Features of Using the Existing Regional Charging Infrastructure in the Transition To Environmental Transport

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Abstract. In modern cities, the high level of air pollution from road transport leads to the need to develop and operate new types of environmentally friendly vehicles. Currently, one of these is electric transport. The fleet of electric vehicles is growing rapidly. It necessitates the development of an appropriate charging infrastructure. However, the features of the location of the Russian Federation, which are predominantly low temperatures and variable climatic conditions, necessitate studying the existing charging infrastructure and developing new approaches to calculating the number and location of its facilities. The article presents an analysis of previously performed studies in the field of calculating the size and location of charging stations and a comparative assessment of the operating features of the existing regional charging infrastructure in the Russian Federation. The factors affecting the number of charging sessions were identified. The plan of further research is presented, aimed at calculating the number and location of charging stations in the regions of the Russian Federation.

1. Introduction

Modern cities are characterized by high levels of air pollution, due to the high content of carbon (more than 75%), solid fine particles and carbon dioxide. According to United Nations data, more than 70% of the urban population breathes air that does not meet the standards for maximum permissible concentrations of substances. Reducing this indicator is one of the goals of the developed international programs aimed at creating sustainable cities (having a safe, comfortable and environmentally friendly urban environment).

The ecological development directions are the use of renewable energy sources, transition to zero-emissions transport and the creation of energy-efficient homes. Reducing emissions of harmful substances from road transport is also one of the priority objectives of the transport strategy for the development of the Russian Federation until 2030 and the strategy for the development of the automotive industry until 2025. This is due to an increase in the level of motorization of the population, which over the past 10 years amounted to more than 13% and led to the formation of one of the main sources of urban pollution - road transport. Currently, 60 - 70% of gas pollution is formed as a result of emissions of harmful substances from road transport [1].

As a result, reducing emissions of harmful substances from vehicles and the transition to environmentally friendly technologies is one of the main scientific and practical tasks considered in the automotive industry. In this case, one of the world's priority areas is the transition to the operation of electric vehicles. The fleet of registered electric vehicles in the world over the past 5 years has increased more than 4 times and on September 1, 2019 their number exceeded 5 million units. However, the share of sales of these vehicles depends on the introduction of various tools to stimulate their purchase, in particular on the introduction of subsidizing programs, tax incentives, and the availability of charging infrastructure.

In the Russian Federation, the fleet of electric vehicles is in its infancy (as of July 1, 2019, the number of electric vehicles exceeded 4600 units), and demand stimulation tools are only just beginning to develop. Thus, the creation of a charging infrastructure is considered as the main condition for the transition to the operation of electric vehicles in accordance with the development strategy of the
automotive industry. This is also provided for in the action plan for the implementation of this strategy, which indicates the need to develop proposals for the formation of a program to equip the road and city infrastructure with complexes of charging stations for vehicles with electric motors. Until now, methods have been developed in the world for the rational arrangement of charging stations. In the Russian Federation, the use of these methods leads to the formation of a developed infrastructure with a large number of charging stations and their low profitability, which is due to the smaller number of electric vehicles, the presence of personal charging stations and the peculiarity of public charging stations in the winter. As a result, the aim of the research is to study the operating features of the existing regional charging infrastructure to identify patterns of influence of various factors on the number of charging sessions and to calculate the number of charging stations in the city network to meet the demand that is formed when using electric vehicles in variable climatic conditions characteristic of the territory Russian Federation.

The second section of this article presents an analysis of previously performed studies in the field of location and determination of the size of charging stations in various cities of the world, as well as the sequence of analysis of the existing regional charging infrastructure in the Russian Federation. The third section presents the results of the study. Further development of the study is presented in the fourth section.

2. Methodology
Currently, problems related to the location of charging stations and the calculation of their size are being actively studied in the field of transition to environmentally friendly vehicles [2-8]. The definition of these indicators, as a rule, is based on the theory of queuing systems, which are considered as the correspondence of the flow of requirements and the intensity of their service. At the same time, the minimization of the waiting time and the maximization of the productivity of charging stations can be specified as the objective function, as presented in the research of Qin H and Zhang W [9]. To achieve this objective function, various scenarios were simulated and a distributed scheme that will allow the distribution of charging stations and reservation of stations for minimum waiting time was proposed. However, minimization of the cost of its creation is also considered as an objective function when we study the location and size calculation of fast charging stations. At the same time, Sadeghi-Barzani P, Rajabi-Ghahnavieh A and Kezami-Karegar H also take into account energy losses by electric vehicles to approach the charging station, the costs of installing electrical poles and substations [10]. To solve the problem, the authors developed a genetic algorithm and proposed an index to assess the loss of charging cost, which was then used to evaluate various infrastructure development policies.

A model for the location and size estimation of fast charging stations and battery replacement stations was proposed by Zheng Yu, Dong Zh, Xu Ya and so on [11]. It was used for a comparative analysis of the effectiveness of the implementation of these infrastructure facilities serving public transport - taxis. As a result, a modified differential evolution algorithm and the LCC criterion were used for evaluation, which made it possible to identify the rationality of introducing battery replacement stations in public transport.

Optimization of the charging infrastructure for electric vehicles was also performed by Asadov D G. In this study, the author considers the network of charging stations as a queuing system, the effectiveness of which is evaluated as a result of identifying the correspondence between the number of incoming applications and the intensity of their processing. As an objective function, he offers minimization of total costs, which include both operational and capital components. To achieve the objective function, the author studies the features of the operation of mobile power units used in agriculture, on the basis of which he develops a methodology for calculating the number of charging stations required for their maintenance.

Minimization of operating and capital costs was also considered by Long J, Zenchun H, Yonghua S and Zhouwei L [12]. They proposed a method for optimizing the location and size of charging stations for electric vehicles based on an analysis of data on charging needs and the structure of the road network using simulation methods and graph theory. The developed method was tested using Stockholm data. As a result, the authors proposed to arrange several charging stations in large road junctions, which minimize the time and energy costs for recharging vehicles.

An analysis of data on the behavior of electric vehicle users and the demand for charging stations was carried out by Morrissey P, Weldon P and Mahony M [13]. In the course of this study, it was
revealed: the number of charging sessions per day performed by fast and slow charging stations; the duration of the charging session when using fast and slow charging stations; power consumption by electric vehicles. The authors also established the probability of refueling an electric car at a fast or slow charging station and compared this value with the probability of refueling a traditional car with fuel at a gas station at different times of the day. The results of this study are aimed at developing a network of charging stations in Ireland, taking into account the specific needs and characteristics of the behavior of electric vehicle market participants in the country considered.

Thus, in the course of this research, it is necessary to analyze the existing features of the behavior and use of charging stations in various regions of the Russian Federation to further develop an algorithm for calculating the number of charging stations and their location in urban areas in order to minimize operating costs for the owner of electric vehicles and capital costs for creating infrastructure.

To conduct the study, data were collected using the PlugShare service, as well as the energy company, which is the owner of charging stations in the city of Tyumen, PJSC “SUENKO”. The initial data is the number of connections per day, the number of infrastructure users, the time of the charging session, and the amount of energy consumed per charging session. Initially, random errors were removed from the data provided using the Rocher criterion. Then, according to the data obtained, the dynamics of changes in indicators for various regions was identified and distribution functions were constructed.

3. Results and Discussion

Currently, in the Russian Federation, the largest number of charging stations is located in Moscow and St. Petersburg, as shown in figure 1. The most developed regional charging infrastructure is located in Tyumen and Vladivostok. The creation of a charging station network contributes to an increase in the number of electric vehicles charged from public charging stations, which is shown in figure 2. However, the introduction of a payment for the charging session also has a significant impact on the number of vehicles served. So, on September 1, 2019, a private network of 7 public charging stations “EZS RusHydro” was organized in Vladivostok. The price of charging session is 11 rubles / kWh. In Tyumen, the network of public charging stations, which is organized by PJSC “SUENKO” and JSC “Tyumenenergo”, is free as of September 1, 2019. As a result, a comparative analysis of the data on the list of charged electric vehicles from public charging stations in Tyumen and in Vladivostok showed that the introduction of a payment for the charging session leads to a significant decrease of parameter presented in figure 2. Thus, the share of electric vehicles charged from charging stations in Tyumen is more than 70%, and in Vladivostok - less than 2%.

![Figure 1. The number of charging stations used for electric vehicles in the regions of the Russian Federation.](image1)

![Figure 2. Listed number of electric vehicles charged from public charging stations in September 2019 in the regions of the Russian Federation.](image2)

An increase in the number of electric vehicles and the number of charging stations leads to an increase in the number of charging sessions performed during the month, which is shown in figures 3-6. Figures 3 and 4 show the dynamics of changes in the number of charging sessions in cities located in the temperate cold climate of the Russian Federation.
Figure 3. Dynamics of changes in the number of charging sessions during the month in Tyumen from 10/01/2018 to 09/30/2019.

Figure 4. Dynamics of changes in the number of charging sessions during the month in St. Petersburg from 10/01/2018 to 09/30/2019.

Figure 5. The dynamics of changes in the number of charging sessions during the month in Moscow from 10/01/2018 to 09/30/2019.

Figure 6. Dynamics of changes in the number of charging sessions during the month in Krasnodar from 10/01/2018 to 09/30/2019.

With a general trend aimed at increasing the number of charging sessions, a decline is observed in the winter. Previously, the authors established the dependence of the change in the number of charging sessions on the ambient temperature in Tyumen [14]. Currently, the hypothesis is supported by data from a comparative analysis of the charging infrastructure operation in various regions. So, when analyzing the data on the number of charging sessions performed in cities located in temperate and warm-temperate climate with mild winters, the authors did not reveal a decrease in the studied indicator in the winter, which is shown in figures 5, 6.

The decrease in the number of charging sessions depending on the operating conditions of electric vehicles and charging stations is also presented using the calculated indicator - the number of charging sessions of one electric vehicle per month, which is shown in figures 7, 8.
Figure 7. The dynamics of changes in the number of charging sessions of an electric vehicle during per month in Tyumen from 10/01/2018 to 09/30/2019.

Figure 8. The dynamics of changes in the number of charging sessions of one electric car during per month in Moscow from 10/01/2018 to 09/30/2019.

The presence of low temperatures leads to a decrease in the number of charging sessions by 40 - 47%. At the same time, an analysis of the data presented in figures 7, 8 also revealed an increase in the number of charging sessions performed by one electric vehicle during the month when it is operated in large cities, where the average annual mileage of vehicles is greater. Accordingly, an increase in the need for a charging session and an increase in the number of electric vehicles in comparison with a small city causes an increase in the number of charging sessions performed per day, which is represented by the distribution functions of the daily number of charging sessions (figure 9, 10).

As a result of processing data on the number of performed charging sessions per day, normal distribution functions were constructed. It was revealed that the mathematical expectation for a small city with 69 rechargeable electric vehicles per month, the number of charging sessions is 8 units. At the same time, in a large city, where more than 80 electric vehicles are charged per month, this indicator is 12 units. However, to further evaluate the effect of the average annual mileage on the number of charge sessions performed, a correlation analysis must be performed. At present, as factors influencing the number of charging sessions, the ambient temperature and the number of electric vehicles in use have been identified, which is confirmed by the data of correlation and regression analysis presented in studies previously performed by the authors.

4. Conclusion
One of the main conditions for the transition to environmentally friendly transport is the creation of a developed charging infrastructure. In the analysis of previously completed work, the need was identified to study the features of using the existing charging infrastructure in the regions of the Russian Federation.
As a result of this study, the hypothesis about the effect of low ambient temperatures characteristic of a temperate climate on the number of charging sessions is confirmed. It was found that lowering the ambient temperature leads to a decrease in the number of charging sessions by 40-47%. At the same time, the analysis also confirmed the hypothesis about the influence of the number of operated electric vehicles on the number of charging sessions and the assumption was made about the influence of the average annual mileage of vehicles on the considered output indicator. In the course of further studies, a correlation and regression analysis will be carried out to assess the tightness of the connection between the average annual mileage of vehicles and the number of charging sessions.

The results of the study will be used to build a simulation model for calculating the rational number of charging stations in the regions of the Russian Federation, taking into account the variable operating conditions of electric vehicles.

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