

Feasibility of Electrifying Urban Goods Distribution Trucks

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ABSTRACT

This paper discusses the feasibility of electrifying medium to heavy urban goods distribution trucks. As a case study, an existing transport system in the Swedish city of Gothenburg is used. The project is a joint research effort between a vehicle OEM, an electric utility, a fleet operator, the Swedish Transport Administration and two research organizations.

One main objective is to determine if and when different electrified powertrains are cost efficient to the end user. The results indicate that by 2015 conventional powertrains are still probably the most cost effective alternative in all applications studied. But in 2025, electrified powertrains are most cost efficient for most transport scenarios. These results indicate a transition in preferred powertrain technology for urban trucks within the coming ten years. It is important to point out that this result may not be general. Driving patterns, energy price developments and technology maturity of components such as batteries and motors greatly influence the total cost of ownership and large regional differences in when such a transition may occur are expected.

In addition to the total cost of ownership, important issues for a successful deployment are policies (e.g. restricting access to urban areas for noisy and polluting vehicles), information and communication solutions (e.g. adapted route planning), access to a cost effective charging infrastructure (and low-carbon electricity production) and new business models. These must all be developed in parallel to the vehicle and powertrain technology. The large number of different stakeholders involved in this transition is also a challenge in itself.

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INTRODUCTION

With its inherent energy efficiency, lower running costs, low emissions and reduced noise, the concept of electrification (hybrid, plug-in hybrid or full electric powertrains) of urban goods transport might well be a win-win situation for all stakeholders involved. The paper discusses the findings of a cross-industry project with several actors in the transport value chain including vehicle manufacturer, transporter, electric utility, information and communication technology providers and transport authorities.

In order to assess the viability of electrification, this paper deals with the technical and economic aspects linked to the implementation of different vehicle designs. In particular results from a novel approach of selecting vehicle

powertrains from a total cost of ownership (TCO) point of view is presented. Optimization is used to identify the best candidate for vehicle electrification in this particular transport application. A number of actual urban goods distribution routes have logged and combined with previously available driving patterns. In addition forecasts of vehicle, powertrain and energy costs have been made for years 2015 and 2025 as input to the analyses.

Since the internal combustion engine enjoys a status as the dominant design, Midler & Beaume [1] argues that it is necessary to take into account such factors as customer practices, ecosystem borders and regulations in order to break this dominance. The introduction of electrified vehicles in city logistics thus calls not only for an evaluation of the costs and technical difficulties but also of other types of values created or lost in comparison with business as usual. In order

to evaluate such factors, information and communication (ICT) needs were evaluated together with possible business model changes.

ELECTRIFIED URBAN COMMERCIAL VEHICLES

Recent progress in energy storage technology and automotive electric motors and drives are beginning to bring electrified commercial vehicles for city application (such as city buses, goods distribution and refuse) to most markets globally. Some examples are the Electric Maxity from Renault Trucks, New Energy buses in Shanghai from Sunwin, electric refuse trucks from PVI and city distribution vehicles from Smith Electric Vehicles. Analysis firm Frost and Sullivan [2] estimates that nearly 7% of all medium/heavy commercial vehicles manufactured globally in 2020 will have hybrid or fully electric powertrain systems.

Urban distribution centers in combination with hybrid electric vehicles were studied in the ELCIDIS EU-project [3]. This project concluded that there are no predominant objections to the use of hybrid and electric vehicles in urban distribution, neither from company managers nor from drivers, and certainly not from local authorities. Despite the fact that the generation of electric vehicles used was not perfectly developed, they proved to be more energy efficient than their combustion engine counterparts and the impact on energy-use and environment was considerable. Similar conclusions were drawn from the early Volvo plug-in hybrid demonstration project "Hildur" [4] in Göteborg in which two distribution trucks were tested for three years in urban transportation.

After studying French national as well as European research programs on logistics, Dablanç [5] mentions the city of La Rochelle as a good example; with a shared use freight terminal, using electric delivery vehicles. Dablanç urges cities to abandon access criteria based on trucks' weight and size, and to adopt criteria based on environmental indicators.

The recent EU white paper on transport [6] sets the target to achieve essentially CO₂-free city logistics in major urban centers by 2030. Local, regional as well as federal authorities will likely push the use of zero emission vehicles in city centers by means of regulations and incentives.

Calstart in 2011-2012 lead a US industry wide task force on electrified commercial trucks called the E-truck taskforce [7]. They concluded:

1. Incremental cost is the biggest barrier to E-truck purchase/production, but costs do show decline over time; incentive funding is needed in the transition period to cover 50% or more of incremental cost
2. Vehicle quality, warranty, and support are barriers to faster adoption and need to be improved
3. Fleets need better performance data on E-trucks in real-world usage to validate the reliability and business case of the vehicles, including guidance on best use profiles for their operation and payback

4. Infrastructure cost and planning complications are a surprise to fleets and are important next tier issues needing resolution

Finally the E-truck task force project identifies the best use profiles for successful deployment of trucks, targeting return-to-base, fixed route, centrally-refueled urban/suburban fleet applications. It describes the required needed in daily mileage as 70-100 miles, alternatively vehicles with significant energy use from body or equipment on board.

USE CASE COLLECTION

Transport Task Description

To define use cases for goods distribution in Göteborg, major transporter Schenker and their contractors "TGM" and "Bäckebloms åkeri" were studied. The applications in focus are goods distribution to shops and offices and the distribution of refrigerated and frozen goods to shops and restaurants. The use cases are limited to trucks >3.5 tons.

TGM and Bäckebloms åkeri distribute goods in the area of larger Gothenburg including the city of Gothenburg and 12 surrounding municipalities. This area is divided into about 60 distribution areas, where one distribution truck covers a single area in one shift. Additionally, there are a number of extra trucks that distribute in different areas depending on the need. ~7 of the trucks distribute within the city center of Gothenburg, ~25 in the area surrounding the city center, ~25 cover of the areas further from Gothenburg, and the remaining trucks are extra trucks. Except goods distribution, also refrigerated and frozen foods are delivered by about 10 vehicles covering the all distribution areas.

Vehicle and Route Data Collection

To study the goods distribution of TGM and Bäckebloms åkeri, observations of drivers during shifts, interviews and data logging of trucks were done. The observations in-vehicle provided information on the typical delivery and collection schedules, type of goods and the use of trucks (e.g. auxiliary systems such as tail lift and cooling systems).

Data logging was also performed to collect vehicle route data on maps, speed and acceleration of the vehicles versus time, daily driving distance and the weight of goods. Location, speed and acceleration of the vehicles and the weight of the goods were recorded continuously during two weeks, see [figure 1](#).

The distribution routes of TGM and Bäckebloms åkeri were seen to be quite general and similar to the competitors in the region. According to Schenker, the very small distribution areas in the city are in Gothenburg more specific to Schenker due to the large amount of customers in the city and the very short distance between them.

ELECTRIFICATION SCENARIOS

To create electrification scenarios, it was assumed that also the future vehicle solutions should meet the needs of the



Figure 1. Example of logged routes (speed vs. time was logged) for several shifts and fleet operators. Distribution can be categorized into zones; the city center, the immediate surrounding area, and the outer area of larger Gothenburg.

current use cases and no radical changes in how goods are distributed locally are expected within the 2025 time frame.

To maximize the environmental advantages it is necessary to include both the goods distribution in the city center and the surrounding areas of Gothenburg. The city center distribution makes up only ~10% of the vehicle fleet of TGM and Bäckebols åkeri, but the vehicles cause emissions and noise in a densely populated area. It is therefore important to consider this case as a scenario. It has a specific requirement for low noise levels during goods distribution. The typical distance travelled during one shift is very short, up to 40 km.

For the surrounding areas of the city center, both the noise level and emissions are still of high importance. Here, the vehicles enter densely populated areas during delivery routes where a low noise requirement is important. The vehicles also use motorways to some extent, and the distance driven during a shift increases to ~80 km per shift. For TGM and Bäckebols åkeri, this distance is an average for ~40% of the fleet.

Another important part of the TGM Bäckebol fleet is the ~40% of the vehicles that most often has a distance up to 140 km per day. This includes both distributions of general goods and of frozen and refrigerated goods. This distance varies more than for the previous cases due to longer distances between customers. There is a higher need for flexibility in the required distance during a shift. Here, due to the longer distance driven and the more remote location of customers, the requirement to lower emissions is higher than that of low noise. However, when a vehicle enters a densely populated area, such as a town center, there is still a noise requirement.

Taking the collected data into account, 16 different scenarios were developed for the study. These scenarios contain different combinations of daily driving distance (40, 80 or 140 km per shift), different transport task (standard or

refrigerated) different charging possibilities (only night or night & lunch charging) and one- or two-shift use (a max 1 h charging opportunity in each shift is assumed). [Table 1](#) summarizes the different scenarios.

Table 1. Definitions of the different scenarios used in the optimization and analysis.

Scenario	Truck type	Shift driving distance (km)	Charging and use schedule
1	Box	40	Night
2	Box	40	Night & lunch
3	Box	40	Night & lunch, dual shifts
4	Box	40	Night, dual shifts
5	Box	80	Night
6	Box	80	Night & lunch
7	Box	80	Night & lunch, dual shifts
8	Box	80	Night, dual shifts
9	Fridge	140	Night
10	Fridge	140	Night & lunch
11	Fridge	140	Night & lunch, dual shifts
12	Fridge	140	Night, dual shifts
13	Box	140	Night
14	Box	140	Night & lunch
15	Box	140	Night & lunch, dual shifts
16	Box	140	Night, dual shifts

The vehicles considered in the study are distribution trucks with an unloaded mass of about 8000 kg. Two variants of truck bodies are considered, one with a standard box body, [figure 2](#), and one with an actively refrigerated body for frozen and refrigerated goods.

In addition, the projects partners together also made local price forecasts for diesel fuel price and electric energy price up to 2025. The prices presented in [figure 3](#) are excluding