EVs	No	x			
4	Berlin, etc.	Parcels	2011	20	Van	3 tonnes	Test EVs	No	x			
5	Frankfurt, etc.	Parcels	2011	6	Truck	5.5 tonnes	Test EVs	No	x			
6	Karlsruhe	Parcels	2013	6	Truck	7.5 tonnes	Test concept	Yes	x			
7	Düsseldorf	Courier items	2011	1	Van	3 tonnes	Emission/Image	No	x	x	x	
8	Hamburg	Courier items	2010	1	Van	1.5 tonnes	Emission/Image	No	x		x	
			2012	6	Scooter	50 kg						
9	Berlin	Textiles	2013	2	Truck	12 tonnes	Test concept	Yes	x	x		x
Services												
10	Hamburg	Fast food	2012	6	Scooter	50 kg	Cost reduction	Yes	x	x		
Transport on-own-account												
11	Hamburg	Bakery products	2012	4	Van	3.5 tonnes	Emission/Image	Yes	x		x	
12	Hilden, etc.	Bakery products	2011	1	Van	3 tonnes	Emission/Image	No	x		x	
13	Hilden, etc.	Bakery products	2013	1	Van	3.5 tonnes	Emission/Image	Yes	x	x	x	
14	Solingen, etc.	Toiletries	2012	2	Truck	7.5 tonnes	Test EVs	No	x	x		x
15	Dortmund	Household articles	2013	1	Truck	12 tonnes	Test concept	Yes	x	x		

German Federal Government subsidized a total of 220 electric mobility projects in 8 pilot regions with a sum of 130 million Euros. In 2010 and 2011, the companies' main purpose of deploying freight EVs was to test their functionality and implementation into the daily routines. Reaching a profitable operation was not the main focus. Companies found that the vehicles were, technically, suitable for certain transport tasks, but also realized that a direct substitution of conventional vehicles did not fully exploit the strengths of EVs. Thus, in follow-up tests in 2012 and 2013, companies adapted and tested new delivery processes and concepts to capitalize on the advantages of EVs. When the main motivation of utilizing EVs was reducing emissions, process adaptations, similarly, led to a more profitable use of freight EVs in 2012/2013.

Aggregating measures that led to profitable operating of EVs revealed four main concepts:

1. Reduction of capital investment and operational costs.
2. Increase of vehicles mileage.
3. Capitalizing on green image.
4. Exploitation of new business opportunities.

The first two concepts aimed at reducing the total costs of ownership of electric vehicles: Costs of investment for an electric vehicle in the cases were twice to three times higher than the costs for a comparable diesel vehicle according to the companies. This gap grows with the weight of the vehicle, since the size of the cost-intensive batteries increases. In order to reduce the gap, companies relied on subsidies for the purchase price as offered in demonstration projects. Further costs saving measures were replacing passenger-sized cars for freight delivery with electric scooters, or converting depreciated diesel vehicles to EVs. Companies adapted their logistic processes to increase the vehicles mileage (concept two). Thus, they capitalized on the lower operational costs of the EVs to decrease the total costs of ownership of the vehicles. This was achieved by, e.g., recharging the vehicle while reloading cargo, quick charging, and deploying the EV on multi-shifts or training the driver in eco-drive strategies.

Through applying concepts three and four, the companies increased the profit generated through the EVs: Through communicating the benefits of electric mobility (concept three), some companies acquired new customers or justified a higher priced green product. The unique characteristics of the silent and locally emission free vehicle technology were exploited in concept four to generate new business opportunities. Examples are noiseless deliveries at night or deliveries in pedestrian zones limited for conventional vehicles by time windows.

The overall profitability strategy was, thus, to increase the productivity of the freight EVs by reducing TCO and increasing the profit.

4 Study B: Trends in Electric Urban Freight Transport in the North Sea Region

57 freight EVs case studies, in seven countries of the North Sea Region, were examined by a descriptive statistical analysis. The case studies were carried out in 2012; case study countries included Belgium, Denmark, the UK, Germany, the Netherlands, Norway and Sweden. This study analyses the data further to (i) detect common trends within the countries of the North Sea Region and (ii) to validate and enhance the findings of the study on profitability concepts and measures in Germany with a broader regional focus and more cases.

The study found a total of 57 cases comprising 5,239 electric vehicles. Case descriptions are detailed in the project report (E-Mobility-NSR 2013). A summary of the number of vehicles in the cases is depicted in Table 4. In order to identify trends, the data is analysed regarding vehicle size and transport segments.

4.1 Vehicle Sizes

In the above cases, two groups of EVs were most often recorded in urban freight transport: (i) slow and light vehicles; (ii) medium heavy trucks of 3–7.5 tonnes.

(i) Slow and light vehicles, including electric scooters, electric cargo cycles and heavy electric quadricycles, were deployed most often. Electric scooters were equipped with a carriage box to transport small freight up to 50 kg. Some scooters had a changeable battery to enhance their range. Swedish cases were dominated by a single company which deploys a large fleet of 4,500 small and light vehicles in commercial transport. In Germany, these vehicles were utilized in fast food delivery. Heavy electric quads had top speeds between 40 and 65 km/h with a payload ranging from 200 to 1,000 kg. They were utilized as an economic alternative to electric vans on slow and short routes. Examples include mail distribution or municipal services such as foliage removal in parks. Electric bicycles or tricycles had a payload of up to 300 kg. The identified models could electrically assist the driver for up to 100 km. Those electric vehicles were most often deployed in commercial inner city transport, such as courier services and parcel delivery. Slow and light vehicles proved advantageous in heavy traffic since they were often allowed on bicycle lanes, and also could be parked easily. Furthermore, electric cargo cycles could enter pedestrian zones anytime, while motorized delivery vehicles were restricted by time windows. To compensate for the lower cargo carrying capacity, slow, light vehicles were often combined with micro-consolidation hubs, enabling the driver to reloaded freight and continue delivery.

Table 4 Number of cases and vehicles identified in E-Mobility NSR state-of-the-art study 2012

		Total		Thereof: Vans			Thereof: Vans		Thereof: Slow and light vehicles			
		No. of Cases	No. of Electric vehicles	>12 tonnes	7.5–12 tonnes	3.5–7.5 tonnes	3–3.5 tonnes	<2.3 tonnes	Quads/ trailer	Heavy quad	Scooter	Cargo cycle
Total		57	5,239	3	8	158	140	70	2	995	1908	1910
Country	Belgium	11	134	3	1	2	46	25	0	48	0	9
	Denmark	10	19	0	1	8	6	4	0	0	0	0
	UK	11	133	0	0	111	0	6	0	5	0	11
	Germany	9	128	0	2	18	87	9	0	0	12	0
	Netherlands	11	26	0	4	18	1	0	2	1	0	0
	Norway	2	297	0	0	0	0	26	0	40	231	0
	Sweden	3	4,502	0	0	1	0	0	0	901	1,665	1,890
Segment	Commercial	27	4,958	1	6	34	86	35	2	943	1,902	1,904
	Own-account	9	22	0	1	2	8	6	0	5	0	0
	Service	12	178	0	1	95	35	26	0	9	6	6
	Municipal	9	81	2	0	27	11	3	0	38	0	0

(ii) Medium heavy trucks in the range between 3 and 7.5 tonnes substituted conventional trucks in all transport segments; commercial transport, transport on own-account, services and in municipal fleets and services. They constituted the majority of utilized EVs in Denmark, Germany, the UK and the Netherlands. These vehicles were all converted from mass produced diesel models.

(iii) The study found no vans between 2.3 and 3 tonnes and few light vans below 2.3 tonnes. The latter were utilized especially in services, courier and mail distribution, where lighter and fewer items were carried. Heavy trucks, above 7.5 tonnes, were even more rarely recorded. Heavy trucks were expensive compared to their diesel counterparts, due to their large, cost-intense batteries. A loss of payload because of the heavy batteries was found an additional barrier.

(iv) Different strategies of testing and utilizing freight EVs were found within the participating countries. The existence of local manufacturers or conversion companies proved an important bottleneck. As an example, in the UK a large number of heavy electric trucks from two British manufactures were used, while in Germany manufacturers and companies focused on light electric freight vans.

4.2 Transport Segments

Nearly half the cases, and the majority of vehicles, fell into the segment of commercial freight transport. An explanation is that EV characteristics were especially suitable in mail and parcel delivery. Here, EVs were often deployed on pre-planned routes and recharged at the companies' depots. The short urban delivery routes included many stops, which enabled energy recuperation through regenerative breaking. Furthermore, mail and parcel delivery companies often utilized large fleets of the same vehicle type. Thus, the companies were interested in testing EVs, which offered independence from fossil fuels and exemption from potential future emission charges. Cases were relatively evenly distributed between municipal services, transport on own-account and services. Municipal fleets were easily accessible to administrations which strove for environmentally friendly transport, and also served as role models in communicating the advantages of EVs.

4.3 Profitability Concepts

An analysis of the 57 state-of-the-art cases resulted in verification of the identified concepts and additions to the underlying measures. An overview of all identified measures is provided under the respective concepts in Table 5.

Table 5 Concepts and measures pursued to operate freight EVs profitably in the North Sea Region

Measures	Cases (n = 57)	
	Count	Share (%)
1. Reduction of capital investment and operational costs		
• Customizing freight EVs	5	9
• Purchase of discounted or second hand models	2	4
• Profit from purchase subsidies or EV project subsidies	32	56
• Use of slow and light EVs (scooters, cargo cycles, quads)	18	32
• Exemption from city toll	9	16
• Limit changes of business processes and daily routines	1	2
2. Increase of vehicles mileage		
• Intermediate charging, quick charging	10	18
• Battery swap	1	2
• Energy efficiency training of drivers (eco-driving)	5	9
• Seven days a week or multi-shift delivery	2	4
• Improvement of routing and scheduling of EVs (suggested or planned)	3	5
• External energy for heating, cooling, waste compacting	9	16
• Solar roof on EV to charge during operation	3	5
3. Capitalizing on green image		
• Enhancement of customers base with 'green' customers	13	23
• Environmental labels or awards	5	9
• Offering green products	18	32
• Marketing /Image building	35	61
4. Exploitation of new business opportunities		
• Night time delivery with noiseless EVs	2	4
• Access to zones with spatially or temporally limited access	9	16
• Freight bundling	10	18

Most companies relied on their environmentally friendly EVs for image building and subsidies when acquiring electric vehicles. However, the following good practice examples show that companies did apply measures other than just relying on financial subsidy of the purchase price. By exploiting the strengths of the EVs they increased their productivity and, thus, reached a profitable operation of their freight EVs.

4.4 Good Practice Examples

All of the following good practice examples feature a different combination of profitability measures (marked in italic) leading to a profitable operation.

(i) Inner City Last Mile Delivery
Cost reduction: customized EV; slow, light EV; subsidies.
Mileage increase: solar roof.
Image: new green customers; winning awards; green product; marketing.
New business opportunities: access to pedestrian zones; freight bundling.
A Dutch company combines a city logistic approach with a custom-made slow electric quad-trailer vehicle carrying boxes. The vehicle delivers pre-consolidated parcels and goods to shops in inner city areas and takes back recycling materials and returns on the way out. The interchangeable bodies are transported from the consolidation centre to the delivery area and loaded on the vehicle by forklift. The emission free vehicle is permitted to enter pedestrian zones outside of time windows and thus has an advantage in delivery times and costs. The existing customer base was enhanced by customers interested in green delivery. Solar panels, mounted on the roof of the vehicle, recharge the batteries via solar energy and extend the range during operation. Since the vehicle is very slow, young drivers are allowed to drive it, adding an educational perspective.

(ii) Courier Service
Cost reduction: small, light vehicles; exemption from city toll.
Mileage increase: intermediate charging.
Image: new green customers; winning awards; green product; marketing.
New business opportunities: freight bundling.
A London-based courier service, specializing in green urban freight delivery, utilizes electric cargo tricycles and, for bigger or heavier loads, electric quads. The cargo cycles are advantageous in congested traffic and are easy to park; the quads are exempt from city toll and road tax. The drivers take up cargo from micro-consolidation centres and change vehicles, once the battery is empty. Since the company operates an all-green fleet, the environmentally friendly delivery and gained sustainability awards are supporting the communication strategy.

(iii) Service
Cost reduction: exemption from city toll.
Mileage increase: intermediate charging; eco-driving strategies; multi-shift delivery.
Image: winning awards; marketing.
A company in London delivers groceries, ordered online, with electric trucks. In order to extend the range and benefit from the lower operational costs, the vehicles' batteries are partly recharged when taking up new freight, twice a day. To further increase the range, drivers are trained for eco-driving strategies, including regenerative breaking.

(iv) Haulage
Cost reduction: customized EVs; project subsidies.
Mileage increase: battery change, multi-shift delivery.
Image: Marketing.

New business opportunities: Night delivery.

A Berlin-based haulage company is testing a battery change concept for their heavy electric trucks in textile logistics. This will allow the EVs to be deployed on triple-shifts and thus amortize through low operational costs. Though night deliveries are not prohibited for conventional vehicles, a higher acceptance of night deliveries with EVs is expected.

(v) Parcel Delivery

Cost reduction: Customized vehicles; project subsidies; limited changes to daily routines.

A parcel delivery company utilizes a large fleet of similar 7.49 tonnes diesel vehicles for urban distribution. The combustion engines and powertrains of the trucks reach the end of their life after around 500,000 km, while the chassis is still sound. A conversion company fits a new electric motor, powertrain and batteries, at a cost similar to the purchase price of a new conventional diesel vehicle. Thus EVs having lower operational costs are profitable. By refurbishing old vehicles the company also reduces waste. An additional advantage is that the drivers are familiar with the vehicles. Operations stay the same (except charging/fuelling), which leads to reduced costs for maintenance and repair, compared to EVs of other manufacturers.

5 Conclusion

Charged by green energy, electric vehicles reduce greenhouse gas emissions as well as local air pollutants and noise. Many EVs in the case studies proved, technically, suitable for urban freight transportation tasks. So far, renowned car manufacturers offer only small electric vans below 2.3 tonnes. Despite the availability of those vehicles, the EVs most often deployed in urban freight transport were small and light vehicles, i.e. electric cargo bikes, electric quads and scooters; followed by converted medium heavy electric trucks between 3 and 7.49 tonnes.

Beyond reducing noise and emissions, small, light, electric vehicles reduced land use. For freight transporting companies in the case study they were advantageous in dense inner city traffic with limited parking spaces and when accessing pedestrian areas. In several cases deliveries were combined with micro-consolidation hubs close to the delivery area. These hubs enabled reloading of cargo to compensate for the limited mileage of the slow vehicles. In this way, the delivery efficiency was increased through the consolidation of goods. Another typical application was the delivery of mail and parcels.

Medium heavy electric trucks were mainly provided by local companies which convert existing diesel models. A common problem though, was the low quality of after-sales services. In the majority of cases medium heavy vehicles were used for commercial transport tasks. Here, transport was often characterized by pre-planned, reoccurring, short, urban tours with many stops, the possibility to recharge at the depot and large fleets of similar vehicles. These conditions were favourable for the current technology of freight EVs. Comparable cases were also found in service or transport on own-account under similar conditions. EVs in municipal fleets were an exception: they served as role models and were easily accessible for municipalities that wished to foster environmentally friendly transport.

As a general rule, the larger electric trucks become, the more heavy and expensive batteries are needed for propulsion. Thus, implementing profitability measures becomes increasingly important the heavier EVs get. A direct substitution of conventional commercial vehicles with EVs did not fully exploit their strengths, hence does not often lead to a profitable operation. One important reason was that the purchase price of EVs is two to three times higher, but their operational costs are about 50 % lower than of diesel vehicles. In financially successful cases, measures to increase the turnover generated with the EV were pursued, while at the same time the total costs of ownership were reduced. In this way the rentability of the commercial electric vehicles was increased.

Under the precondition that EVs were deployed on technically suitable urban tours, the vehicles were profitable in the perception of the companies, when the EVs strengths were exploited to increase their productivity. The profitability concepts included:

i. Reducing the capital investment for the EVs, for instance by saving costs for a city toll, customizing vehicles into freight EVs or, most importantly, benefiting from EV subsidies.
ii. Increasing the kilometre range to benefit from low operational costs. The most common measures to increase the range were to recharge the battery in-between tours and to utilize external energy for heating or cooling.
iii. Capitalizing on the vehicles' sustainable image by including the EVs in the company's marketing communication to gain new customers.
iv. Exploiting of new business opportunities, such as night time delivery with noiseless EVs or access to zones with spatially or temporally limited access for conventional vehicles.

5.1 Implications for Policy Makers

For policy makers who want to raise the share of environmentally friendly EVs, the following recommendations are proposed:

- Promote the usage of small, light EVs like electric cargo cycles, scooters or quads. If additional funds are available, infrastructure, such as bicycle lanes—wide enough for the fast and bulky cargo cycles—can be supported.
- Encourage local conversion companies to gain expertise with freight EVs and foster purchase of those EVs in R&D pilot projects. This ensures a supply of suitable vehicles, which are not yet provided by renowned manufacturers. At the

same time, reliable and fast after-sales and service structures are a key to ensure that delivery companies gain confidence in EVs. These structures need to be in place even if the supplying conversion company has to file for administration.

- Communicate that, through low operational costs, EVs can amortize. Eco-driving training and intermediate (quick) charging enhance the daily range and facilitate the amortization of the vehicles. Beyond this, regulations which encourage multi-shift delivery would enhance the profitability of EVs.
- Regulatory advantages, like the right to enter pedestrian zones throughout the day (in combination with a city logistics approach) or penalization of conventional vehicles, i.e. through a city toll, have proven to offer substantial advantages to companies deploying EVs.
- Finally, financial advantages for heavy freight EVs should be considered. These are currently applied at different levels in the various countries of the North Sea Region. They include subsidies of the purchase price, free recharging at public chargers, exemptions from parking fees or the city toll, or compensating for the disadvantages of heavy batteries by allowing drivers with a class B license to drive EVs up to 7.5 tonnes.

5.2 Limitations

The findings of this study have several limitations. The researched area covers the European North Sea Region. Thus, in other regions, different measures to reach profitable operations might be feasible. The paper focuses on a period between January 2010 and May 2013. Already, within this period, a change in motivation was observed, shifting from just testing vehicles to adapting logistics processes to benefit from the EVs' strength (compare Sect. 3 of this paper). Since electric mobility is evolving rapidly, new cases, concepts and measures might have been implemented in companies after mid-2013. These will have to be included in a future study.

5.3 Outlook and Implications for Research

Apart from the obvious need for further developments in the area of battery technology, the following further research is suggested: to identify and validate transport segments which are predestined for multi-shift delivery and to identity and rate appropriate policies supporting off-hour delivery; to understand eco-driving strategies for heavy (loaded) electric trucks; to support the implementation of slow, light EVs, such as electric cargo bikes, scooters or quads/trailer vehicles, in combination with micro-consolidation centres; to initiate a meta study, which collects further cases of urban electric freight transport, as i.e. provided by the BESTFACT project, and enhance the profitability concepts and measures suggested in Sect. 4 of this study.

Further development of electric urban freight transport holds a large potential for reducing dependency on fossil energy and enhancing the quality of life in growing urban areas. Although freight EVs might not become as popular in the media as some passenger EVs, they can become an important support for reducing freight transport-related emissions.

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