THE POTENTIAL FOR ELECTRIC UTILITY VEHICLES IN CRAFTSMEN ENTERPRISES

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1. INTRODUCTION

This article explores the use of electronic travel logs to analyse travel patterns. The logs where obtained from loggers installed in vehicles owned by Norwegian craftsmen and service enterprises. Workers in these types of enterprises depend on using vehicles to transport personnel, equipment, and material to work sites in order to carry out their work. Unlike “white collar” professionals who can use public transport or even non-motorized modes when moving between clients (in urban areas), craftsmen hardly have alternatives to the car.
The travel patterns will be used to assess the potential for making their transportation more sustainable, by replacing their diesel utility vehicles with battery electric utility vehicles (EUVs).

The craftsman sector involves a number of small enterprises offering different professional services on the premises of customers, within geographic regions (e.g., carpenters, electricians, metal workers or information technicians serving customers). The article also analyses transport activities of service enterprises such as facility servicing, janitors, security and cleaning firms, that have much of the same transport needs as craftsmen when it comes to the need to transport tools, equipment or materials. These groups provide vital products and services for their local communities.

Despite their number and transport requirements, little research has been conducted to map Craftsmen transport activities as pointed out by Hislop and Axtell (2011), or to identify means to mitigate their transport related environmental impact. Mobility generated by economic activity has primarily been analysed in terms of goods transportation, and commuting trips, i.e., travel between home and regular place of work (Aguilera, 2008).

The article contributes to the ongoing research agenda on measures to make professional users transportation more sustainable and on diffusion of innovations.

2. NORWEGIAN CONTEXT

2.1. Policy and incentives

The electric vehicle market in Norway is heavily incentivized as seen in table 1. In the 1990s the incentives were introduced to allow experimentation with electric vehicle and around 2000 to nurture a growing EV industry in Norway, whereas from 2010 the focus shifted towards supporting climate policy goals, as seen for instance in Figenbaum et al (2015). In 2016 the transportation authorities suggested in the planning document for the National Transportation Plan, that only zero emission passenger vehicles and light duty vans and distribution trucks shall be sold from 2025, essentially phasing out diesel vans (NTP 2016).

Some of these incentives are weaker for electric utility vehicles than for passenger vehicles, for instance the exemption from the registration tax as utility vehicles are taxed less than passenger vehicles. Some incentives may be worth more for craftsmen owning EUVs than for owners of passenger vehicles, for instance the exemption from toll roads and the access to bus lanes. The most important incentive is the exemption from the registration tax. The VAT exemption does not affect professional buyers of vehicles as they do not pay VAT on means of transportation used in the business.

Table 1 Electric vehicle incentives in Norway, adapted from Figenbaum and Kolbenstvedt 2015.

Incentives	Introduced	Benefits for buyers of passenger vehicles, influence on relative advantage	Future of the incentive as presented in the governments revised budget for 2015 (may 2015) and decision in parliament.	Effect on electric van market
Fiscal incentives: Reduction of purchase price/yearly cost gives competitive prices				
Exemption from registration tax	1990/1996	The tax is based on emission and weight and makes ICE vehicles more expensive. Example of ICEV taxes: VW Up 3000 €. VW Golf: 6000-9000 €,	Continued until 2020. Will be reviewed against the achievement of the Norwegian climate policy goals for 2020 and 2030. For ICE vehicles the registration tax will be tuned further to reduce emissions	Reduced advantage compared with passenger vehicles because the tax rates are lower. Typical tax for small diesel van is around 2000-2500 €.
VAT exemption	2001	Vehicles competing with BEVs are levied a VAT of 25% on sales price minus registration tax.	Unchanged through the end of 2017. Will consider replacing it with a subsidy scheme, initially at the level of the VAT exemption and slowly ramped down.	Most Craftsmen buyers have full refund of VAT and no advantage of this incentives
Reduced annual vehicle license fee	1996/2004	BEVs and hydrogen vehicles 52 € (2014-figures). Diesel rate: 360-420 € with/without particulate filter.	Half rate of ICE vehicles to be introduced 01.01.2018 and full rate from 2020, i.e. the incentive will be removed from that year.	Same rates apply as for passenger vehicles
Reduced company car tax	2000	The company-car tax is lower but BEVs are mostly not company cars.	This incentive may be removed from 2018	Not relevant
Direct subsidies to users: Reduction of variable costs and help solving range challenges				
Free toll roads	1997	In the Oslo-area the saved costs are 600-1 000 € per year for commuters. Some places exceed 2 500 €/year	The government will appraise the environmental effects of introducing differentiated fees for toll roads (main roads and toll rings around cities) and ferries based on the environmental characteristics of vehicles as well as a low rate for BEVs and FCEVs.	Potentially larger effect on vans if they drive more trips during the day.
Reduced fares on ferries	2009	Similar to toll roads saving money for those using car ferries.		Unknown
Financial support for charging stations	2009	Reduce the economic risk for investors in charging stations, reduce range anxiety and expand usage options.		Most charge onsite, not needing public stations.
Financial support for fast charge stations	2011	More fast-charging stations become available, increases BEV miles driven & market.		Make it possible to reach customers farther away, but not economic due to income loss when waiting.
User privileges: Reduction of time costs and providing users with relative advantages				
Access to bus lanes	2003/2005	BEV users save time driving to work in the bus lane during rush hours. High value to user in regions with large rush-hour delays.	Local authorities may be given the possibility to introduce restrictions in their jurisdictional district if zero emission vehicles hinder busses' ability to navigate the bus lanes.	Larger effect because time saved can be sold at a higher price than the average time cost of commuters
Free parking	1999	Users get a parking space where these are scarce or expensive and save time looking for a space.	Local authorities will be given the authority to decide whether this incentive is to continue in their jurisdictional district	Less effect, must park where the work is, and max time constraint of parking space is an issue
Free charging		Not regulated in national laws, but is often bundled with free parking	Local authorities will be given the authority to decide whether this incentive is to continue	Most have free electricity available at work site.

2.2. Statistics on ownership and use of EUVs.

There are around 400.000 vans in Norway of which 330.000 with payload less than 1.000 kg. There were 72.100 vans in Oslo and another 59.426 in the surrounding province, Akershus in 2014 (SSB 2014). The number of vans and small lorries is growing (SSB 2016a), contributing to increased congestions and emissions. The Craftsman sector employs about 9% of the workforce in Norway (SSB, 2016b) and account for 11-16 % of the vehicle based transport in Oslo, 15% in Bergen and 5% in Trondheim (Vågane et al 2014). The sector mainly uses small and large diesel vans. Craftsmen share of transport with vans is increasing (SSB 2014).

Although Norway has experienced a booming electric vehicle market in recent years, the number of electric vans (EVs) is still very limited. This is partly due to limited availability and high costs, and partly caused by incompatible technology (limited range versus travel needs).

However, technology is improving at a fast rate, and studies suggest a great potential for replacing diesel vans with electric vans (e.g., Myklebust and Steen, 2012).
Since 2014 the market has been stable around two percent of the total van market. In contrast the electric passenger vehicle market took off from 2013 with a market share reaching 18% in 2015 due to more incentives as seen table 3, and more private users having a compatible driving pattern (Figenbaum and Kolbenstvedt 2016),

1811 electric vans were registered in the Norwegian vehicle registry on 31.12.2015 (NPRA 2016). The spread on models, industries and geography is shown in figure 1. 1053 (58%) of these vehicles were registered in Oslo and Akershus of which 674 owned by leasing companies that could be used anywhere. Craftsmen own roughly 8% of the EUVs, service oriented enterprises (cleaning, facility services, guard companies) own another 4% as seen in figure 4. The fleets owned by authorities, another 14%, is also used for mobile work such as janitors at government facilities, home nursing etc. Peugeot Partner is the bestselling EUV thanks to a supply agreement with the province (and municipality) of Oslo. Renault Kangoo is the second most used vehicle followed by the Nissan E-NV200.

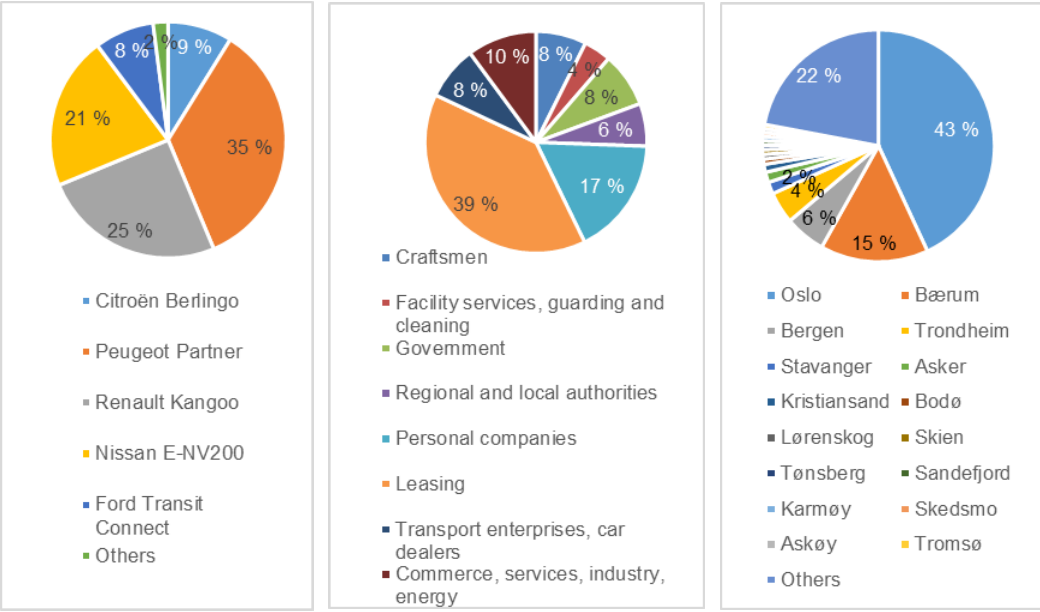

Figure 1 Types of battery electric utility vehicles in the fleet, the split on owner types and where they are registered. Source: NPRA 2016.

According to Statistics Norway (SSB 2015), small vans were on average driven 14519 km/year in 2015. Vehicles in the provinces of Oslo and Akershus have driving distances about 10-15% above the national average (Ibid). Passenger vehicles on the other hand drove on average a distance of 12387 km in 2015 (Ibid). The average age of Vans was 8.4 years in 2015 versus 10.5 years for passenger vehicles (SSB 2015b). The shorter life of vans is an advantage as electric vehicle battery life may not last the full lifetime of passenger vehicles.

2.3. Electric utility vehicles on the market

Currently four small electric vans are available in the Norwegian market, figure 2 and table 2. They are sold in various seating, cargo and size configurations.

Figure 2 Electric vans in the Norwegian market, left to right: Renault Kangoo, Nissan E-NV200, Peugeot Partner, Citroën Berlingo, Source: Manufacturers web pages

Table 2 Characteristics and prices (2015) of electric vans and their ICE counterparts. Source: importers web sites.

	Peugeot Partner L1	Peugeot Partner Edition L1	Nissan E-NV200	Nissan NV200 (WS comfort)	Renault Kangoo Z.E.	Renault Kangoo
Propulsion system	Electric	Diesel Basic 1.6 Blue HDI 75 hp	Electric	Diesel working star edition 110 hp	Electric	Diesel 1.5 dCi 75 hp
Sales price	215.800 NOK	187.849 NOK	209.900 NOK	208.806 NOK	199.900 NOK	210.141 NOK
Price excl. vat/ registration tax	215.800 NOK	139.900 NOK	209.900 NOK	150.879 NOK	199.900 NOK	157.168 NOK
Registration tax	0 NOK	17.311 NOK	0 NOK	23.469 NOK	0 NOK	18.241 NOK
VAT (if appl.)	0 NOK	30.638 NOK	0 NOK	34.458 NOK	0 NOK	34.732 NOK
Transport volume	3.3 m^3	3.3 m^3	4.2 m^3	4.2 m^3	3 m^3	3 m^3
Max load	695 kg	785 kg	588 kg	677 kg	625 kg	595 kg
Seats	3	3	2	2	2-3	2-3
Range	170 km		170 km		170 km	
Charge time	6-11 hours		7-12 hours		6-8 hours	
Fast charge	80%/30min		80%/30min			
CO_2 emission		112 g/km		130 g/km		112 g/km
Energy consumption		4,3 l/100 km	130 Wh/km	4,9 l/100 km	155 Wh/km	5.2 l/100 km

3. THEORETICAL FRAMEWORK

Passenger vehicle movement patterns have been tracked using GPS devices in the US, Italy, Sweden and Germany. Pearre et al (2011) used driving data from 484 instrumented gasoline vehicles tracked over a period of one to three years to analyse passenger vehicle driving patterns in the Atlanta (Georgia) region in the US. Among their findings was that frequency of use is not strongly related to distance per day and that there is a segment of frequently used vehicles that are only used locally and thus a potential early BEV market. Björnsson and Karlsson (2014) utilized logged data over 30 days for a sample of 432 Swedish vehicles to analyse the battery requirements and economics of Plug-In hybrid vehicle configurations. The found that commuters would be the first group for which PHEVs could become economic and work place charging could have the potential of halving the marginal battery cost. Khan and Kockelman (2012) used GPS data from 255 Seattle households over a period of a year to conclude that BEVs with a 100 miles' range covers the travel needs of 50% of single vehicle households and 80% of multi-vehicle households, apart from four days per year. Gennaro et al (2014) used a sample of 28 000 vehicles travel over the month of May 2011 for the regions of Modena and Firenze to estimate potential for replacing some of these vehicles with BEVs. They found that the share of the commercially owned vehicles moving at any time was always below 16%, and that up to 25% of the vehicles could be replaceable with BEVs. Jacobson et al (2015) compared German and Swedish vehicle movement data and concluded that the driving pattern of "second cars" in multivehicle households is better suited for BEV adoption than "first cars" and cars in single vehicle households.

The use of existing travel logs to analyse movement patterns of Craftsmen and Service enterprises, as is done in this paper, is a novel methodology in transportation research.

4. MATERIAL AND METHOD

4.1. Data - logging of driving

Data logs of the transport activity of 115 vehicles used by seven anonymous Craftsmen and service companies in the Oslo area, see table 3, were obtained from a travel log system, the "TravelLog" by Guard Systems (GSGroup 2016). These 115 vehicles represented about 0.1% of the total fleet of light duty vans in the Oslo and Akershus provinces.
TØI and GS Group obtained permission to get access to already stored GPS data for the vehicles operated by these companies.

Table 3 Vehicles and companies in the sample

Company	Number of vehicles	Postal code	Municipality
A	4	1279	Oslo
B	7	0598	Oslo
C	7	0283	Oslo
D	15	0373	Oslo
E	4	3472	Røyken ~20 km South-west of Oslo city centre
F	29	1477	Lørenskog ~15 km East of Oslo city centre
G	49	0585	Oslo

The system uses a GPS to log the vehicle position and speed. The data is sent over the mobile internet to a centralized database that the owners of the vehicles have access to. Two weeks of data, covering the period 9-22. March 2015, was retrieved from this database.

4.2. Interviews with EUV users

14 Craftsmen businesses owning EUVs, including some service oriented companies within cleaning and guard services, where interviewed in the Oslo area and in Trondheim (Julsrud et al 2016). The interviews were conducted at the premises of the businesses, normally with one of the leading operational managers of the company. The interviews centred around their vehicle usage in general, how the EUVs are used and function in their daily business, barriers and challenges along the way, and the selection of vehicle in the purchasing process.

5. CALCULATION

The data records obtained from GS Group contained the following information:

customer	unit	zip	logged time	longitude	latitude	speed
1094	254179	1279	09.03.2015 00:30	10.69796944	59.47059266	0

Customer:	Anonymous code for the vehicle owner
Unit:	Anonymous code for the vehicle
Zip:	ZIP (Postal) code
logged time:	Data and time of logged data point
longitude, latitude:	Longitude and latitude of the vehicles position.
Speed:	Vehicle speed km/h

The logger unit has a GPS and logs the vehicle position and speed each km of driving and during the following events:

- Manoeuvers around curves
- Start/stop of periods of high speed
- Fast accelerations
- Start/stop of congested traffic
- Ignition on/off
- Every hour/half-hour when ignition is off.

It is the immediate status of the system that is logged and sent to the central database. Data records can be lost if the communication with the central system is lost or the signal is weak. The dataset was cleansed for erroneous data and the longitude and latitude position was transferred to the UTM33 coordinate system to facilitate calculation of trip distances. For each vehicle (unit) the data set was split into trips. A new trip was assumed whenever there was more than 25 minutes between trips. The position data for the trips were transferred to travel activity maps using GIS. The distance travelled between data records was calculated and summed up to trip distances. The maps of travel show that the trips in general trace the roads well, apart from one of the companies, that used older data loggers storing less activity. A crude estimate for annual driving was obtained by multiplying the two weeks of data by 23.

6. RESULTS

6.1. Input from interviews

From the interviews with companies owning EUVs (Julsrud et al 2016), it was apparent that they have a highly variable driving pattern depending on where they get assignments. Such a variability of driving could preclude replacing diesel vans with EUVs given their limited range and long charge times. Several craftsmen had departments only doing servicing and upgrades on existing buildings or installations and they had extremely variable driving needs that often changed during the day. These companies stated that EUVs could definitely not be used by these Craftsmen. The craftsmen that most easily can adopts EUVs are those that work on larger project lasting longer time periods making it possible to plan the transport to and from the location. Electricians seems to be the group of craftsmen that are most interested in taking EUVs into use and that have fewest barriers to overcome.
Some dedicated service oriented cleaning companies, estate managers and janitors on the other hand had a highly predictable mostly local driving pattern suitable for EUVs, and they could also more easily find and use available charging plugs.

6.2. Geographical spread

When looking at the data-logs of the seven companies located in and around Oslo, it became apparent that companies A, C and E used their vehicles within a small geographical zone in the greater Oslo area, as seen in table 4 and figures 3 and 4. Companies B, D and G use their vehicles over a larger regional zone covering much of Eastern Norway. Company F covers large parts of Norway, driving up to 1200 km from the office. Companies F and G are large companies and some long distance driving should therefore not preclude the opportunities to replace some of their vehicles with EUVs. Most of their driving was also in the greater Oslo area. Company B have few vehicles and operate in a large geographical zone. Replacing diesel vehicles with EUVs will thus be challenging for this company. The data logs from company B shows more disturbances than those of the other companies.

Table 4 Geographical spread of travel by each company.

Company	Widest distance from office	Geographical zone
A	60 km	Larger Oslo Area, south to Moss
B	200 km	Eastern Norway
C	20 km	Larger Oslo Area
D	220 km	Eastern Norway (mainly south part)
E	50 km	Larger Oslo Area
F	1200 km	Eastern, Middle and North Norway
G	200 km Norway - 250 km partly Sweden	Eastern Norway + trips to Western-Sweden

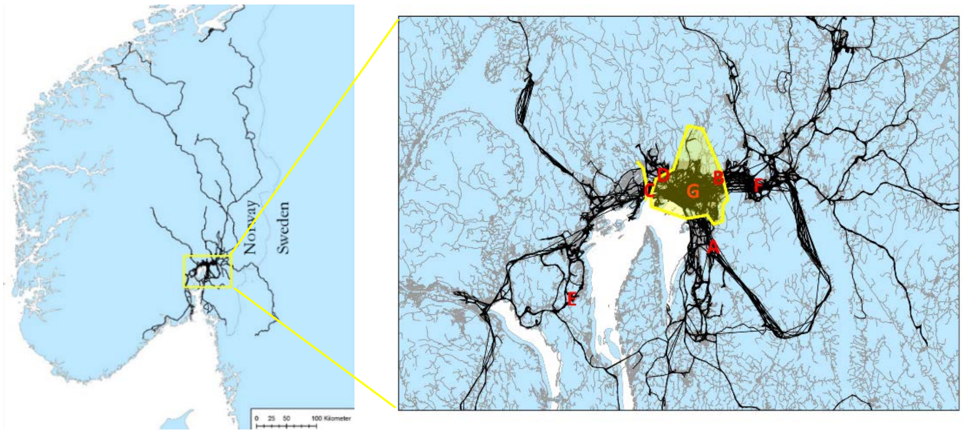

Figure 3. Distribution of driving by Enterprises A-G on a national scale (left), and within the greater Oslo area (right). Yellow lines (right chart) shows the approximate position of toll roads around Oslo, Red letters marks the approximate position of enterprises A-G based on the postal code.

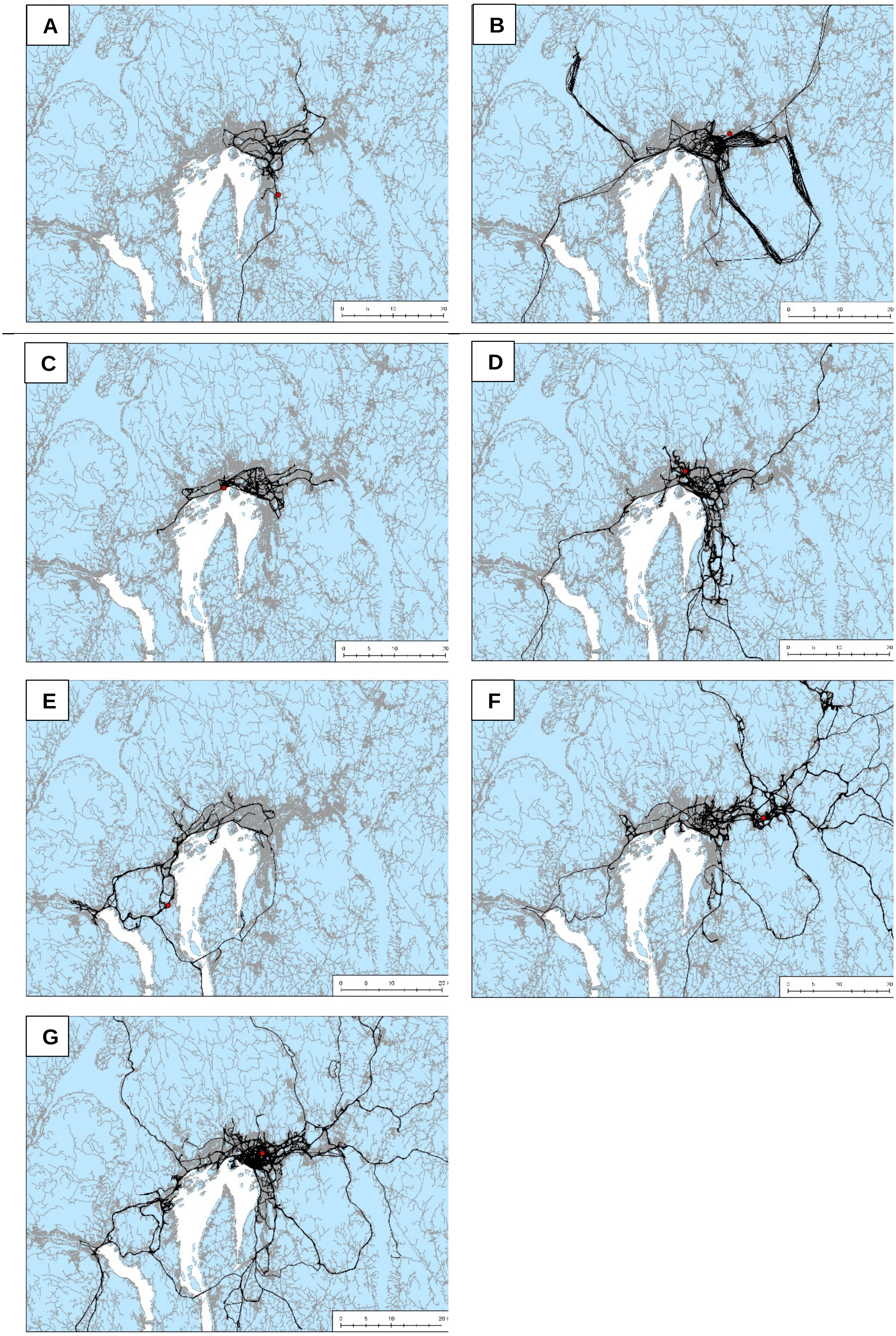

Figure 4. Travel pattern of Enterprises A-G in the greater Oslo area. Red dots mark the approximate position of the Enterprises.

6.3. Travel per year

Figure 5 shows the estimate for average driving per year. The estimated annual average travel length was 12207 km. The median annual travel length was 10947 km.

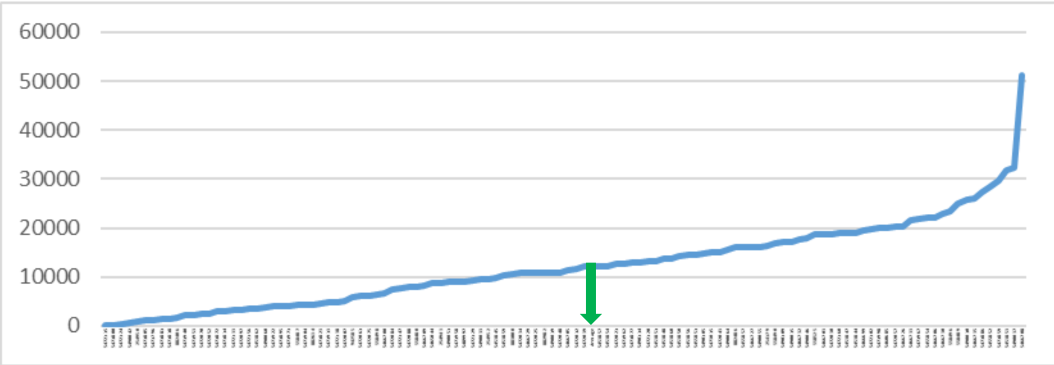

Figure 5 Estimated yearly driving based on 2 week of data logging. Km. Arrow marks average.

The large share of vans with very short driving distances is surprising. Some of these companies are located in dense parts of Oslo, potentially explaining these short distances. Figure 6 shows the spread of the estimated number of days of usage per year per vehicle. Half the vehicles are used the expected 181-240 days per year (a working year in Norway consists of 230 days), 22% are used on more days and 28% on fewer days.

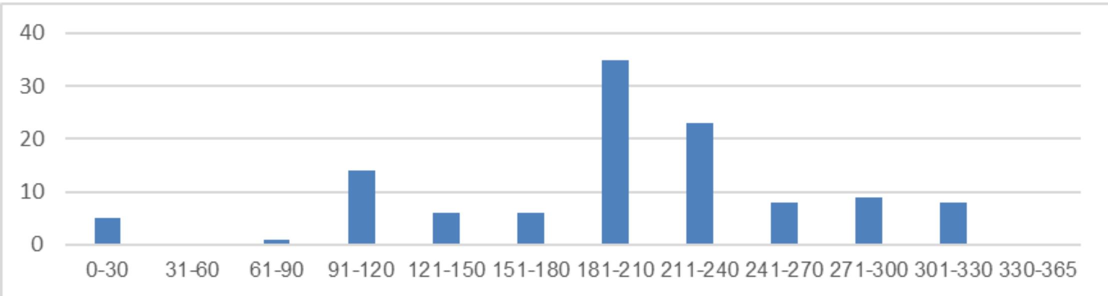

Figure 6 Number of vehicles per interval of days of usage per year.

Figure 7 shows the number of days the vehicle is driven in distance interval, the number of days of driving exceeding the distance interval, and the share of days that can be covered. Driving is shorter than 80 km on 84% of days, and less than 120 km on 94% of days. Only 1% of days of driving is longer than 200 km.

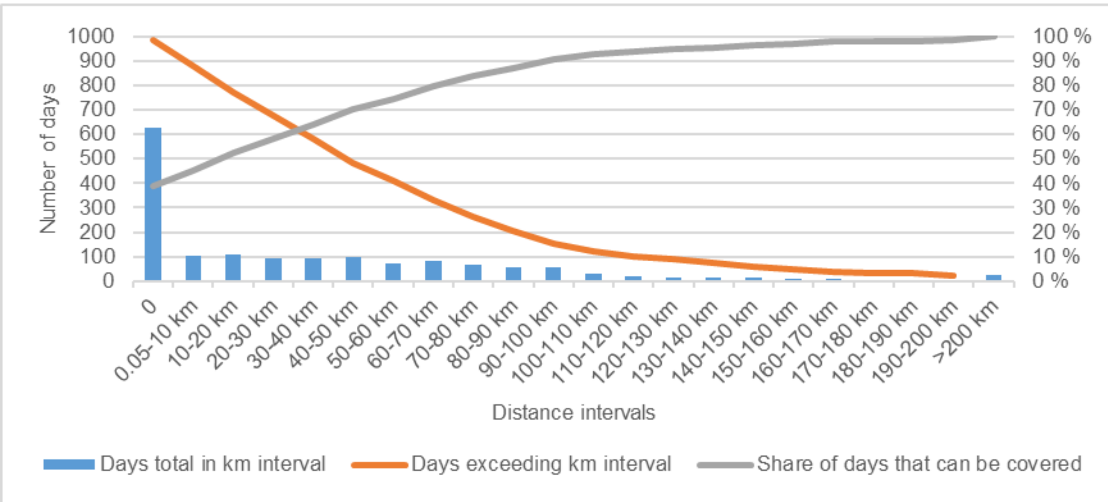

Figure 7 Days of travel by distance intervals, days exceeding and share of days that can be covered.

6.4. Travel during an average day

The movement data from the data loggers was compared with toll road data of small enterprise owned vehicles passing through the toll gates of Oslo (Vågane et al 2014) as seen in figure 8. The toll road data also contains small passenger vehicles owned by enterprises. The movement data was scaled up by the size of the fleet of small vans in Oslo and neighbouring province Akershus. The curves have the same shape. The morning peak at 07:00 and the afternoon peak at 15:00 correspond to the start and end of the normal working day for craftsmen. The peak at 11.00 is likely due to driving to a place to eat lunch or using the vehicle as a “lunch hour warming hut”. Apparently the tail in the afternoon is larger for toll road data, but as seen in the right part of the figure, this is likely due to vehicles not passing through the toll road gates. The shape of the curve with three peaks resembles that of Gennaro et al (2014) for commercial vehicles in Modena and Firenze, apart from the share of the commercial fleet moving at any time was less than 15%, roughly half that of the Oslo data. Their group of “commercial vehicles” is however a much broader group than that logged in Norway.

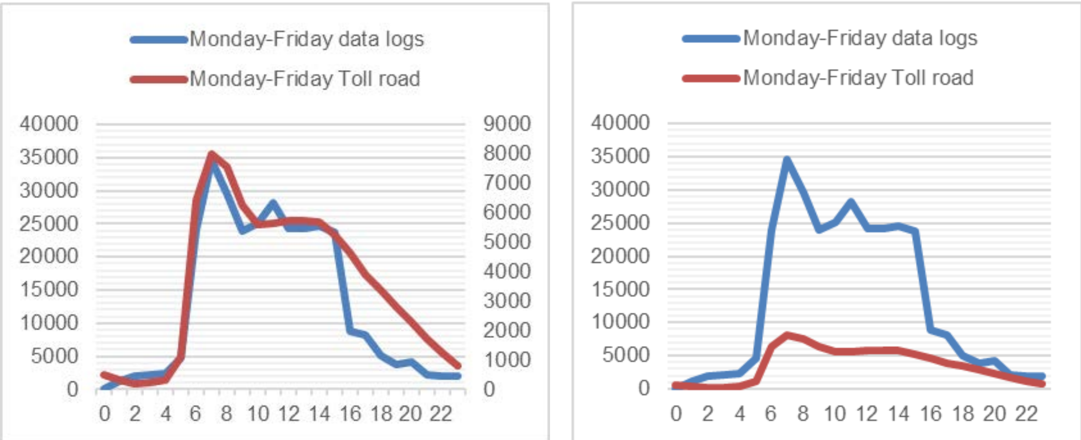

Figure 8 Travel activity per hour, average Monday-Friday. Left: vans passing the toll gates of Oslo on the right axis, estimated travel of vans scaled up from 115 logged vans to the total fleet on the left axis. Right: vehicles passing toll gates and travel of logged vehicles on the same scale.

6.5. Maximum day of travel

The maximum day of travel is the basic determinant of the suitability of EUVs for Craftsmen. A colour coding scheme was used to estimate the suitability as seen in table 5. The basis for the scheme is that the summer and winter range can be some 25% and 50% less than the official range of current EUVs of about 170 km. Each time the vehicle stops and restart some time later, the batteries are drained when electric heaters are used to reheat the vehicle, leading to a need for additional safety margin. Therefore, the distance intervals where split in driving up to 50 km and driving in the 51-80 km range.

Table 5 Colour coding of vehicles and evaluation of possibility to replace the diesel van by an EUV, by the day of maximum driving distance over the two-week period.

Distance driven day of maximum driving	Evaluation of potential to replace diesel vans with EUVs
Always under 51 km,	All vehicles can be replaced
51-80 km	Vehicles can likely be replaced, all vehicles if diesel heater installed
81-120 km	Potential depend on road-type, driving style, speed, cargo, topography, temperature, charging
Over 120 km	Not compatible unless possible to charge during day

Figure 9 shows the spread of the vehicles by maximum daily driving distance over the 2 weeks of data logging using the colour codes from table 5.

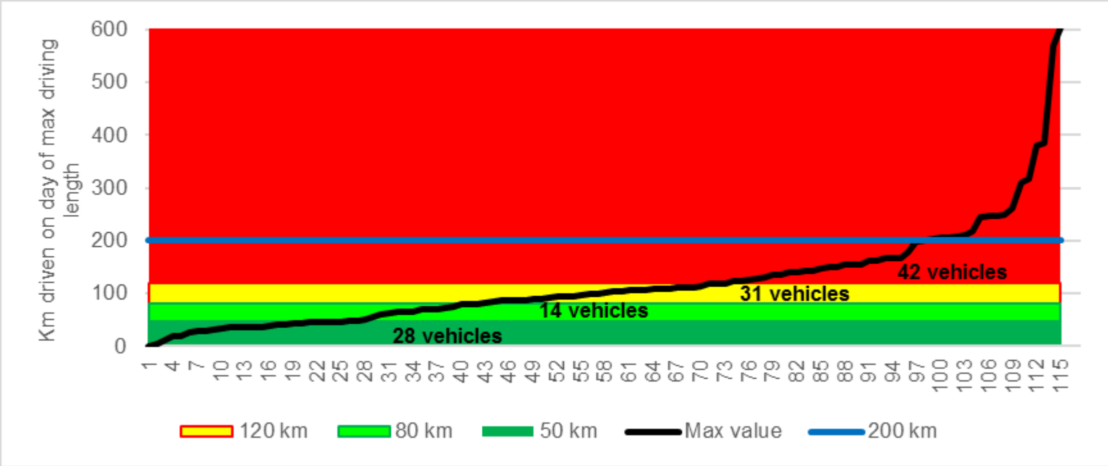

Figure 9 Vehicles divided in potential for being replaced by EUVs, based on the length of travel on the day of maximum travel, over the 2 weeks of 9-22. March 2015 (black line).

24% of these vehicles are unconditionally replaceable and a further 12% of vehicles in the light green zone are likely replaceable, especially if they use diesel heaters. Another 27% could be replaceable if recharged during the day or if they are used under light travel conditions (flat, not too cold, few start and stops). The remaining vehicles are unlikely to be replaceable, although charging during the day could make some compatible.
The interviewees (Julsrud et al 2016) stated that all vehicles would be replaceable with range above 200 km. The graph shows that about 15-20% of the vehicles are driven occasionally above 200 km.

Figures 10 shows the percentage of vehicles by maximum day of travel intervals, transport work of vehicles by day of travel distance intervals, and transport work by vehicles by maximum day of travel distance intervals.

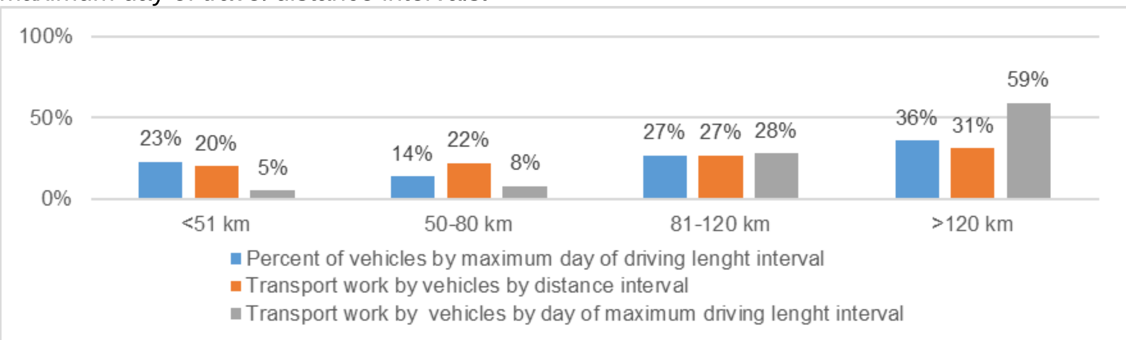

Figure 10. Percent of vehicles by maximum day of travel length interval, transport work by all vehicles by daily distance interval, transport work by vehicles by day of maximum day of travel length interval.

The potential for replacing vehicles (blue colour) is much larger than the potential for replacing transport work when only replacing vehicles never exceeding the maximum day of travel limits (grey). The split of the driving by all vehicles (red colour) by days of travel within these intervals is the theoretical potential to replace total transport work for all the vehicles in the sample. EUVs would then replace diesel vehicles on all travel in these intervals. The figure shows that with a limit of 80 km driving on the maximum day of travel, then 41% of vehicles can be replaced but only 13% of the total transport work will be replaced. If all transport could have been replaced with EUVs on days of travel less than 80 km, then 42% of the transport work could be replaced. A 50% increase in range, which could be achievable in a five-year timeframe, would result in a much higher substitution of transport work. The share of vehicles would then be 68% and transport work share 41%. In the interviews with EUV owners, several stated that the range was “almost good enough”, but a bit more would make the vehicles much more useful which is confirmed by the data logs. 36% of the vehicles drive occasionally above 120 km and stands for 59% of the total kilometres driven by the sample. To reach into the potential of these vehicles, three approaches could be followed, 1) charge during the day, 2) new technology, 3) redistribute travel.

6.6. Redistributing transport so that fewer vehicles drive long distances

The potential for replacing transport work may be enlarged if the transport activities of the companies can be redistributed, so that electric utility vehicles can undertake the short distance trips they are capable of doing. The company having most vehicles, company G, had 11 out of 49 vehicles in the red zone, i.e. driven more than 120 km on the day of maximum travel distance. Redistributing the long distance driving between the vehicles allowed that number to be decreased to three, and yellow zone vehicles to five as seen in table 6 6, demonstrating a potential to increase use of BEVs by optimizing routing. Note that this would involve redistributing assignments between craftsmen, so that some specialize on doing the work closest to the company base with EUVs, and those with assignments further away use diesel vehicles. The interviewed companies stated that they had found a need to redistribute travel and swap vehicles after they had taken the EUVs into use to be able to make efficient use of them. Most of the EUVs were used for field support by the work supervisors of the Craftsmen enterprises and it is likely easier for these users to swap vehicles than it is for the craftsmen themselves.

Table 6 Transport work over 2 weeks, per vehicle category and estimated distance per year per vehicle in each category, before and after a theoretical redistribution of transport between vehicles owned by company G.

	Before redistributing travel			After redistributing travel		
	# Vehicles	Total transport work 2 weeks, km	Average per year per vehicle km	# Vehicles	Total transport work 2 weeks, km	Average per year per vehicle km
Red zone # vehicles	11	8 499	18 500	3	5 935	47 500
Yellow zone # vehicles	12	6 046	12 100	5	3 630	17 400
Green zones # vehicles	26	3 649	3 400	41	8 629	5 100

Company G had at the outset a rather unusual driving pattern with many vehicles covering very short distances. It is located in a fairly central location in Oslo and detailed GPS data indicates that the company has work in the immediate neighbourhood of the company office. The very short distances covered by the vehicles in the green zone make the company a candidate for introducing electric vans. If the technology improves to a range all year of 120 km, then the gain in replaceable vehicles and transport work of redistributing travel between vehicles, will be reduced from 15 vehicles and 4980 km to 8 vehicles and 2564 km.

6.7. Stop pattern – Overnight charging and opportunity charging

The stop pattern of the vehicles reveals opportunities for charging. A normal full recharge, when the battery is completely empty, takes about 8-11 hours depending on vehicle type. On 95% of the days the overnight stop time exceeded 11 hours and the vehicles would thus be capable of being fully recharged. Each hour of daytime charging from 16A/230 V power supplies (effectively charging at 12 A, 2.8 kW), can potentially increase range by about 15 km in the summer and 7-8 km in the winter. Combining stopping time with potential range increase per hour of charge, and assuming the vehicles charges at every stop, the potential average daily range increase will be about 85 km in the summer, and 40 km in the winter. The number of definitively replaceable vehicles then increase from 28 to 50 as seen in figure 11.

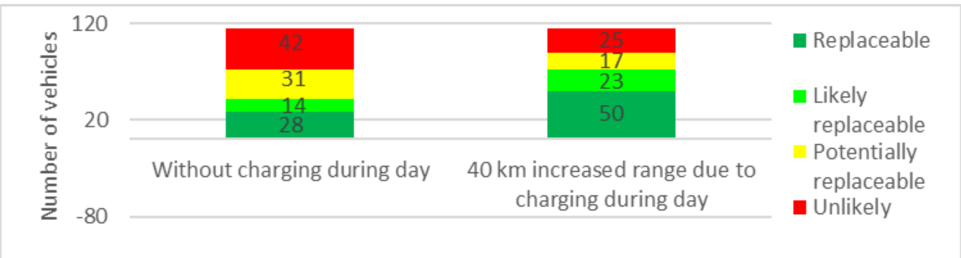

Figure 11. Number of replaceable vehicles with and without charging during the day.

6.8. Economics of EUV usage in Norway

The economics of EUV usage is calculated by looking at the total cost of ownership over 5 years. The purchase cost gap between an electric van and a diesel van is about 45-75 000 NOK when the registration tax is included and VAT excluded, and 60-85 000 when all taxes are excluded. The total cost is evened when taking into account value loss, fuel/electricity cost, financial cost, a 1 000 NOK annual oil change cost on diesel vans, as shown in figure 22. VAT was excluded, assuming all companies are eligible for a 100% VAT refund. The value loss of the vehicles has in all cases been set to 70% over 5 years, but battery electric vans may have a higher loss being a new technology with uncertain residual value. The life of the battery is a crucial question. Modern electric vehicles now typically have an eight year, 70% battery capacity warranty on the batteries. Although these EUVs have a five-year long battery warranty, the batteries will likely last longer than 8 years. Some of the interviewed companies stated that the life of vans in craftsman enterprises can be as short as five years, so battery life is likely not an issue for Craftsmen.

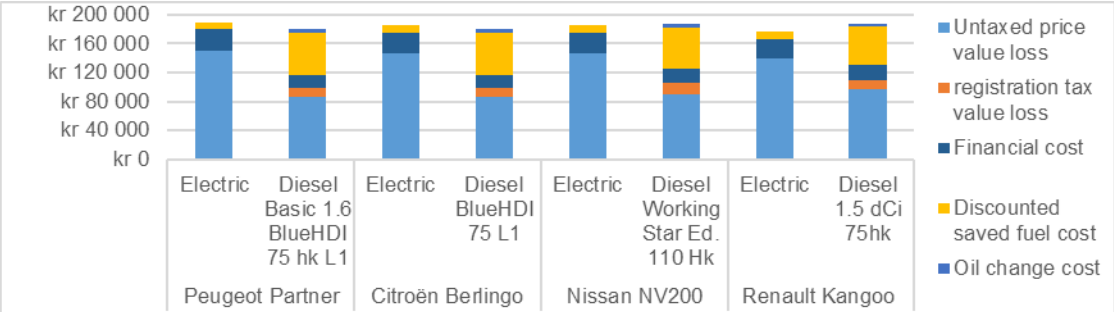

Figure 12 Economics of electric vans in 2015-2016, Total Cost of Ownership five years.

7. DISCUSSION

The potential for replacing vehicles is large but the impact on transport work is much more limited. If a company can redistribute vehicles within the fleet, then more vehicles and more of the transport work can be replaced by EUVs. Redistributing vehicles would also allow EUVs to be used more in the summer when range is longer, rather than the winter range limiting the usage pattern also in the summer. Realizing the full redistribution potential will obviously not be possible. As the vehicles in the sample are anonymous it is also not known if they are truly interchangeable (size, type of equipment). It might as an alternative be possible to swap assignments rather than vehicles. Another option to extend the usability is to charge during the day. On average the real winter range (corresponds to all year range) can be expanded by some 40 km on average, an increases the number of replaceable vehicles by 70-80% when fully utilized. The travel pattern of these vehicles was analysed over a period of two weeks. The travel pattern over the rest of the year is not known, but it is likely to be variable. The ability to redistribute vehicles between missions, will thus be even more important.

EV technology has best user economy when the vehicles are used as much as possible due to their low energy cost per km and high production cost compared with diesel vehicles. Figure 23 shows the vehicles estimated annual usage, the range limits and a rough estimate of saved yearly energy costs. The green areas are the economically viable areas if the electric van has a purchase cost of up to 100 000 NOK more than a diesel version of the same vehicle. The smallest green area is currently the most economic usage area that is also within an all year range limit of electric vans of 80 km. Based on the result here, the viable market without incentives would be around 5%. Within the red area there are many vehicles, but little to save on fuel cost per year. The orange area offers some fuel savings and is within EUVs range capabilities. Local incentives may tip the total cost of ownership in favour of EUVs. The second largest green area will be reachable with second generation longer range vehicles sometime after 2016. The largest green area could be covered if the all year range goes up to 200 km. 200 km is also the range at which the interviewees said all their vehicles could be electric. Such long range EUVs are unlikely to come on the market until after 2020.

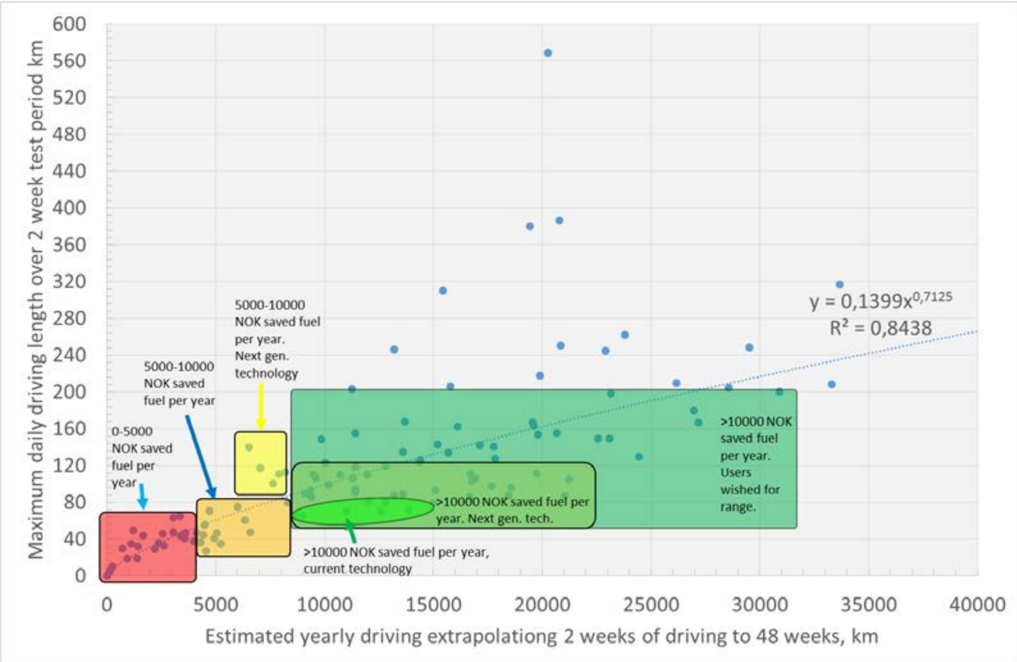

Figure 13 Economics and practicality of electric vans

8. CONCLUSION

Anonymous data from data loggers have proven to provide valuable insights into Craftsmen and service oriented enterprises vehicle based transport. Their travel patterns could be derived and used for evaluating the potential to replace their diesel vehicles with EUVs.
A surprisingly small sample was enough to generate a driving pattern per hour of day very similar to that of similar types of vehicles passing the toll road gates around Oslo. The travel logs demonstrated a surprisingly large radius of action of some vans. One company covered much of Norway but the majority operated in a 200 km area around Oslo.

While EUVs is a promising technology from an environmental point of view, their limited range lead to practical challenges for Craftsmen and Service enterprises. This situation is rather typical for new technology. In the beginning of the diffusion process there are often drawbacks of an immature technology, leading to barriers to adoption. The range barrier can be overcome by taking EUVs into use when the travel patterns match the range. Further adoption can be possible by redistributing travel between vehicles so that some do the short distance driving. Another option is to recharge the vehicles during the day. Improvement of the technology, i.e. longer range, will also expand the potential. While owners of EUVs in general say it is difficult to redistribute travel, many found it was necessary and feasible to do so after they had bought one. Charging during the day or redistributing vehicle can expand achievable range by 50% and increase the number of replaceable vehicles as much as next generation electric vans could do, indicating that adaptations to user habits can substantially expand the potential of EUVs in the initial market introduction phase.

Tapping into electronic travel log data give reliable insights into the travels of craftsmen and other professional vehicle users. Privacy issues with these datasets is however a challenge.

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