Evaluation of user experience in the operation of electric vehicles in the Arctic regions

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Abstract. The availability of electric vehicle (EV) technology for users in various regions of the planet has increased significantly in recent years due to the reduction of their cost and the development of service infrastructure. Electric vehicles have traditionally focused on operation in temperate and warm climates, but gradually they are also beginning to be used in the northern and Arctic regions of the planet with a cold climate. One of the main keys to the success of electric vehicle technology in the northern and Arctic regions is an understanding of the user experience (UE) that arises in drivers when using EVs in the special climatic conditions of such regions. This article presents the results of an experimental assessment of UE users of battery electric vehicles in the northern and Arctic regions on the example of one of the largest Arctic regions of the planet – the Republic of Sakha (Yakutia).

1 Introduction

The growth in the number of electric vehicles (EVs) is an important factor in improving environmental and economic sustainability for the Arctic regions of the planet where, due to the existing complex logistics, the supply of petroleum products for cars with a traditional power plant is often carried out only in the summer months by river or sea transport with special Arctic delivery, which leads to an increase in the cost of petroleum products and the risks of supply disruptions.

Modern transport uses the most modern and sophisticated technologies and systems [1-25], in promoting such new EV technologies to new markets, including the Arctic regions of the planet with their special climatic conditions, an important factor is the analysis of the user experience (UE) arising from the user's contact with similar technologies [26-56], including EV technology.

According to [38], most people are reluctant to invest in new battery EV technology until it becomes more popular. "A sufficiently large number of innovators or early adopters should serve as proof to the rest of the population that the technology is suitable for everyday use" [38]. The study [39] focuses on the impact of the first user experience in a test drive on the

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overall acceptance of battery EV technology and the decision to purchase an electric vehicle. Various aspects of UE of battery EV users have been discussed in [40]. Overall, approaches to evaluating various aspects of UEs of a wider range of emerging technologies and applications have received considerable attention in [43, 51].

This article presents the results of a study by UE of battery electric car users in the Arctic regions. The results are shown on the example of one of the Arctic regions - the Republic of Sakha (Yakutia) (Sakha, 2022).

The Republic of Sakha (Yakutia) is located in the northern hemisphere relative to the equator, between 55° and 75° north latitude - the length from north to south is 2000 km. The length from west to east is 2300 km. Over 40% of the territory is located beyond the Arctic Circle, over 80% - north of 60° north latitude, here is the cold pole of the Northern Hemisphere of the planet. The average temperature in winter is -30...-55 °C.

Current trends in the spread of EV technology in the Republic of Sakha (Yakutia) are shown in Figure 1 (according to data from the main trading platform for the sale of cars for the region (Car Sales Database, 2022).

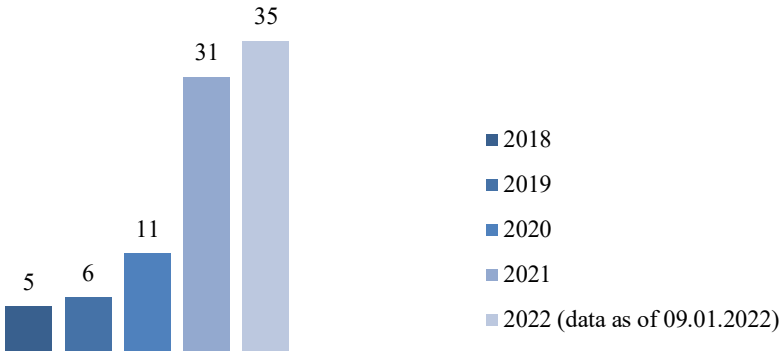

Fig. 1. Number of EVs sold in the region.

2 Materials and Methods

This section provides an overview of the electric cars involved in the experiment and the methodology used to analyze the UE of EV users.

Five models of battery-electric cars were selected, from three manufacturers Toyota Nissan and Honda (Table 1), since according to the analysis of the data presented at the main trading platform for the sale of cars in the region (Car Sales Database, 2022), these five models are dominates in the market of the region in question. Each of these models represents the current state of UE in terms of the operation of electric vehicles in the Republic of Sakha (Yakutia).

Table 1. Electric cars chosen for the experiment.

Stamp	Model	Percentage among all EVs in the region (%)	Number of EVs selected for the experiment
Toyota	C-HR	31.5	6
Nissan	Leaf	40.8	7
Honda	X-NV MN-V	24.6	6 1

For the study of UE users of electric cars when they are operated in the Arctic regions, an important condition is to clarify the indicators affecting the UEs.

Indicators that affect user experience can be subjective and objective. Subjective (implicit) UE scores are not construed factors (Brooks and Hestnes et al., 2010), including patient emotions, expectations, and experiences. In contrast, objective (explicit) UE scores are controllable and include technical and non-technical aspects of maintenance (Brooks and Hestnes, 2010). For example, network connectivity, physical environment, and service area are technical factors, while the ease of use of the technology, the cost of the service and the context of the service are not technical factors (Zhang and Nirwan, 2011). Consequently, any poor performance on clear indicators will lead to a significant deterioration in UE.

The questionnaire developed by the authors for the experiment (Table 2) displays such aspects of the UE as:

- the cost of operating an electric vehicle;
- the charging speed of the electric vehicle in the region of operation, in conditions of low street temperatures;
- the frequency of failures and malfunctions occurring in low temperatures (including extremely low (-35...-50° C);
- availability of service, including the availability of qualified personnel and spare parts for EV repairs.

Table 2. Contents.

UE Indicators	Question Number	Questions
The cost of operating an electric vehicle	1	I didn't feel any discomfort.
	4	The level of spending was annoying
	8	I was restricted in my movement due to the level of expenses
	9	The level of expenditure was not acceptable
Charging speed of an electric vehicle in the region of operation, in conditions of low street temperatures	2	I was completely satisfied with the charging speed
	12	Charging process was comfortable
	14	Charging speed didn't live up to my expectations
Failure and fault rates occurring under low temperatures (including extremely low temperatures (-35...-50 °C)	3	There were no failures or malfunctions
	7	Failures and malfunctions were more than my expectations
	10	Failures and malfunctions were less than my expectations
Availability of service, including the availability of qualified personnel and spare parts for EV repairs	5	I am completely satisfied with the availability of the service
	6	The level of service can be called sufficient
	11	I didn't use an EV repair service
	13	The level of service is not sufficient

The algorithm for evaluating the UE of EV users consisted of three stages (Figure 2). The stages were specifically designed to create a system for collecting baselines reflecting the UE of EV users in the Arctic regions.

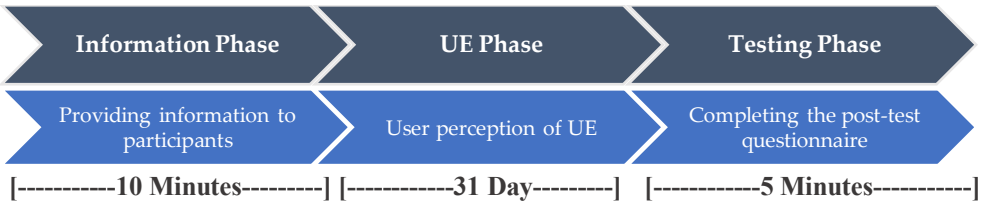

Fig. 2. UE evaluation algorithm.

For the experiment, the period from March 1, 2022 to March 31, 2022 with a range of average daily temperature (-10...-30° C) was chosen. This period was chosen due to the fact that March is the first month of the year when users begin to operate electric vehicles. In the winter months (December-February), EVs are usually stored in a heated garage and are not operated, because the average daily temperatures reach -55° C, in such conditions it is necessary to use the on-board heater turned on in constant mode at full capacity, which leads to accelerated discharge of the battery and the risk of its premature breakdown.

During the period chosen for the experiment, users had to evaluate the UE when operating the EV. The completed questionnaire must be submitted by the participants and the experiment before April 1. The place of the experiment was determined to be the city of Yakutsk, which is the capital of the Republic of Sakha (Yakutia) (Yakutsk, 2022). The coordinates of Yakutsk are 62°01′38" fromnorthern latitude and 129°43′55" eastlongitude. Population - 318768 people. The area of the city is 122 km².

A total of 15 participants were recruited. To avoid the impact of the preliminary impact on user ratings, users with no more than 8 months of experience in owning an electric vehicle were selected, i.e. users who had no previous experience of operating an EV in the winter in the Arctic regions. At the same time, each participant had at least a 3-year period of driving a car with a traditional power plant running on gasoline/diesel fuel.

Participants entered groups corresponding to the brand of their car (Toyota, Nissan and Honda).

None of the participants had previously had experience in operating an EV in the winter season, while seven of them had previously experienced the experience of operating cars with a hybrid power plant in the winter season in the Arctic regions, the rest had experience in operating only cars with a traditional power plant running on gasoline/diesel fuel. By the beginning of the experiment, all participants within the three groups had a sufficient level of familiarity with the features of the operation of the electric vehicle based on at least 30 days of experience in EV control.

3 Results and Discussion

Measuring the level of cost of operating an electric vehicle, user ratings were favorable to the Toyota group. Participants reported that their costs for operating an electric car were more acceptable than when operating a car with a traditional power plant, which allows them to become less limited in their movements.

Estimates of the charging speed of an electric vehicle in the region of operation in conditions of low street temperatures show that a higher level was observed in the Toyota and Honda groups.

The results of the evaluation of the failure rate and malfunctions that occur in EVs during operation at low temperatures showed that the failure rate was acceptable for all groups equally.

4 Conclusions

This article evaluated the UE of battery-electric vehicle users in the Arctic regions.

UE scores were collected using a questionnaire developed by the authors.

Overall, the user ratings obtained show that the Nissan and Toyota groups have a higher UE score when operating EVs in arctic winter conditions. A slight decrease in the UE score for indicators related to EV charging and repair may be due to limitations related to the lack of service infrastructure in the Arctic regions, including charging infrastructure and repair infrastructure. Thus, it is believed that the necessary future development of the service

infrastructure can mitigate some of these shortcomings, thereby bringing the overall quality of service of the Honda Group in line with the Nissan and Toyota groups and the overall increase in the UE rating of EV technology users in the Arctic regions.

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