DEVELOPMENT OF CHARGING INFRASTRUCTURE WITH REGARD TO DIFFERENCES OF REGIONS IN ENVIRONMENT OF SLOVAKIA

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Abstract. Nowadays, electric cars are becoming more and more popular in personal transport as well. One of the reasons is, in particular, that the electric car does not create any local emissions and is still considered one of the alternatives for the future in passenger transport. Also, there are often state incentives for the purchase of electric cars in the form of contributions or tax reductions. However, the charging infrastructure itself is an integral part of electromobility. Low coverage rates can be a barrier when customers decide to switch to electric cars and plug-in hybrids. Special representation, which is the supporting part of the cell and requires increased attention, represents the building and development of the charging infrastructure. From the point of view of current standards in real deployment, the contact conductive charging technology is applied. Ensuring compatibility should be a key characteristic of the infrastructure with as many car brands as possible and building a sufficient network of charging stations. Current issues at the international and national level, from the point of view of the infrastructure in question, are directed towards the use, current number and sufficient number of charging stations. The article focuses on the national level and analyzes the development of charging infrastructure in the environment of the Slovak Republic. Attention is mainly paid to high-power public recharges and recharging points. The article compares the coverage of the charging infrastructure in selected regions, while it was determined how the coverage is affected by regional differences from the point of view of their development. Finding answers to key questions is also possible using input indicators such as the number of inhabitants, area and maturity of the region. In addition, the state of the standardized solution is determined, as well as building an interoperable charging infrastructure.

Keywords: alternative fuels, European Union, GDP, electric cars, charging infrastructure.

Introduction

One of the key prerequisites for the transition to alternative fuels is the construction of a sufficient charging infrastructure for electric vehicles. Building the charging infrastructure does not require any special intervention in the road infrastructure. Despite this, the development of this infrastructure across Europe is two-speed. According to a report by the European Court of Auditors, approximately 70 percent of charging points for electric vehicles are built in countries such as the Netherlands, France and Germany. Countries in the eastern and southern parts of Europe lag behind [1; 2].

In the framework of electromobility, the Slovak Republic has built several support mechanisms, the aim of which is to overcome obstacles preventing successful implementation of electromobility in practice. In the strategic documentation, in the section – opportunity for economic growth, the development of electromobility is documented by a SWOT analysis. Among the weaknesses is the lack of infrastructure for charging electric vehicles. Thus, we come to a problem where the use of electric vehicles can be restrictive, unless the charging infrastructure is sufficiently built.

At the same time, a lower rate may arise when expanding these vehicles. Another important fact is the level of construction in individual parts of Slovakia with regard to various indicators, such as population density, area and GDP. Therefore, managers should take into account all these indicators and think about the risks associated with underestimating possible alternatives [3; 4]. The aim of the article is to assess regional disparities from the point of view of economic factors and their impact on the construction of the charging infrastructure in the region.

Materials and methods

Slovakia has eight regions. In order to find how the maturity of a given region affects it, it is necessary that individual regions be compared on the basis of certain indicators. The following Table 1 shows the individual indicators in the given regions (NUTS 3). These data are from 2021, when the population census was carried out in Slovakia and GDP data were available.

DOI: 10.22616/ERDev.2023.22.TF093

Table 1

Selected indicators in individual regions in Slovakia [5; 6]

Region (Nuts 3)	Indicator			
	Area (Square meter)	Population density (Person per square kilometer)	Status of permanent resident population (Person)	Regional gross domestic product at current prices (million €)
Bratislava	2 052 617 826	351.56	721 625.50	27963.150
Trnava	4 146 298 964	136.42	565 652.00	10976.482
Trencin	4 501 804 613	127.86	575 581.50	8811.549
Nitra	6 343 730 676	106.52	675 723.50	10052.046
Žilina	6 808 447 154	101.43	690 569.00	10997.650
Banská Bystrica	9 453 999 352	65.93	623 293.50	8694.033
Prešov	8 972 685 089	90.08	808 294.00	8985.499
Kosice	6 754 324 613	115.67	781 252.00	12042.572

It can be seen from Table 1 that the highest population density is in the Bratislava region and also the largest regional gross domestic product in current prices. This may be due to the fact that the main city of Slovakia is located in the given region. It is interesting that this region is the smallest in terms of area of all the ones compared.

In order to be able to compare the regions in a relevant way, it is necessary to recalculate the individual points to% from the point of view of Slovakia as a whole. Subsequently, it is possible to examine the correlation between individual indicators. The correlation coefficient is measured on a scale that varies < -1, 1 > , if the correlation coefficient is “0”, it means that there is no correlation between variables. If it is equal to 1, the variables are directly interdependent, an increase in one variable causes an increase in another. If it is equal to -1, an increase of one variable leads to a decrease in another variable. Table 2 shows interpretation of the values of the correlation coefficient.

Table 2

Interpretation of values of correlation coefficient [7]

Interpretation	Value of correlation coefficient
Very high correlation	0.90 to 1.00 (-1.00 to -0.90)
High correlation	0.70 to 0.90 (-0.90 to -0.70)
Moderate correlation	0.50 to 0.70 (-0.70 to -0.50)
Low correlation	0.30 to 0.50 (-0.50 to -0.30)
Little if any correlation	0.00 to 0.30 (-0.30 to 0.00)

$$Correl(X,Y) = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}} \quad (1)$$

Results and discussion

According to the current data of the Slovak Electric Vehicle Association (SEVA), at the beginning of 2023, 1,483 public charging points were available in a total of 629 locations in Slovakia. Year-on-year, the number of public charging points increased by 45% and the number of locations by 46%. There were 1,483 charging points in Slovakia as of January 15, 2023. There are 1,053 charging points from the category of normal charging points with a power of 22 kW (alternating current - AC) and 334 charging points with a power of 50 kW for direct current (DC). The remaining 96 are ultra-fast DC chargers with an output of 150 to 350 kW (DC). Charging locations are distributed throughout Slovakia. In terms of infrastructure coverage, the Bratislava region stands out somewhat (22% of all locations), which is natural, since the highest number of electric cars are also registered there. It is followed by Prešov and Kosice self-governing regions (both 14%), Nitra and Trenčin regions (both 11%), Žilina and Banska Bystrica (both 10%). The smallest share of charging locations is in the Trnava self-governing region (9%) [8]. Table 3 shows the individual indicators expressed in percentage terms. The input data are from 2021, with the exception of charging locations, whose status was at the end of 2022. We examined charging locations that were affected by indicators from the previous period.

Table 3

Selected indicators in individual regions in Slovakia converted to percentages [5; 6; 9]

Region (Nuts 3)	Charging locations in%	GDP in%	State of the number of electric cars (BEV + PHEV) in%	Area in%	Population in%
Bratislava	22	28.5	43.7	4.2	13.3
Trnava	9	11.1	8.7	8.5	10.4
Trencin	11	8.9	7.3	9.2	10.6
Nitra	11	10.2	9.6	12.9	12.4
Žilina	10	11.2	8.9	13.9	12.7
Banská Bystrica	10	8.8	6.7	19.2	11.5
Prešov	14	9.1	6.7	18.3	14.9
Kosice	14	12.2	8.4	13.8	14.4

The results of the regions in Table 3 are recalculated as percentages expressing the share from the whole of Slovakia. When focusing on charging stations, there are the most of them in the Bratislava region. The same region also has the highest GDP and number of registered electric cars. The fewest charging locations are in the Žilina and Banská Bystrica regions. The Banská Bystrica region has the lowest GDP and number of electric cars. For a better illustration, we displayed the individual data graphically in Figure 1.

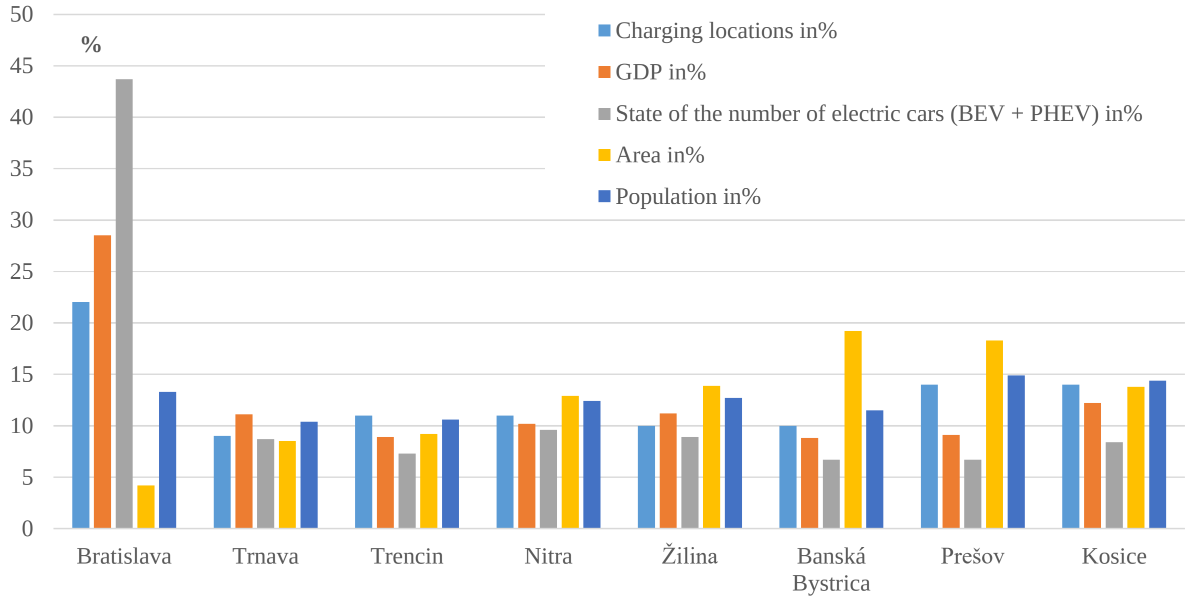

Fig. 1. **Sample length by day**

Figure 1 shows how charging locations copy GDP and the state of the number of electric cars. When focusing on area and population, the dependence is no longer obvious. In order to determine the degree of correlation, we compared individual indicators with charging locations.

When $x \in$ Charging locations, $y \in$ GDP and $\bar{x}$, $\bar{y}$ are string values AVERAGE x and y

$$Correl(X,Y) = 0.89. \quad (2)$$

When $x \in$ Charging locationsy $\in$ State of the number of electric cars (BEV + PHEV) and $\bar{x}$, $\bar{y}$ are string values AVERAGE x and y

$$Correl(X,Y) = 0.89.. \quad (3)$$

When $x \in$ Charging locations $y \in$ Area and $\bar{x}$, $\bar{y}$ are string values AVERAGE x and y

$$Correl(X,Y) = -0.47. \tag{4}$$

When x $\in$ Charging locations $y \in$ Residents and $\bar{x}$, $\bar{y}$ are string values AVERAGE x and y

$$Correl(X,Y) = 0.54. \tag{5}$$

As part of the comparison with charging locations, a high correlation was found with GDP and also with the status of the number of electric cars. The correlation was 0.89 and was only 0.1 point short of very high correlation. Based on this, it can be pointed out that the development of electrical infrastructure reflected the economic maturity of the regions. When focusing on the area, a low correlation came out, and when focusing on the population, the result was a moderate correlation.

In Slovakia, there is an important document, "Draft of the National Policy Framework for the Development of the Alternative Fuels Market", following the Art. 3 of the Directive 2014/94/EU of the European Parliament and of the Council on the introduction of infrastructure for alternative fuels. The aim of this document is to determine the measures for the development of the market of alternative fuels in the field of transport and the development of the relevant infrastructure with a focus on the aforementioned fuels [10; 11].

At the end of the previous year, the Ministry of Economy submitted the Action Plan for the Development of Electromobility in the Slovak Republic (2022) to the interdepartmental comment procedure. It follows from the action plan from 2019. Within the charging infrastructure, ultra-fast charging points (UFC) play a very important role, which offer the greatest power and thus the fastest charging of electric cars. They are especially important for transit movements on highways and expressways, while the current comprehensive coverage of the UFC infrastructure is lacking. Therefore, one of the action plans is to build such a network - the goal is to increase the number of ultra-fast chargers on highways and expressways in the TEN-T (Trans-European Transport Network) network in the number of at least 228 charging points. As it follows from the evaluation of the interdepartmental comment procedure, the Ministry of Economy considers Bratislava and Žilina urban hubs to be suitable locations for pilot projects. In the third place is the area between Prešov and Košice. Also important are DC charging stations, which have their application and importance especially in places that are close to ventilated roads or main roads. In more populated and less frequented places AC stations are fully sufficient. As part of the financial measures for building the charging infrastructure, the construction of at least 2,600 publicly accessible AC points, 500 publicly accessible DC points and 2,000 non-public wallboxes is therefore planned [12].

In 2035, according to the approved legislation, the sale of ordinary vehicles with a combustion engine will end in the entire European Union, and only completely emission-free vehicles will be sold. Several present concerns are considering the transition to a fully electric portfolio in the European Union already around 2030. That is why it is necessary to pay attention to building the charging infrastructure [8].

Conclusions

The future is represented by vehicles with an alternative drive. The documents, plans, strategies express active and systematic support for the expansion of these vehicles, including the construction of an appropriate infrastructure. Prerequisites are being created in every direction for a sudden and significant acceleration of the expansion of these vehicles. The construction of the infrastructure currently depends on the number of vehicles within the region as well as its maturity. As part of the contribution, we discovered a problem with the fact that the construction does not reflect the area of the region itself and the number of inhabitants living in it. Underestimating these two indicators worsens the availability of the charging infrastructure in less developed regions. This may also result in a lower willingness of residents to switch to electric cars. As part of the draft strategy for the development of electromobility in the Slovak Republic and its impact on the national economy of the Slovak Republic, space is being created for drawing of various grants and contributions for construction of the infrastructure. Also, in the Slovak environment, there are often challenges aimed at less developed regions. As part of these challenges, attention should be paid to construction of a charging infrastructure, which will make it possible to improve accessibility throughout Slovakia and will motivate purchasing of electric cars.

Acknowledgements

This publication was realized with support of Operational Program Integrated Infrastructure 2014 - 2020 of the project: Innovative Solutions for Propulsion, Power and Safety Components of Transport Vehicles, code ITMS 313011V334, co-financed by the European Regional Development Fund.

EUROPEAN UNION
European Regional Development Fund
OP Integrated Infrastructure 2014 – 2020

MINISTRY
OF TRANSPORT
AND CONSTRUCTION
OF THE SLOVAK REPUBLIC

Author contributions:

Conceptualization, J.K.; methodology, J.K., M.B.; software, J.K.; validation J.K., M.B.; formal analysis, J.K., M.B.; investigation, J.K., M.B.; data curation, J.K. and M.B. writing – original draft preparation, J.K. and M.B.; writing – review and editing, J.K., M.B.; visualization, J.K.; project administration, J.K; funding acquisition J.K., M.B. All authors have read and agreed to the published version of the manuscript.

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