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The potential of light electric vehicles for specific freight flows

insights from The Netherlands

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Publication date
2017

Document Version
Other version

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Link to publication

Citation for published version (APA):
Balm, S., Moolenburgh, E., Anand, N., & Ploos van Amstel, W. (2017). *The potential of light electric vehicles for specific freight flows: insights from The Netherlands*.

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THE POTENTIAL OF LIGHT ELECTRIC VEHICLES FOR SPECIFIC FREIGHT FLOWS: INSIGHTS FROM THE NETHERLANDS

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KEYWORDS: light electric vehicles, electric freight transport, cargo bike, city logistics

ABSTRACT

The number of light commercial vehicles in cities is growing, which puts increasing pressure on the liveability of cities. Light electric freight vehicles (LEFV) and cargo bikes can offer a solution, as they occupy less space, can be manoeuvred easily and does not emit tailpipe pollutants. This paper presents the results of the first half-year of the LEVV-LOGIC project (2016-2018), aimed at exploring the potential of LEFVs for various urban freight flows. Delivery characteristics, trends, practical examples and the judgement of experts are combined to assess the potential of LEFVs for seven major urban freight flows. The preliminary analysis concludes that every urban freight flow has a certain level of potential for using LEFV. In particular parcel and food deliveries have high potential; however, deliveries related to services and the last phase of construction work can also be switched to LEFV. In comparison, non-food deliveries to retail establishments and the collection of waste collection have less potential. Though the latter can change when recycling standards become higher.

INTRODUCTION

The demand for city logistics is growing and changing (Taniguchi et. al, 2015). Underlying factors for the changing demand are the rising e-commerce market, the growth of inner city construction work, the increase of self-employed workers, and various trends in the food and HoReCa (i.e. Hotel, Restaurant and Café) market. The average shipment size in city logistics is becoming smaller and deliveries are becoming more time-critical (Ploos van Amstel, 2015) leading to an increase in the number of light commercial vehicles[1] (LCV).LCV registrations in Europe have increased from 1.3 million in 2009 to 1.7 million in 2015 (ICCT, 2016). In 2015, LCVs are accounted for approximately 11 percent of the total light duty vehicle market, which was 8.5 percent in 2009. The London Assembly Transport Committee reported an increase of 11 percent in kilometers driven by LCVs, while truck traffic remained the same (London Assembly Transport Committee, 2016).

Policy-makers around the world are facing the challenge of keeping their growing cities liveable, in which urban freight traffic plays an important role (ALICE/ERTRAC). ALICE/ERTRAC estimates that between 10 and 15 percent of all vehicle mileage driven in cities involves freight traffic, of which 80 percent is done by LCVs. The delivery of goods and services are required for the functioning of cities, but the delivery vehicles put increasing pressure on the city in terms of pollution, congestion, accessibility and loss of public space.

One of the opportunities for improvement may be found in the use of light electric freight vehicle (LEFV). LEFVs are smaller in size, can be manoeuvred easily and do not emit tailpipe pollutants. There is a growing interest among logistic service suppliers to use LEFV for city logistics (ECLF, 2016). A recent survey in The Netherlands shows that this interest is mainly driven by environmental consciousness and innovative ambitions, and less by financial considerations (LEVV-NL, 2017). The survey also revealed that LEFVs are already used for a variety of deliveries (see Figure 1) of which parcel, food and post are the most common.

Figure 1 Use of LEFVs in The Netherlands (n=40)

Within the LEVV-LOGIC project, the Amsterdam University of Applied Sciences (AUAS) and the Rotterdam University of Applied Sciences (RUAS) work together with 30 public and private organizations to explore: how LEFVs can be a financially competitive alternative to conventional freight vehicles. The project runs from 2016 to 2018 and starts by exploring the potential of LEFV for specific freight flows. This paper presents the results of the first half year, in which we answer the question: *what are potential freight flows for light electric freight vehicles based on market and delivery characteristics?*

The rest of the paper is organised as follows. The article begins with a definition of LEFV followed by an overview of the research that has been carried out in the field of LEFV. The next section explains the research methodology used in this research. Based on the methodology, the subsequent section describes selection of the urban freight flows and discusses future trends and potential of using LEFV for various urban freight flows. The

[1] Gross vehicle weight below 3,5 metric ton

succeeding section analyses the expert opinion on use of LEFV using Multi-actor Multi-Criteria Analysis (MAMCA) method followed by discussion on the results. Finally, the paper ends with conclusion about the results showing directions for further research.

DEFINITION OF LEFV

The Dutch LEVV-LOGIC project defines light electric freight vehicles as electrically powered or electrically assisted vehicles that are in size smaller than a van and have a maximum loading capacity of 750 kilograms. It includes electric cargo bikes and L-category vehicles (LEVV-LOGIC, 2016). This brings the first limitation of the vehicles as large or heavy goods are not suitable to be delivered using LEFV. Next, LEFVs have a limited range in terms of kilometres and speed and are consequently not suitable to drive on high ways. Private and/or public infrastructure is needed to charge the batteries before or between trips, depending on the intensity of use.

Figure 2 Examples of light electric freight vehicles (v.l.t.r.: Urban Arrow, Stint, Goupil)

STATE OF THE ART

In projects such as DELIVER, FREVUE and ENCLOSE the potential of electric delivery vehicles has been explored extensively from technical, financial, logistical and policy perspectives. Despite the time and money spent on research and development, large-scale implementation of electric vehicles has not taken place yet. In fact, the uptake of EV's for freight delivery in The Netherlands slows down (Altenburg, 2016). While electric vans are credible option (European Environment Agency, 2016; FREVUE, 2015), the share of electric vans in the total fleet of LCV in The Netherlands is only 0.1 percent (Altenburg, 2016). The EU project FREVUE concludes after four years of research that the business case of EV's remains a challenge. The environmental friendly vehicles do not offer sufficient operational advantages to compensate for the significant higher purchase price (Quak et al., 2016).

In the meantime, the discussion on the negative impact of transport has developed into a broader debate including, next co climate change and health issues (air quality and noise nuisance), public space occupancy and the attractiveness of cities in general. From that point of view, LEFVs offer an additional social benefit compared to conventional delivery vans due to its smaller size. Next, LEFVs are competitive with conventional delivery vans in purchase price (Lebeau et al, 2015). Further operational benefits have been observed as the vehicles are faster in congested cities (CityLog, 2012). LEFVs are (often) allowed on cycle lanes and can be parked easily and closer to the delivery address, which saves time searching for a parking place. Hence, increased operational benefits can be obtained from using LEFVs on routes in a dense network.

Scientific knowledge about the use of LEFVs in city logistics is limited (Schliwa et al, 2015) and focused largely on the use of cargo bikes for courier services (Quak et al., 2014; Gruber et al, 2014; Schliwa et al, 2015; Gruber & Kihm, 2016). Barriers to expansion can be found in terms of lack of cooperation with other logistics service providers (Schliwa et al, 2015) and the reluctance of customers to embrace a new technology (Gruber & Kihm, 2016). For LEFVs to be successful in urban freight market, there need to be opportunities for innovation and growth.

Non-scientific work shows many practical examples of using LEFVs. Next to the courier, express and parcel (CEP) services, examples are found in the field of basic catering products such as meal delivery (Pro E-bike, 2016). Like CEP services, meal delivery services are characterized by time-critical deliveries. According to Outspoken Delivery in the UK, speed and reliability are the biggest selling points of delivery using LEFVs (Schliwa et al, 2015), which explains the suitability of LEFVs for time-critical deliveries. Another market in which LEFVs are popular are municipal services such as inspection, gardening and local waste collection (Pro e-Bike, 2016). This can be explained by the leadership role that (local) governments take in the transition towards electric mobility (ECF, 2016).

From the state-of-the art study we derive four criteria that can reveal the potential of LEFVs for a particular freight flow. The criteria are shown in Table 1.

Table 1 Criteria

Criteria	Motivation
1. *Small and light shipments*	The vehicles have limited loading capacity
2. *High network density*	The vehicles are limited in range but save time during parking (and searching)
3. *Time-critical deliveries*	Speed and reliability are great selling points
4. *Opportunities for innovation and growth*	Customer demand and competition influence transition towards new concepts

Different estimations about the potential of light (electric) vehicles and cargo bikes for the logistics sector have been made. For example, the European Project Cycle Logistics estimated that 38 percent of the motorized commercial trips in cities can be performed using cargo bikes (Cycle Logistics, 2014). The study differentiates services versus delivery; however, distinction of the suitability of cargo bike for specific goods flows is not made in this study. Besides, the study only considers pedalled vehicles and includes bikes without electric assistance and is therefore not completely comparable with our definition of LEFV.

The LEVV-LOGIC project aims to reduce the number of inefficient LCVs in city logistics. The project does not solely search for a one-to-one replacement of traditional vehicles, but explores new logistics concepts and business models using LEFVs. To achieve this goal, we need demand for logistics and corresponding delivery characteristics as starting point. We therefore use the criteria from Table 1 to assess the potential of LEFV for different freight flows.

METHODOLOGY

In this section we describe the different steps that we take to determine the potential of LEFVs. The methodology combines different aspects, as shown in Table 2. These are: 1) street observations, 2) delivery profiles, 3) practical LEFV examples, 4) city logistics trends and 5) the judgment of experts. The first topic is used for the selection of different freight flows. The second and third topic focus on the current situation whereas topic four focuses on future trends. For topic five, we have asked experts to evaluate the criteria from Table 1 per freight flow.

The boundaries and scope of research are as follows:

- Except for future trends, input for this study will mainly be extracted from Dutch data and information, as observations were done in Amsterdam and Rotterdam and surveys where distributed in The Netherlands.

- The study looks primarily at the demand for freight transport. The logistic concept and financial viability for LEFV is research focus for 2018. Mainly physical and operational characteristics are therefore subject to research.

Table 2: Aim, method and data per step

Step	Aim	Method	Data
1) Street observations	Distinguish freight flows	Street observations	Unloading activities of 627 vehicles in commercial areas in Amsterdam and Rotterdam.
2) Delivery profiles	Understand the characteristics of deliveries in cities.	Surveys among receivers in Amsterdam and Rotterdam.	Delivery profiles from 209 shops, HoReCa and businesses in Rotterdam and Amsterdam
3) Examples of LEFV in practice	Know how LEFV are already used in practice	Survey among users of LEFV.	40 respondents (users of LEFV)
4) City logistics trends	Discuss how logistics trends impact the future use of LEFVs.	Literature review.	Variety of national and international studies concerning todays and future trends.
5) Judgement of experts	Assess freight flows using a consistent set of criteria	Individual evaluations, using criteria derived from previous research.	6 experts

POTENTIAL OF LEFV FOR DIFFERENT FREIGHT FLOWS

Selection of freight flows

To identify the potential use of LEFV in urban freight transport, we need to understand the variety of urban freight flows and their characteristics. Therefore, data has been collected in the two largest cities of The Netherlands: Amsterdam and Rotterdam. The data collection is done during two days of street observations on 10 different locations in these cities. For the street observations, the vehicle-type and the type of freight flow for each delivery were registered. The type of freight flow was derived from the company name shown on the vehicle. Figure 3 shows the results for both cities together. It shows that a high percentage of vehicles could not be categorized at all, as these vehicles did not show a company name.

Based on the observations, we distinguish six main urban freight flow activities: food, construction, services, parcel, waste, and retail non-food. The category “other” includes municipal deliveries and general cargo. Next to the freight flow category, we registered the type of the vehicle (gross vehicle weight below or above 3.5 metric ton). This information helps in assessing the possibility of using LEFV since an operational shift from a truck to LEFV is less likely than a shift from LCV to LEFV.

Figure 3 Observed unloading vehicles in commercial areas (n = 627)

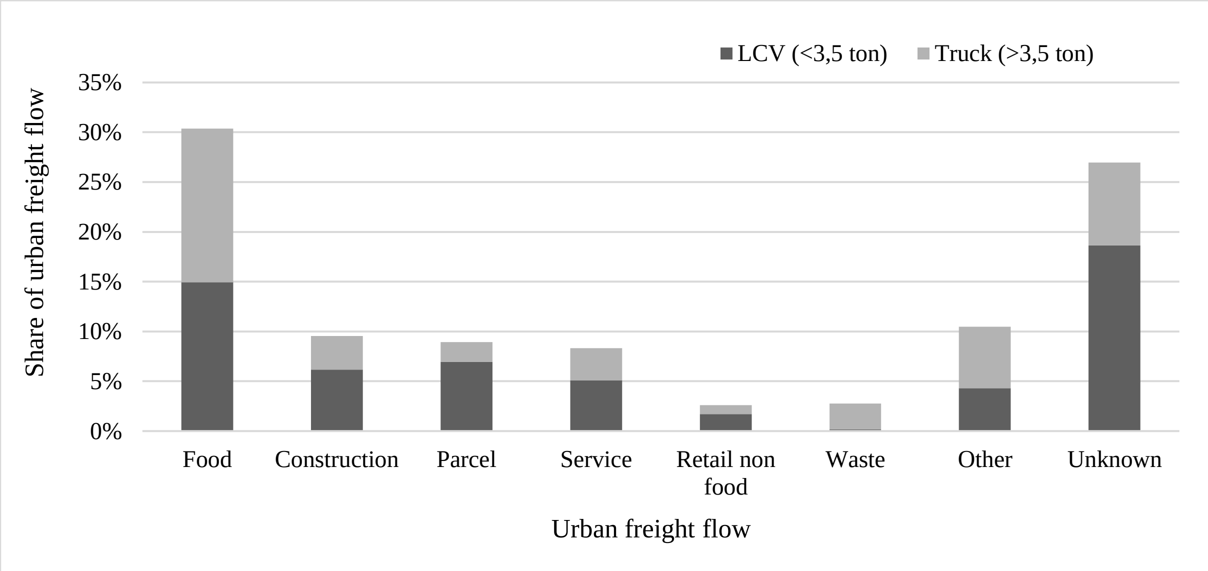


Figure 3 shows that food delivery is the largest urban freight flow in the commercial areas: about 30 percent of the vehicles were identified as food delivery (e.g. supermarkets, HoReCa) vehicles. When we exclude the "unknown" category, the share of food deliveries even rises to 40. Nearly 60 per cent of the deliveries was done using LCV. Trucks are mainly used to deliver food to large supermarkets, transport general cargo and to collect waste. The share of LEFVs in urban freight flows was negligible (< 1 percent).

In the rest of the section we describe the seven urban freight flows using input from the street observations (step 1) and the questionnaires from receivers (step 2). Next, examples of current users of LEFV in the Netherlands are given (step 3). Finally we mention current trends within each flow that can influence the use of LEFVs in the future (step 4).

Description of freight flows

We divide the food flow into B2B and B2C, due to the differences in distribution characteristics.

Food (B2B). B2B food logistics mainly consists of food distribution from suppliers to supermarkets and HoReCa. Full truck deliveries to supermarkets are not considered as potential shift to LEFVs because of the high volumes delivered by trucks and low number of stops per route. We therefore exclude truck flow in further evaluation. Deliveries to HoReCa and smaller supermarkets on the other hand, are characterized by multiple, low volume deliveries per week served by mainly LCVs. On average the HoReCa firms that participated in the survey receive 16 deliveries/pick ups a week (including waste collection). Nearly half of all deliveries to HoReCa companies are done by refrigerated vehicles. The shipments consist of crates or packages, of which 25 percent of all deliveries use roll containers. Deliveries are mainly done in the morning and are time dependent.

Dedicated wholesalers in the Netherlands such as Sligro and Hanos have a few electrical vehicles in practice, but none of them perform their deliveries using LEFV. The volume can be a barrier for the use of LEFVs, considering the high number of crates and packages delivered per stop. However this year one of the biggest HoReCa wholesalers in the Netherlands, DeliXL, starts delivering their customers in the city of Amsterdam by LEFVs, in cooperation with Bubble Post.

Due to demographic changes such as urbanization, increase in tourism, increase in (knowledge) immigration and changing food habits (e.g. low calorie/fat, organic, locally grown) the number of specialized stores (e.g. organic supermarkets) is increasing. Such stores receive a variety of small volume items from different suppliers. Similarly, small HoReCa establishments also get smaller quantity orders but more frequently. Such low volume goods can be potentially supplied using LEFVs if the warehouse of the supplier is located just outside the city area. The survey among receivers showed that many of their small suppliers are located within the city area. These suppliers can potentially use LEFV for B2B inner city food distribution.

Food (B2C). Delivery of food from supplier to customer (B2C) accounts for a small portion in the total food flow using LCVs in cities. Currently 2 percent of all groceries are bought online and shipped to the customers (ABNA, 2016). Deliveries are time-critical and customers expect to receive deliveries within a relatively small time-frame, mostly just after working hours. These deliveries are served in crates or boxes by LCVs. In addition, volumes delivered in this segment are relatively small compared to the B2B flow.

Considering the survey among current LEFV users (see Figure 1), respondents using LEFVs to deliver food and meals are respectively 15 percent and 9 percent. LEFVs as well as bikes without electric assistance are already used quite a lot to deliver meals, by local companies and by global firms as Burger King and Domino's. A fast growing company in food delivery is Picnic (2017), an online grocery store. This company delivers groceries at the customer's home using small electric vehicles.

The B2C flow of the food sector is rapidly changing. Online grocery shopping and weekly food boxes (e.g. Hello Fresh and the Dutch Maaltijdbox) are fast growing markets in the food sector. For 2025, a total online share of 9 percent is predicted for the food sector (ABNA, 2016). Additionally, home or office delivery of meals and catering services (e.g. UberEat, Deliveroo, Foodora) are also increasing considerably. The market size for food delivery in the Netherlands nearly doubled in three years (FSIN, 2016). LEFV has high potential for online grocery market using local cross-docking and home delivery of food due to lower average volume, more frequent deliveries and a dense network.

Small Retail (non-food). Small retail delivery includes all non-food deliveries to smaller shops, which are part of the commercialized areas in the cities, including fashion shops, drug stores or media stores. Non-food small retail has big share in terms of establishments in the commercialized areas in Amsterdam and Rotterdam. According to the observations, more than half of all retail shops are delivered by LCVs and the rest is done by truck. The truck deliveries are mainly directed to the big retail chains in the Netherlands such as Hema and the Media Market. Similar to the truck deliveries to big supermarkets, full truck deliveries to big retail stores have no potential to use LEFV due to the large volumes delivered per stop. However, small retail companies are mainly delivered by LCVs and therefore we see potential for LEFV. Receivers in this segment have three to four suppliers (up to 16) and receive eight deliveries a week on average. Goods are generally delivered in parcels. Although the frequency of deliveries is lower for this segment compared to the food segment (B2B and B2C), relatively small volume per delivery can be an advantage for the use of LEFV.

Service provider Bubble Post delivers to small retail shops in Amsterdam and Rotterdam. Suppliers make use of their consolidation centers outside the city center. From this center, small electrical vans supply the customers in the city which results in less driven kilometers in urban areas. Another example is Cityhub who holds the inventory of a retail outlet in in a hub on the city periphery, from where deliveries are made by a small electric vehicle.

E-commerce and rise of omni-channel shopping is a common trend among all the sections of retail segment (Deloitte, 2015). Many consumers no longer distinguish between buying in a store and buying online and often prefer to collect the item at store due to convenience or free delivery. On the retailer side, the popular trend is 'fulfill from the store' (Douglas, 2014).

Retailers (e.g. WalMart) are planning their operation in such a way that they can ship product to online buyers from a warehouse or from a store, or let the customer pick up the product. Such trends may give rise to delivery of small volume order at store or delivering customers from a store. LEFV can be efficiently implemented in the latter case.

Parcel services. The courier, express and parcel flow (CEP) includes delivering non-palletized items to businesses and consumers. According to the observations, parcel deliveries in the cities are mainly done by LCVs. A minor share of this flow includes parcel services deliveries destined for the bigger retail clients delivered using trucks, which makes these flows less suitable for LEFV. The parcel service to consumers is characterized as fine-mazed, which consists of a small number of packages and volume per stop, a high density of stops and small and light shipments (ACM, 2016).

According to the LEFV-NL survey concerning current LEFV users, 16 out of 40 users deliver parcels. Among them are the established companies such as PostNL and DHL, but also new companies such as Fietskoeriers.nl and Cityhub deliver the last mile distribution for parcel services or web shops using a LEFV.

With the increase in online shopping, the CEP market is bound to grow at a high pace. According to a report by ING (Luman, 2015), by 2025 approximately 40 percent of shopping will be done online. Such trends will result in higher B2C total volume and a decrease in average shipment size and weight. Customers demand 'same-day' or even 'same-hour' delivery, but at the same time, are reluctant to pay for higher service levels putting companies under high operational pressure. Use of LEFV is a promising alternative to LCV in congested areas with high density of customers.

Services. The segment "services" includes wide variety of transport movements by workers such as electricians, plumbers, facility cleaners, laundry services etc. Based on the street observations, services are accountable for 11 percent of urban freight flows. The flow is not generated by a demand for goods but professional services are provided on the premises of the customer. Therefore the total parking time for services is higher compared to other freight flows. LCVs are commonly used by the service industry (Figenbaum, 2016). The flow can furthermore be described as time dependent due to urgent maintenance matters.

Deudekom Movers and the ANWB roadside assistance are two examples of service providers using LEFVs for daily activities in the city center. Accompanied by an e-bike with trailer, the roadside assistance of ANWB| carry out their services in various Dutch cities. Moving company Deudekom performs some of their moving activities (i.e. archiving) using a cargo bike.

In the service market there is a trend towards 'facility as a service'. This means that payment agreements are based on the result and not on the amount of time spent on the task. Consequently, servicemen have to arrive on time and finish their work in as little time as possible. Servicemen need to find a proper parking place (unlike deliverymen who often quickly park on the road) considering the amount of time needed for the service. Also, parking costs are high in urban areas. The use of LEFVs may increase the operational efficiency by reducing travel and parking time and reducing running costs (e.g. diesel, parking cost). Also, as serviceman carry relatively small volumes (e.g. service tool-kit, coffee refill, print cartridge), the use of LEFV is arguable from the loading capacity perspective.

Construction: Final outfitting. Based on the street observations, construction logistics is the second biggest flow in the city. It includes freight transport during different construction stages such as infrastructure, rough construction, rough outfitting and final outfitting. The first three stages are served by trucks due to high volume and weight of goods and therefore not considered to be suitable for LEFVs. According to the observations, final outfitting is characterized by relatively small and light construction shipments, for which the use of LCVs is dominant. In some cases the driver delivers not only goods, but also performs service (i.e. installation) at the location resulting in longer parking times at site.

The use of LEFV in the construction segment is yet very rare. Currently Dutch construction company Heijmans uses a LEFV, mainly on the construction site itself. The potential for LEFV in construction is experienced to be efficient, due to the maneuverability and less parking problems in city centers (Heijmans, 2016).

Increase in urban population has put immense pressure in urban housing market causing a trend of high construction activities in the cities compared to rural areas. Delivering construction equipment and materials in urban areas causes lot of inefficiencies. During the last phases of the construction (i.e. interior and outfitting) different variety of materials (e.g. bulbs, switches, ventilators) are required and often supplied by different suppliers or carried by contractors. Volume and weight of material used during this phase allows the use of LEFV as it can contribute to efficient and sustainable logistics.

Waste collection: With a share of 4 percent of the total amount of urban freight deliveries, waste is not one of the biggest flows in the city. Nevertheless the amount of volume collected from the city is high. Results from observations show a variety of companies collect waste in Rotterdam and Amsterdam. Respectively 7 and 13 different companies operate in this segment within the city. The majority of these companies collect the same type of waste in these areas.

In the city of Amsterdam, waste is collected from companies (86 percent) and households (14 percent) (City of Amsterdam, 2015). We can distinguish several types of waste collection such as general waste, organic, glass, paper, plastic and batteries. General waste collection is the biggest flow in the city and therefore collected using large garbage trucks. The goods are mainly transported in garbage bags, and characterized by a dense network.

An increasing number of municipalities in the Netherlands work together with waste companies who experiment with electric vehicles. The authorities of Amsterdam and Rotterdam even have EV’s in their fleet, nevertheless LEFVs in the waste segment are not common. One example comes from Waalre, a Dutch town with nearly 17.000 inhabitants. The local authority experiments with a cargo bike for the collection of waste.

Throughout the world (especially in Western countries), separation of waste is an ongoing trend (Szczepanski, 2016). Glass, paper and plastic have either high volume or weight and thus not suitable to be transported using smaller vehicles such as LEFVs. Organic waste is not very high in volume and must be collected regularly due to odor and hygiene purpose. Similarly, battery waste is also characterized by small volume and can be potentially collected using LEFVs.

Receivers’ perspective

To get an overview of the potential of LEFVs for urban freight deliveries from a receivers’ perspective, we asked 106 receivers in the city of Rotterdam how they perceive the potential of LEFVs. More than half (58 percent) of the receivers see the possibility to receive their goods with small electric vehicles. In particular receivers of food (B2B and B2C) and small retailers foresee a successful shift to LEFV. The positive effects on the environment and business image are mentioned as main reasons to receive their goods by LEFVs. Some receivers, particular within HoReCa, even see LEFVs as a possible marketing tool, because of the positive environmental effects and increased environmental consciousness of their customers.

MUTLI-CRITERIA EVALUATION

The delivery characteristics, future trends and best practices for each flow type described in the previous section provide better understanding on the potential of LEFVs. In the next section, we add the intuitive judgment of experts to our research, using a multi-criteria assessment approach.

Setup

Four criteria (refer Table 1) as defined from the state-of-the art are used to assess the suitability of LEFVs for the different freight flows. The assessment has been carried out with an expert panel consisting of six persons from the Netherlands, including the authors. They all have an academic title in logistics or business and multiple years of research experience in city logistics. Each person has individually evaluated seven different freight flows using four criteria, which resulted in a 7x4 matrix per person. A 7-scale has been used for the evaluation of criteria, with 1 being not applicable (i.e. the criterion applies to <15 percent of the deliveries in this freight flow); 4 being neutral (i.e. the criterion applies to 50 percent of the deliveries in this freight flow) and 7 being very applicable (i.e. the criterion applies to >85 percent of the deliveries in this freight flow). For the evaluation, the decision-making model from MOBI of Vrije Universiteit Brussels has been used, which is regularly used in urban freight research for Multi-Actor Multi-Criteria Analysis (Macharis, 2012; Keseru, 2016). The online MAMCA software enables the collection of individual evaluations from different actors. The experts were invited to make the evaluation online, without knowing the judgment of the others.

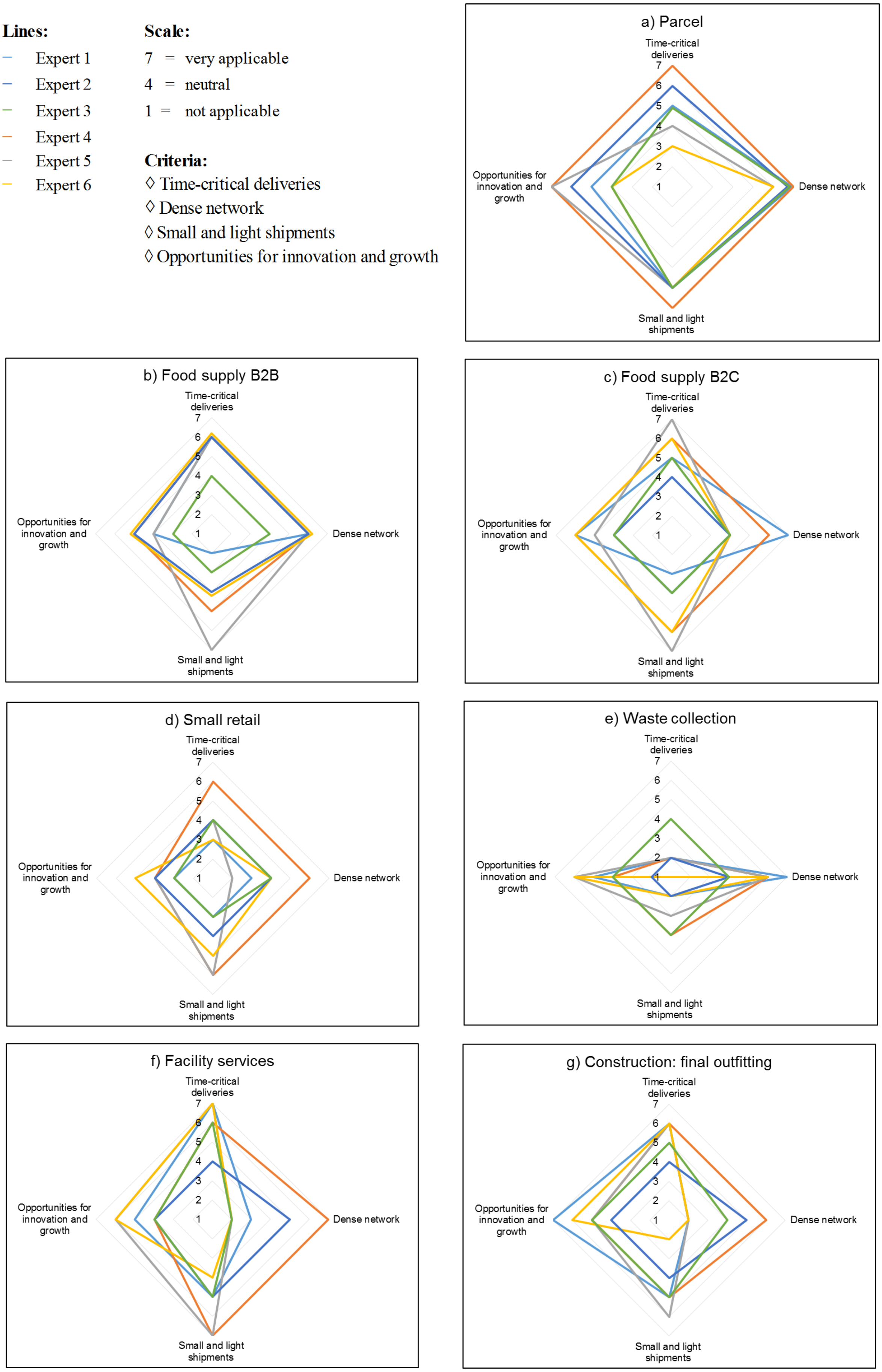
Outcome

The outcomes of the multi-criteria expert evaluation are shown in Figure 4, where the individual evaluations are presented jointly in a radar graph per freight flow. The aim of the joint presentation is to determine the relative degree to which deliveries **i**n a particular freight flow can be carried out using LEFVs, taking the different criteria into account. It furthermore shows the degree of consensus among the experts in their evaluation of the different criteria. For example graph 4f show that little consensus exists on the network density of (facility) service deliveries, while the experts agree on the network density of parcel deliveries (see 4a). Overall, it is clear that the experts judge differently, which may reveal ambiguity in the definition of freight flows and criteria and should be taken into account in following steps (see discussion). Next to the radar graphs we have determined the average scores for each freight flow as shown in Table 3. Overall, based on the four criteria, parcel deliveries offer the greatest potential and waste collection and retail the least. Service deliveries offer potential in terms of the degree of time critical deliveries and shipment size/weight. Food supply B2B and waste collection face challenges with the loading capacity of LEFVs.

Table 3 Average scores

	Time-critical deliveries	Network density	Small and light shipments	Opportunities for innovation and growth
Parcel	5	7	6	6
Food supply B2B	6	6	4	4
Food supply B2C	6	5	5	5
Small retail	4	4	5	4
Waste collection	2	6	3	5
Construction: final outfitting	6	4	5	5
Facility services	6	4	6	5

Figure 4 Multi-criteria evaluation



DISCUSSION

The aim of this research is to describe the potential of LEFVs for specific freight flows. The diversity of the city logistics sector and a lack of delivery data impedes a strict quantitative approach. Therefore we have combined delivery data, with a qualitative description including trends, practical examples and the intuitive judgement of the experts. The individual steps of our research have some limitations, which we discuss in this section.

First, street observations are very area-specific. The number of HoReCa, businesses and houses in an area influence the share of food, parcel and service deliveries as well as the intensity of waste collection. Also temporally circumstances such as construction work, school holidays or public events, affect the observed traffic. Next, street observations only provide limited information, as it does not reveal the origin of the vehicles or route characteristics.

Delivery profiles, collected from receivers, provide detailed information on the delivery of a certain establishment, but are difficult to generalize. It requires a sufficient number of respondents with a clear understanding of the request, which is a time-consuming exercise. Also within a certain freight flow or receiver type, many differences exists. For example, a four-star hotel is supplied differently than a bed and breakfast. Maintenance services can have different characteristics than installation services and food can be delivered fresh or canned. Such diversity and variety makes it difficult to derive general conclusions on the potential of LEFVs for specific freight flows.

Practical examples of LEFVs are helpful to explore whether or not, as well as how, LEFV can be used for a specific flow. However, the underlying reasons for the use of LEFVs can be diverse, such as strategic considerations, intrinsic motivation, subsidy opportunities, marketing opportunities or operational benefits. Next, the environment in which a LEFV is used will influence its success. For example, the existence of environmental zones, logistic facilities, cycle lanes, slow traffic zones and traffic congestion strongly connected with the potential operational benefits.

The abstract approach using freight characteristics and concrete approach using practical examples have been combined with the intuitive judgement of experts. The evaluation by logistic experts is a first attempt to assess the potential of LEFV in a Delphi study setup (i.e. a forecasting method). A next step is to discuss the outcomes with the experts and to repeat the evaluation, which should lead to more consensus. Furthermore, additional actors with different backgrounds can be invited to the evaluation. They can be logistics experts from abroad, but also representatives from the public and private sector. At this stage we have not yet attached weights to the different criteria. Further practical-oriented research should develop more knowledge on the relative importance of the different criteria in relation to the freight flow. For example, we may assume that a dense network is more determinant for the suitability of LEFVs when the value of goods is low (e.g. waste). Next, when public or private actors are invited to the evaluation, they are likely to have different criteria for the evaluation of freight flows. For example, a public authority may want to include the contribution to pollution and nuisance, while a logistic service provider might want to include whether the company is familiar with a market.

CONCLUSION

This paper has combined freight data, practical examples and judgment of experts to answer the first research question of the two-year LEVV-LOGIC project: *what are potential freight flows for light electric freight vehicles, based on market and delivery characteristics?* We conclude that every major urban freight flow can be partly served using LEFVs.

Food delivery B2B is the largest flow in inner cities in terms of delivery vehicles. The share of vans within this flow, the degree of time critical deliveries and network density contribute to the potential success of LEFVs for this flow. Number of current users that deliver food to businesses using LEFVs do confirm these findings. The B2C food flow is, as a whole, considered to be suitable for delivering using LEFVs. Its share in urban freight distribution is still small, but the flow is more dependent on time and consists of several smaller shipments compared to the B2B food flow. In addition, food delivery to customers is expected to continue to grow and therefore the network is expected to become denser.

Non-food retail is measured as one of the smallest urban freight flows in terms of the number of delivery vehicles. This is partly explained by the fact that large retail chains are delivered with full-truck loads. Deliveries to smaller retailers can be suited using LEFVs, considering the size and weight of shipments. Experts do not evaluate the use of LEFVs for this flow as highly potential. The degree of critical deliveries, network density and opportunities for innovation and growth is relatively low. The lack of growth and innovation opportunities for retail establishments is explained by the increase of e-commerce.

The increase of e-commerce leads to a positive evaluation in another sector. Hence, the use of LEFVs has great potential for the parcel market. Street observations show a large percentage of LCVs used for parcel delivery. Moreover, the small shipment size is an important characteristic for this flow. Experts evaluate the parcel flow as the most promising of all urban freight flows, with positive average scores among all criteria. In addition, the potential of LEFV for this flow is underlined by the number of current LEFV users that deliver parcels, including large players such as DHL, UPS and PostNL.

Based on our observations, and by taking expert opinions into account, we conclude that services and (final stage) construction flows in general share the same delivery characteristics. These fairly large flows in inner cities are in general carried out by LCVs. For both flows, experts see LEFV as a promising mode of transport, however it should be further explored whether sufficient operational benefits can be achieved considering the low number of stops per day. On the other hand, as the deliveries require a proper parking space, the potential benefits achieved from easy parking with LEFVs can be relatively high. The facility services flow seems to have a moderate advantage to the construction services, as they consist of even smaller and lighter shipments.

The potential of LEFVs for the waste flow is not as straight-forward. The collection is mainly performed in a dense network, but collection is not time-critical nor light or small. Also, as our research is motivated by the increasing LCV market, we specially focus on freight flows in which the use of LCVs is currently dominant. However, the growing segmentation of waste collection, combined with more frequent collection patterns, could lead to a growth in the potential use of LEFVs for waste collection in future.

The next steps in research are the analysis of logistics concepts using LEFVs for different freight flows, including costs and benefits for different scenarios. This will provide insight into the financial competitiveness of LEFVs. Next, the characteristics of the different freight flows are input for the technical development and infrastructure of LEFVs.

ACKNOWLEDGMENTS

The authors would like to thank Dr. Ron van Duin and Dr. Hans Quak for their contribution as expert, Dr. Cathy Macharis for the use of the MAMCA software and research assistants Ruben Stam, Annemijn van Herwijnen and Oguzhan Varol for their assistance in the data analysis.

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