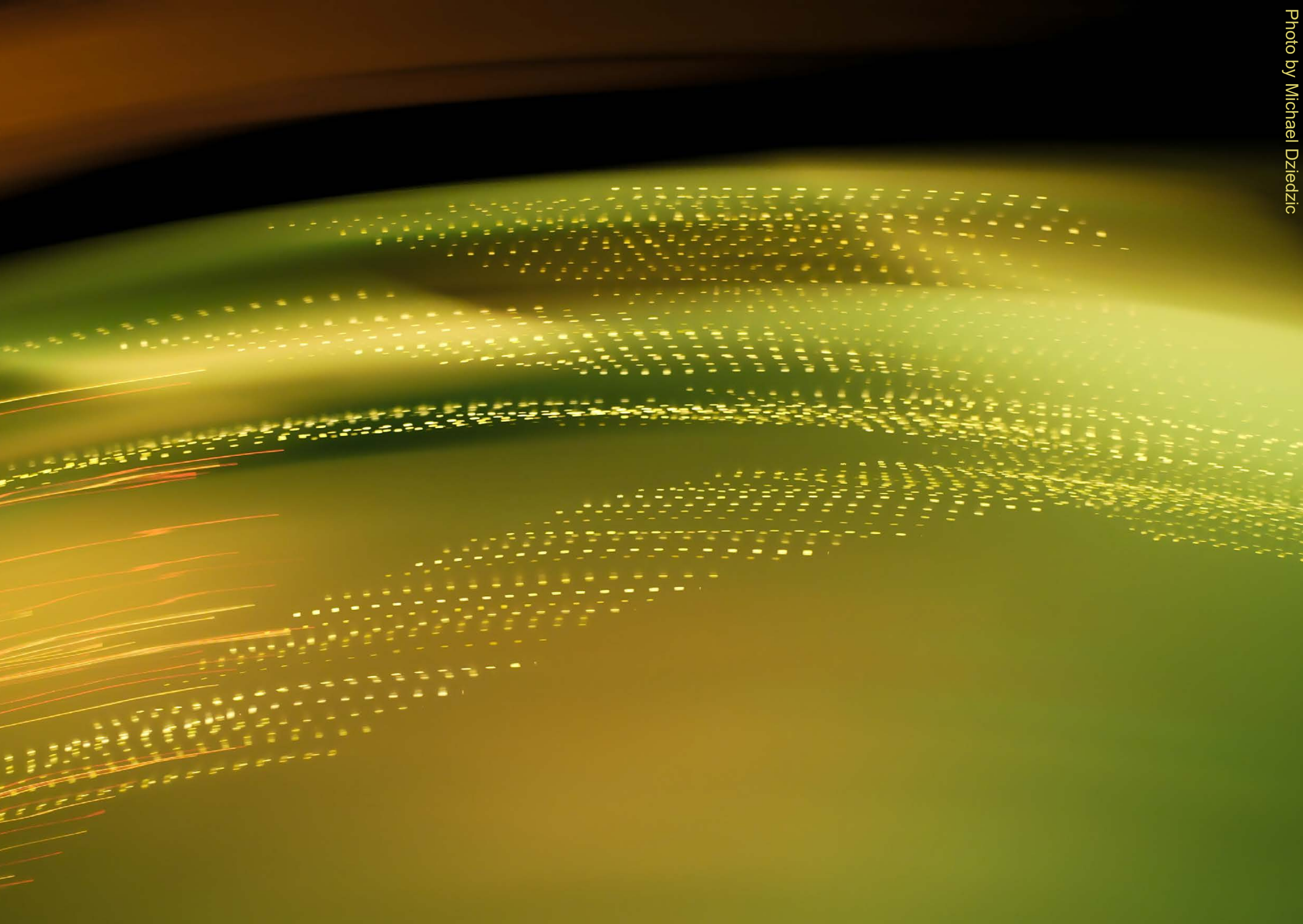

Photo by Michael Dziedzic

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Operation Experience Of Electric Buses In Turku From The Drivers' Perspective

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Generally, as far as the operation of electric city buses is concerned, a different way of thinking from thinking concerning conventional diesel buses must be applied. This means that when new diesel buses are to be purchased, the target is to get suitable vehicles for the purpose intended. But when electric bus operation is in question, the target is not the vehicles alone, but a whole transportation system, including both the vehicles and the recharging infrastructure.

The city of Turku in Southwestern Finland started the procurement process of the first electric buses in 2014. One of the reasons behind the decision to launch electric buses was the city's target to be carbon neutral by 2029. After that year, the target of the city is to be carbon positive, as the first city of this kind in Finland, meaning that there will be a greater amount of carbon dioxide captured than released.

In Turku, a separately funded research project was created around the launching of the e-bus service. The research itself was carried out by Turku University of Applied Sciences (TUAS). The research project aimed to monitor e.g. the energy consumption, reliability and operability of the e-buses, as well as to give the drivers a comprehensive training in safe e-bus operation and economical driving.

Decisions to be made

One of the first decisions needed was the question of whether the e-buses should be used on several or one bus line only. The latter option was chosen. The following question was about which one of the bus lines should be selected for e-buses operation. The selection was directed towards the line ranging from the airport to the harbour through the city centre. This line was selected partly because this line provides visibility of the new bus technology also internationally because both the airport and the harbour connect passengers to foreign countries. The length of the line is almost 13 km. There is about 50 m elevation gain when travelling from the harbour to the airport.

The result of the e-bus tendering process resulted in ordering six 13-meter 2-axle e-buses from a Finnish start-up company named Linkker (Figure 1).

The company Linkker is in favour of opportunity charging, which means several short high-powered charging sessions during the day. The other option to select from was overnight charging with a large enough battery providing sufficient driving range for a

Figure 1. The 13 meter Linkker bus at Turku harbour. Photo by Markku Ikonen.

whole day operation. The consequence of the opportunity charging decision was that two 300 kW fast-charging devices, to be located at each end of the bus line, were included in the purchase agreement.

The main rationale behind the selection of opportunity charging was, like the bus manufacturer expressed it, the fact that the bus is intended to transport passengers, not batteries. With frequent opportunity charging events, the bus needs only a small battery (55 kWh), which is cheaper and more lightweight than a large battery reaching up to the driving range for a whole day. And a lightweight battery results in lower electricity consumption especially in a city line with frequent stops and reaccelerations. The negative sides of opportunity charging are that the charging devices are expensive and the drivers must be able and willing to handle the recharging process of 3-4 minutes up to 20 times per day.

Opportunity charging system utilizes a component called a pantograph, which connects the vehicle to the charging device. Two pantograph types are in use. The most common type is located on the roof of the bus (Fig. 2). For a charging session, this pantograph type raises and mates with a V-shaped receptacle on a pole located above the bus. The other type is called the inverted pantograph (Fig. 3) because the moving parts are located in the charging pole and the pantograph moves downwards and connects the receptacles to fixed rails attached on the bus roof. In Turku, the latter type was selected. Because the buses stay outdoors at the depot, not having even a canopy or a cover above them, snow and ice could hinder the operation of the moving parts, if the "normal" type of pantograph were selected.

Driver training

The driver training, directed to almost 100 drivers, was implemented to a group of about 10 drivers at a time. There were two training days, about one year apart from each other provided for each driver. The first training day concentrated on the operation of the e-bus itself, including safety-related matters and also on the recharging procedure. The second day, about a year later, concentrated on

Figure 2. Pantograph located on the bus. Photo by Markku Ikonen.

Figure 3. Inverted pantograph without cover. Photo by Markku Ikonen.

economical driving aiming at minimizing the electricity consumption of the e-buses in everyday operation.

The second training day started with theoretical considerations in a classroom type of environment. The afternoon was dedicated to actual driving along the actual bus line route so that every 10 drivers in the group drove with the help of a trainer. The fellow-drivers were observing the driving and a second trainer catalyzed conversation and made the observers pay attention to essential things regarding each driver's driving style.

One thing that could have been organized better is the training of new drivers employed later by the bus operator company. There was no systematic procedure to train the new drivers, so they had to start working with most likely a less comprehensive training than the drivers that were employed at the time of the beginning of the e-bus operation.

Drivers' attitudes towards the electric bus

It was perceived that the drivers had very different attitudes towards electric buses. Some of them were very interested and motivated, whereas some others were quite reluctant to take part in the training sessions. There was originally a plan to train only the motivated drivers and let only them drive electric buses. However, because of the difficulties related to the work shift planning, this plan was later buried and all drivers were decided to get the training and start driving also e-buses.

Some hesitating drivers became more interested and motivated after hearing about the environmental benefits of e-buses. Some became more motivated after driving and experiencing personally the low noise and vibration levels of the e-bus. On the other hand, some drivers were enthusiastic to criticize even the smallest details of the bus, which was a new product for the manufacturing company and was under practical terms still under product development phase.

The motivation of the drivers was pursued to be enhanced by informing them about their privileged position having the possibility to give constructive feedback to the manufacturer to improve the product properties and operability. Some drivers felt that this is a unique situation to influence the development process of a vehicle. They gave appropriate comments about factors that should be developed. The research personnel of TUAS forwarded the messages to the bus manufacturer.

However, due to limited human resources in the company, the manufacturer was not capable of responding to the complaints and wishes of the drivers in an appropriate time-frame. The drivers started feeling that the feedback given does not lead to improvements that they wished. This of course turned the attitude and emotions of many drivers to frustration. As a consequence of this, many of them stopped giving feedback.

Also, the problems related to charging increased the stress level of many drivers. Especially in the beginning, the amount of charging problems was quite high. The positioning of the bus beneath the pantograph turned out to be very critical. Having the bus in an incorrect position possibly prevented the charging process. This problem occurred easily especially in winter when the road surface under the charging pole was bumpy and it was more difficult than in summer to stop the bus at an exact position.

Another type of a charging problem encountered was the process being halted without an apparent reason before the state of charge had reached the desired level. The maybe most severe charging problem experienced has been the pantograph remaining in the down position after the end of charging while the system did not prevent the drive-off of the vehicle as designed. This caused property damage.
The opinions from many drivers indicate that they would feel more relaxed if there were no need to recharge the bus during the working day. Thus, the preference of those drivers would be an e-bus equipped with a large battery that needs overnight recharging only.

Dashboard – the driver's interface to the vehicle

The dashboard instrument cluster is one of the most important driver's interfaces to the vehicle. In the e-bus type used in Turku, it is digital with no mechanical parts. The design represents traditional styling with no attempt to differ from conventional instrumentation. The cluster consists of two traditional-looking main gauges, one displaying driving speed and the other indicating the power level either from the battery to the driving wheels or the opposite direction (regenerative braking). The latter shows zero at times when there is no electricity flow.

There are also quite large-sized number displays in the centres of both of the main gauges. The one on the left indicates the driving speed in addition to the gauge

Figure 4. Dashboard instrument cluster of the Linkker electric bus.
Photo by Markku Ikonen.

needle, while the other on the right presents the estimated driving range before the need to recharge. With smaller-sized gauges, also motor and battery temperatures are indicated, as well as air pressure levels of the braking systems and the air suspension. The display also shows the momentary electricity consumption and the average consumption value (Fig. 4).

The state of charge of the battery is displayed with a needle gauge and as a numeric percentage value. Additionally, there is also a display looking like a traditional fuel gauge, which it is. This gauge indicates the diesel fuel level in the tank used to power the diesel-burning interior heater, which is needed at subzero temperatures in addition to the heat pump.

The top speed of the vehicle is restricted to 80 km/h. This can be seen from the speedometer, which has been programmed to show higher speeds than this in a dull colour.

The instrument cluster informs the driver about the well-being of the vehicle as well as about the driving situation at hand, thus playing a significant role in the user interface and when considering man-machine interaction. The styling selected for this vehicle appears to be clear and easy to interpret, which is always a benefit from the driver's perspective. The appearance represents the traditional style that does not differ remarkably from the instrumentation of diesel buses. This seems to have been preferable for the drivers since no complaints regarding the dashboard have arisen.

Conclusions

The drivers appear to appreciate an electric bus that has driving properties close to conventional diesel buses. Low levels of noise and vibrations are respected. Recharging should be as easy and hassle-free as possible. Also, interior heating and cooling, especially in the driver's compartment, should function as well and as reliably as in diesel buses.WW