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The Evaluation of Opportunities for the Development of Access for Charging Electric Vehicles in the Territory of Apartment Buildings

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Abstract. The beginning of 21th century is extremely important for developed countries because of the reduction of their dependence on fossil fuels. The biggest vehicle manufacturing companies are planning to start selling at least one model of electric vehicle and it is expected that by 2025 approximately 10% of the new cars sold worldwide will be electric. In order to reach this goal, some countries are successfully executing an effective electric transport development policy: to create a publicly accessible network for charging electric vehicles, pay incentives for purchasing an electric car, create free of charge parking places and implement other encouraging measures. While analysing world trends it has been noted that the majority of electric cars owners live in private houses. This is due to the fact that people who are living in apartment buildings and planning on purchasing an electric car come across multiple issues when it comes to charging the car at their living area at night. Therefore, the aim of this article is to evaluate the opportunities of developing access points for charging electric cars around the territory of apartment buildings. To achieve this we have raised these main objectives: have the EU member states already foreseen the necessary measures ensuring comfortable charging of electric cars in the territory of apartment buildings?; have the plans for the development of charging facilities in the territory of apartment buildings already been prepared?; which new technologies will be used for the safe charging of electric cars?

Keywords: electric vehicle, charging, territory of apartment buildings.

Conference topic: Sustainable urban development.

Introduction

Although nowadays electric cars in Lithuania are not widely used, in other member states of the European Union (EU) they are becoming more and more popular. In order to increase the desire among the population to use electric transport, an easily accessible infrastructure for electric vehicle charging must be developed. Lithuania, as a member of the EU, is contributing to a long term sustainable development strategy. According to measure 04.5.1-TID-V-515 "Creation of electric car charging networks" of the 4th priority "Encouragement of energy efficiency and production and usage of renewable resource energy" from the European Union Investment Fund's Action Program 2014–2020, in Lithuania it is foreseen to create a publicly accessible charging network in the roads of national significance, the largest Lithuanian cities and resorts. In accordance with this measure, charging networks of high and regular power are estimated to be funded with about three million euro. The foreseen intensity of the funding – the costs of project that is suitable for funding cannot exceed 85%. We can conclude that although in Lithuania it is presumed that funding for the development of electric car charging facilities will be achieved, it is unlikely that the goal which was indicated in the White paper (that, in 2025 about 10% of the new cars sold in the world will be electric) will be accomplished.

The Ministry of Transport and Communications of the Republic of Lithuania commissioned the feasibility study called "Feasibility Analysis of Electric Vehicle Charging Systems in Lithuania". They also commissioned a survey of Lithuanian public and business institutions which was aimed at identifying the needs of modern car users and evaluating how electric cars could match those needs. The results showed that more than half of responders would like to have the opportunity to use electric cars for work but the main obstacles preventing them from doing so are their high price and the underdeveloped infrastructure of the electric vehicle charging access points.

Member states of the EU, for example, in order to increase the use of electric cars are using integrated incentives for electric cars, which include subsidies, tax concessions, free parking in the city centre, etc. Also, many member states of the EU have introduced relevant automobile taxes, the concessions of which, for electric cars, become an effective incentive. For instance, in Norway, because of the high automobile tax and the tax concession for electric cars the costs to own and maintain an electric car are lower than those of an internal combustion engine-powered car (Johansen 2015). That is why the spread of electric cars in Norway is fast and it is one of the leading countries in Europe in terms of relative number of electric cars (Figenbaum, Kolbenstvedt 2013).

Electric cars in Lithuania would become important, but not only for the implementation of long-term EU goals. The greatest benefit of the spread of electric cars would be achieving the goal set in the White paper on Transport: to completely eliminate fossil-fueled cars in urban transport by 2050. In order to achieve this goal, an increase is needed in the use of alternative fuel-powered vehicles in the territory of apartment buildings (Tanaka *et al.* 2014.). Thus, this article will try to solve these main questions: which incentives are used in Lithuania; have the plans for the development of charging facilities in the territory of apartment buildings already been prepared; and in which territories of apartment buildings will we charge electric vehicles and which new technologies will be used for their safe charging? (EC 2011).

Incentive measures for electric vehicle usage in Lithuania

In Lithuania we can distinguish between two types of incentives to use electric cars that should be sorted into "soft" and "hard" measures. At the moment, the main encouragement to use electric cars in Lithuania is the "soft" measure, which is applied to municipal level. For example, on January 19th 2013 a permission was set in the Road Rules that allows electric car users to use lane A which is reserved for public transport; free parking for electric cars in the city centre and towns; and other road signs and markings that appear on the roads and are set in the Road Rules, signing that road signs do not apply for electric cars.

We can make an assumption that "soft" encouragement measures are not effective. This assumption can be supported using the data collected by SOE Regitra, which shows that in 2016 there were only 337 registered electric cars and 3560 hybrid cars (Fig. 1). The most popular electric cars in Lithuania are Nissan Leaf – 165 pc., BMW i3 – 43 pc., and Tesla model S – 28 pc. The most popular among hybrid cars are Toyota – 2150 pc., Lexus – 1039 pc. and Honda – 216 pc. The first serial production electric car in Lithuania was the Nissan Leaf registered in 2011.

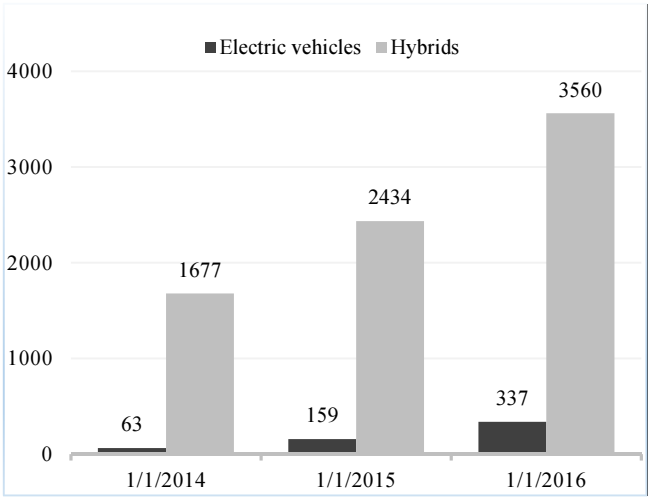

Fig. 1. Electric vehicles and hybrid cars in Lithuania (2014–2016)

In order to continue encouraging the use of electric cars in Lithuania the Ministry of Transport and Communications of the Republic of Lithuania together with the Lithuanian Road Administration under the Ministry of Transport and Communications has prepared a project for a "hard" encouragement measure, which foresees EU funding for charging access points of high and regular power for electric cars on the highways and cities (places that have more than 25 000 residents or a resort status) of the country that amounts to about 3 million euros.

At the moment on highway A1 there are two high-power charging access points in place. Also, at the end of 2016 the Lithuanian Road Administration under the Ministry of Transport and „Lemminkainen Lietuva" signed a contract to build 10 electric car charging access points. The charging points will be built on the rest areas of highways A1 Vilnius–Kaunas–Klaipėda and A2 Vilnius–Panevėžys. The construction works have already been started and it is estimated that they will be finished by Q2-3 of 2017. Also, according to the project it is foreseen that from 2017 to 2022 more than 150 charging points for electric cars of high and regular power will be built in the cities and resorts of the country and more than 30 charging points of high power on the highways. Based on the Estonian practice, it is intended to install charging points every 40–50 km.

Guidelines to install charging points for electric cars in the territories of apartment buildings

In order to accomplish the goals raised in the White paper, the infrastructure for electric vehicle charging must be developed in two stages. With the first stage in the territories of new apartment buildings and with the second one in the territories of soviet-built apartment buildings (see Palevičius 2014).

Territories of new apartment buildings. When building new apartment houses and installing at least 10 car parking lots or an underground and (or) an above-ground garage it is recommended to install a charging point for electric cars in every tenth parking space. However, by installing the charging points it is important to fulfil the provisions of Directives 2014/94/ES "On the installation of alternative fuel infrastructure of October 22nd 2014 given by the European Parliament and Council. It says that there can only be two types of charging points for electric vehicles: of high power which is higher than 22kW and regular power when the electric power is not higher than 22 kW, except electric devices of power not higher than 3.7 kW that are installed in private households or whose primary purpose is not to charge electric cars and which are not publicly accessible (Bai, Lukic 2013). In accordance with the provisions of the directive, the most rational solution is to install charging points of regular power in the new apartment buildings with no commercial activity, whose charging time would reach up to 8–12 hours (Fig. 2) and they would cost not more than 1000 euro (Liu *et al.* 2013).

Fig. 2. Electric vehicles charging station (charging time 8–12 hours)

It is recommended to install public charging points of regular power (Fig. 3) in the new apartment buildings with no commercial activity and that have more than 10 parking spaces, which would be meant for working drivers of electric cars and whose charging time would reach up to 8 hours and their value would be not more than 5 000 euro (Madina *et al.* 2016). It is also recommended to install these charging points as close to the entrance of these buildings as possible.

Fig. 3. Electric vehicles charging station (charging time about 8 hours)

During the major renovation of old apartment buildings, preparatory works for cable laying should be carried out in every tenth parking space. After the major renovation the charging points for electric cars should be installed.

The target result is that by 2022 the overall number of public charging points in the middle areas of Lithuania's 5 major cities, would be not less than 250.

Territories of old apartment buildings. Because of the historical circumstances which resulted with the present arrangement of different types of buildings, the number of car parking spaces that belong to the territories of old apartment buildings may vary from 0.2 to 0.6 for one apartment (Palevičius *et al*. 2016). Also, in such areas the parking lots are chaotically located, therefore they should be rearranged and that requires some big investments. That is why while planning the charging points in these territories, it is firstly recommended to implement the development in parking lots of shopping malls and (or) in a public land which is next to a parking lot (where it is recommended to install the public access points as close to the entrances of apartment buildings as possible). In the parking lot of shopping malls, we recommend to install charging points of high and regular power in every tenth parking space. Charging points of high power will be meant for the clients of the shopping mall (Fig. 4) and charging points of regular power will be meant for the residents of old apartment buildings (Fig. 3).

Fig. 4. Electric vehicles charging station (charging time about 20–30 min.)

The clients of shopping malls and the residents of apartment buildings should be enabled to pay for the charging services electronically (a mobile app, payment card, SMS etc.). Also, the operator of the charging point (shopping malls) can offer some extra methods of payment for the service (i.e., cash, etc.). The prices set by the shopping malls (operators) should be reasonable, easily and clearly comparable, transparent and non-discriminatory (Liu *et al.* 2016). The target goal is to achieve that by 2030 the distance between separate public charging points in the central areas of the city would reach 300–500 metres.

Determination of the weight criteria by Kendall method

A criteria list was created prior to carrying out an expert survey. The above list is made by way of expertise, i.e. a group, consisting of 3 persons formed by the authors hereof, after consulting with the community have selected 5 key criteria (Table 1), which later should be subject to attribution of certain weights. 5 criteria for expert evaluation (Yazdani *et al.* 2016).

Table 1. Criteria list and description

Item No.	Installation Territory (Area)	Description
Q1	Shopping mall parking lots.	Parking lots in the territories of apartment buildings as an incentive measure of development of electric vehicle charging access infrastructures, enabling successful electric car charging for residents thereof, could become underestimated. The owners of major shopping malls agree to allow installing the electric vehicle charging access points, however, it is likely, that some economic disagreements may arise. It is important to point out that shopping malls are densely located in residential districts, and their trading area in Kaunas, Klaipėda and Šiauliai – 1,1 thous. sq. m per 1 thous. inhabitants, Vilnius – 946 sq. m per 1 thous. inhabitants, and in Panevėžys – 620 sq. m. per 1 thous. inhabitants.
Q2	Underground parking of apartment buildings	A draft of amended Directive 2010/31/EU of the European Parliament and of the Council on the Energy Performance of Buildings provides that, since 2025, the re-cabling works for electric vehicle charging should be arranged in new apartment buildings with over ten vehicle parking spaces or those subject to major renovation. It seems complicated to attribute an electric car charging access point to technical systems of a building from technical aspect as this is not much linked to direct use of a building. It would also lead to uncertainty in evaluation of building energy consumption.
Q3	Ground parking of apartment buildings	Re-layout of land parcels as well as re-cabling works should be required in order to install electric vehicle charging access at parking lots of old apartment buildings. A land parcel next to old apartment building is usually owned by the state, therefore, the installation of public access points for electric vehicle charging would not be a problem, however, a land parcel next to new apartment building is usually owned by apartment owner, this means the installation of public access points for electric vehicle charging could be complicated from legal aspect.
Q4	Facade system of apartment buildings	Legislation regulating any installation of access points of regular power for electric vehicle charging in building facade system does not exist in Lithuania. Furthermore, Technical Regulations for Construction and special land terms and conditions provide that minimum distance from open-type vehicle parking lots to dwelling house windows must be at least 10 meters.

End of Table 1

Item No.	Installation Territory (Area)	Description
Q5	Lighting pole structure	Currently the experts of electric car charging access points suggest installing the electric car charging access in lighting pole structures, however such charging would require specific equipment. It is not difficult to install the electric car charging access in a lighting pole structure, however the use of such equipment has to be legalized and electric car owner has to be enabled for electric car charging by concluding an agreement with electricity supplier and electric vehicle access operator. This equipment suggested by the experts is not protected against thefts either.

One of the simplest methods applicable – Kendall Method (Kendall 1970). Ranking is done pursuant to the criteria list, i.e. when the highest rank is given by an expert to the most important criterion, i.e. place or score equal to one. The second most important criterion is given a rank equal to two, the third one – three and etc. The last rank receives the lowest value of ranking. This method is logical and easily applicable in practical calculations (Jakimavičius *et al.* 2016).

Kendall concordance coefficient (Kendall 1970) is linked with the sum of rank of each factor R_j and with regard to respondents or experts:

$$R_j = \sum_{i=1}^{n} R_{ij}. \quad (j = 1, 2, ..., m). \tag{1}$$

The mean rank of each factor $\overline{R}$ is obtained dividing the sum of ranks assigned thereto by number of factors:

$$\overline{R} = \frac{\sum_{j=1}^{m} R_j}{m}, \tag{2}$$

where: R_{ij} – rank given by expert *i* to factor *j*, *n* – number of experts (*i* = 1, 2, ..., *n*) *m* – number of factors (j = 1, 2, ..., *m*).

The difference between sum $\sum_{i=1}^{n} R_{ij}$ of ranks R_{ij} and constant quantity $\frac{1}{2}n(m+1)$ is calculated for each criterion:

$$\sum_{i=1}^{n} R_{ij} - \frac{n(m+1)}{2}. \tag{3}$$

The square of the difference between ranks' sum $\sum_{i=1}^{n} R_{ij}$ and constant quantity $\frac{n(m+1)}{2}$ is calculated:

$$\left[\sum_{i=1}^{n} R_{ij} - \frac{1}{2}n(m+1)\right]^2. \tag{4}$$

Upon calculation as per formulas (1)–(4), the next step is to calculate the concordance coefficient W:

$$W = \frac{12S}{n^2(m^3 - m)}. \tag{5}$$

Significance of concordance coefficient and compatibility of expert evaluation of factor groups is determined by χ^2:

$$\chi^2 = \frac{12S}{nm(m+1)}. \tag{6}$$

Min value of the concordance coefficient $W_{\min}$ is calculated from formula (7):

$$W_{\min} = \frac{\chi^2_{v,\alpha}}{n(m-1)}, \tag{7}$$

where: $\chi^2_{v,\alpha}$ – Pearson critical statistics, which value is found in the table (Montgomery 2008), taking the degree of freedom $v = m - 1$ and significance level α.

The outcome from 8 expert surveys was that the access points for electric vehicle charging should be firstly installed at shopping mall parking lots (0.260), second place – in lighting pole structures (0.233), third place – at apartment building ground parking lots (0.227), other criteria weights of development of access for charging electric vehicles in the territory of apartment buildings are provided in Figure 5.

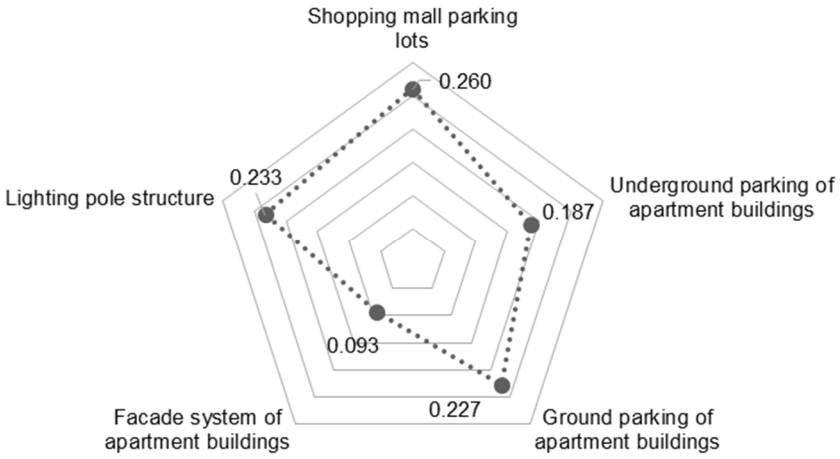

Fig. 5. Determined criteria weights

In order to reach 10% of electric vehicles registered in Lithuania out of all annual new car sales in year 2025, the development of access points for electric vehicle charging in territories of apartment buildings should be carried out following the established criteria. Pursuant to estimated criteria weights, the installation of electric vehicle charging points in territories of apartment buildings is recommended to be performed in three stages (Fig. 6):

Fig. 6. Development of electric vehicle charging points (2017–2025)

First Stage (year 2017) – expanding the public access points for electric vehicle charging at shopping mall parking lots. It is recommended to install the public access points for electric vehicle charging as close to the main entrance of shopping center as possible and arrange at a distance not exceeding 300 meters from the entrance to residential building.

Second Stage (year 2020) – expanding the public access points for electric vehicle charging in lighting pole structures that must be located at a distance not exceeding 300 meters from the entrance to residential building.

Third Stage (year 2025) – expanding the public access points for electric vehicle charging in ground parking of apartment buildings, which contain at least 10 parking lots. This development stage should ensure the electric vehicle charging points to be arranged at every 10 parking lots.

Conclusions

EU funding for development of network infrastructure for electric vehicle charging in towns with more than 25 thous. inhabitants is anticipated in Lithuania. In order to contribute to the objective - 10% of new cars sales in the world to be electric in year 2025 – set in the White Paper, the electric vehicle access development strategy and layout plans must be elaborated in Lithuania.

In Lithuania we can distinguish between two types of incentives to use electric cars that should be sorted into "soft" and "hard" measures. At the moment, the main encouragement to use electric cars in Lithuania is the "soft" measure, therefore "hard" measure incentive system such as development of access points for electric vehicle charging is necessary. It is likely that denser network of electric car charging access points would inspire the use of electric cars.

After the expert surveying and evaluation of weights of electrical vehicle access points in territories of apartment buildings it has been determined the most attractive territories (areas) for development of access points for electric vehicle charging to be in: shopping mall parking lot (0.260), lighting pole structure (0.233) and apartment building parking lot (0.227).

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