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Cost and Safety Aspects of Using Electric and Hybrid Vehicles in Local Food Supply Chain

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Abstract
Integrating electric vehicles in a supply chain and distribution is a viable option when special conditions such as short distance road distribution and environmental considerations as well as small amounts of goods enabling delivery with delivery vans are met. In this paper, possibility of investment in electric vehicles for distribution of local food will be examined and analysed. Safety concerns in electric vehicles will also be addressed and accident consequences and vehicle safety will be analysed and compared with conventional vehicles that use internal combustion engines.

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1. Introduction

In the Republic of Slovenia, charging electric vehicles (EV) and hybrid plug-in electric vehicles (PHEV) on most of the public charging stations, as well as stations owned by Petrol, largest Slovene energy company, was free of charge (Petrol – Elektromobilnost paketi, 2018). For a supply chain and logistics partakers this could be a business opportunity and a possibility to reduce the costs of transport. At the same time, while non-conventional vehicles are entering the market, there is a possibility, as it is with any new technology, that gives rise to significant risk-related concerns and hazards that mass adoption of EVs brings. An example of a local business and its routes have to be examined and modeled for non-conventional vehicle usage for business' distribution to the existing clientele (Lisec, 2018).

The existing distribution routes will be considered and the most appropriate vehicle type (internal combustion engine, two different vehicles with electric engine and plug-in hybrid vehicle) that is most cost efficient will be identified.

Time efficiency will also be calculated for the use of alternative fueled vehicles in local food distribution as well as time delays that occur when refilling conventional internal combustion engines (Renault Kangoo 2018) and delays that occur when charging the EV on charging stations (vehicles Renault Kangoo Z.E 2018 and Nissan e-NV200 2018). When simulating distribution path with PHEV (Mistubishi Outlander PHEV 2018) authors considered that the vehicles uses internal combustion engine after batteries are depleted. After all the business indices are calculated, the study will focus on EV, PHEV safety in comparison to conventional vehicles.

2. Methods

For local food delivery a producer of apple juice and other apple products was chosen from city of Sevnica, whose data were anonymized. The producer has local clients to whom goods are distributed daily, as well as in bigger cities of Slovenia where the distribution takes place once per week. Based on these daily and weekly routes, calculations are made whether an investment in electric or hybrid vehicle is viable, analysing costs, environmental, safety and time factors.

Google maps will be used to calculate both long and short distribution path. Daily distribution (Figure 1) route begins in Sevnica and continues to Krško, Senovo, Brestanica, Blanca, Radeče, Zidani Most, Šentjanž and Planina pri Sevnici. Weekly distribution route also begins in Sevnica and continues to cities of Ljubljana, Maribor and Novo mesto.

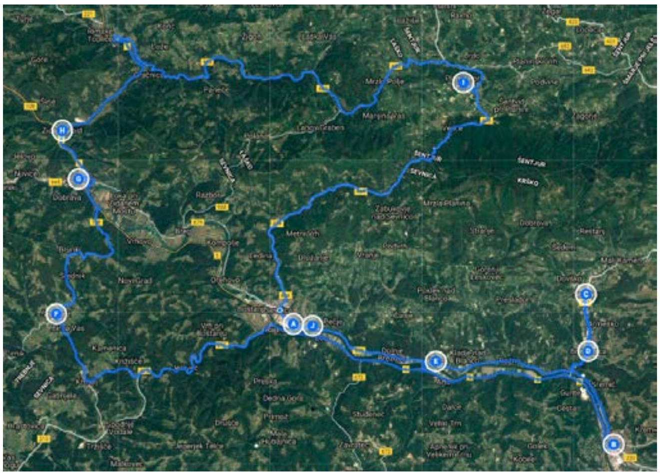

Fig. 1. Daily distribution route

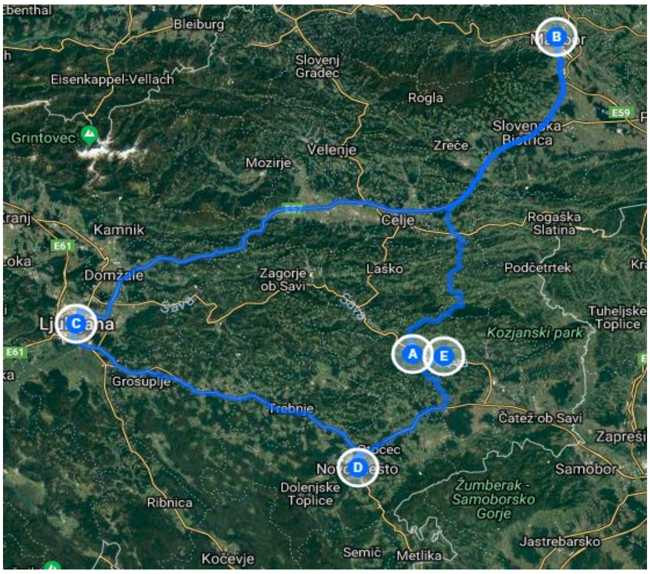

Fig. 2. Weekly distribution route

For distribution route cost analysis is made where all four vehicles are studied and compared, and actual costs of transportation are taken into consideration. If the range of non-conventional vehicles was not sufficient for the planned route, charging on charging stations will be added to the distribution route. Environmental analysis will show the environmental impact on selected routes – where driven distance are taken into account and correlated with energy product (gas or electricity). With time analysis increased use of time is considered for non-conventional vehicles because there are limitations during distribution for actual charging.

3. Cost analysis

Two web applications, Chargemap and gremonaelektriko.si, data show that there are nearly 320 charging stations in Slovenia (Fig. 3), 27 of which are fast charging stations placed on so the called Slovenian highway cross (Electricity Distribution System Operator d.o.o. – SODO, Hitre polnilnice, b.d.), where SODO installed them within European project »Central European Green Corridors (CEGC)«. Fast charging stations are crucial from logistics' point of view, because standard charging is not time efficient and is not appropriate for logistic activities where time constant is essential (Green Transportation, EV DC Fast Charging Standards, 2018).

Table 1 shows monthly costs of conventional vehicles, two EVs and plug-in hybrid EV. It has been taken under consideration that a daily path is done four times a week (16 paths per month) and a weekly one is done once per week (4 paths per month). Technical documentation of EV distributor reveals that during daily paths, none of the EVs needs to be charged during the distribution itself, whilst there is a need to charge both EVs during the weekly, longer path. Figure 3 shows charging stations that are compliant with both vehicles while Figure 4 presents fast charging stations on a highway cross of Slovenia. For the calculations, fast charging stations for Nissan e-NV200 will be used while in standard charging stations for Renault Kangoo Z.E. as fast charging stations are not compatible with this model. Data on web application gremonaelektriko.si shows that charging the vehicles on standard charging stations is free of charge, while usage of fast charging stations was not free of charge and there are several options to choose from: one can sign an agreement with Petrol d.d., which gives a possibility to choose between their predefined packages, or one could use the SODO prepaid card, which enables the users to use the fast charging stations for 5.00 € for every 30 minutes used.

Fig. 3. Electric vehicles charging stations in Slovenia (Source: Renault.si)

Considering the technical documentation of vehicles, the following engine power has been assumed: 44 kW for EV Renault Kangoo Z. E., 40 kW for EV Nissan e-NV, 55 kW (dCi 75 E6) for a conventional vehicle - Renault Kangoo, and for plug-in hybrid EV Mitsubishi Outlander PHEV 70 kW, main battery power of 13.8 kW/h, auxiliary batter power of 70 kW/h and internal combustion engine power of 99 kW. Calculations for PHEV vehicles were made on the basis of technical documentation and with the help of a web application Mitsubishi Fuel Calculator.

When calculating costs for EVs the following have been taken into consideration: home charging (before and after the vehicle departs for its distribution), where the price was calculated on average electricity price for the year 2017; and average current (ET). In instances when home charging did not suffice fast charging and standard charging on charging stations on distribution path were taken into account.

Table 1. Cost analysis of different distribution vehicles

	Conventional vehicle Renault Kangoo	**Electric vehicle Renault Kangoo Z.E.**	**Electric vehicle Nissan e-NV200**	**Plug-in hybrid electric vehicle Mitsubishi Outlander PHEV**
Route	Total costs (€)	Total costs (€)	Total costs (€)	Total costs (€)
Daily route (Sevnica, Krško, Senovo, Brestanica, Blanca, Šentjanž, Radeče, Zidani Most, Planina pri Sevnici, Sevnica)	118.53€	53.21	48.45	106.90
Weekly route (Sevnica, Maribor, Ljubljana, Novo mesto, Sevnica)	98.39	25.65	24.25	88.74
TOTAL	**216.92**	**78.86**	**72.70**	**195.64**

Technical documentation for a conventional vehicle (Renault Kangoo), which has an internal combustion engine with an average use of 4.3 l/100 km (combined driving), has been used. The Ministry of Economic Development and Technology (MGRT) states that retail price of diesel fuel is 1.364 € per litre, as for 31.10.2018 (MGRT, Cene naftnih derivatov, 2018).

As Table 1 shows, costs of EVs are significantly lower, and Nissan e-NV200 is the most cost-efficient. In comparison to conventional vehicles, the fuel cost is lower by 134.06 € and 116.78 € when compared to a plug-in hybrid EV. It is assumed that cost difference would be higher if there is more plug-in hybrid EVs on the market, and not only SUVs which have a higher consumption of their internal combustion engine.

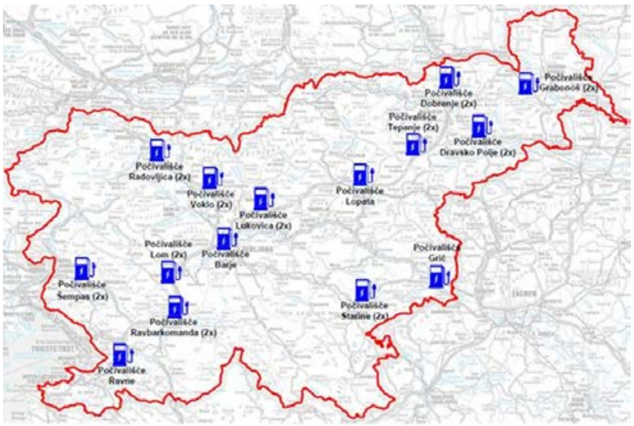

Fig. 4. Fast charging stations on Slovenian highway cross (Source: sodo.si)

4. Safety aspect of electric vehicles in comparison to conventional vehicles

Modern vehicles with internal combustion engine have considerably developed since the beginning of their production. With that know-how and modern tools such as FMEA (Failure Mode and Effects Analysis) it can predicted very accurately what failure could occur in the final product (vehicle) and in the manufacturing process – but to do that efficiently products and process have to mature, so that experience could be improved. Plug-in hybrid EVs and EVs are becoming more and more popular (Denning, 2018). A modern business owner should not only consider costs, but also safety aspects in adopting new technology.

EVs and plug-in hybrid EVs are, on average, 10% heavier than conventional vehicles. This means that in some type of crashes there is a slight safety advantage, for example, than in the case of those involving other vehicles (O'Malley, 2015).

There are, however, different aspects which concern both vehicle types (Kjosevski, 2017). For example, there is electrical safety which can be categorized as follows:

- safety of the electrical system,
- safety of systems function,
- safety while charging batteries,
- maintenance and operation of the vehicle, as well as training (Van den Bossch, 1994).

New methods of testing and developing EVs are still in pending, which means that full data to make a clear conclusion are not available yet. It can be admitted that under some circumstances, electric and hybrid vehicles are safer and under other, conventional vehicles are safer.

5. Summary and conclusion

While searching for the right hybrid delivery vehicle, it has been discovered that there are no such vehicles available in Slovenia, and there are no personal vehicles with trunk size large enough to function as delivery vehicles in distribution. While searching for plug-in hybrid EV, it was found that there were none, but there was a personal vehicle large enough to be used for distribution (Mitsubishi Outlander PHEV).

Time analysis has shown that the use of EV Renault Kangoo Z.E. is not efficient because of long charging time which is 4:05h to 80% full charge. EV Nissan e-NV200 has used 5h more on weekly route than its conventional counterpart, which is a compromise between distribution costs and time efficiency. With shorter route there are no time differences because both vehicles' range is long enough to do distribution without charging. Companies should, therefore, be careful with choosing the right vehicle for their distribution paths.

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在当地食品供应链中使用电动和混合动力汽车的成本和安全方面

關鍵詞

电动车
食品供应
路线规划
替代燃料汽车

摘要

当满足特殊条件（例如短距离道路分配和环境因素）以及满足使用搬运车交付的少量货物的要求时，将电动汽车整合到供应链和分销中是一种可行的选择。

在本文中，将研究和分析在电动汽车上投资用于分配当地食品的可能性。

电动汽车的安全问题也将得到解决，事故后果和汽车安全性将得到分析，并与使用内燃机的传统汽车进行比较。