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METHODOLOGY FOR DETERMINING PARAMETERS OF DESIGN VEHICLE, TAKING INTO ACCOUNT CONDITIONS OF ARCTIC ZONE OF THE RUSSIAN FEDERATION

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Over the past decades, the automotive market has been growing and developing rapidly. Vehicles are constantly modified: their geometric parameters (length, width, height, etc.) and dynamic parameters (power, acceleration speed, etc.) change. For the design and construction of the roadway, as well as subsequent calculations in the field of traffic management (flow saturation, mandatory control, etc.) in accordance with the regulatory documentation, geometric and dynamic parameters of the design vehicle are used, the parameters of which are determined on the basis of Soviet cars of the 80s. As a result of vehicles changes and modifications, it is necessary to update and perform additional calculations to determine the parameters of an improved design - calibrated vehicle. The main purpose of the study is to determine the parameters of the design – calibrated vehicle for performing calculations in the field of construction and traffic management. In the course of the research presented in this article, the analysis of statistical data regarding the best-selling light vehicles, as well as the variability of the geometric parameters of vehicles were determined. Based on all the completed tasks, the result of the work is determination of the design - calibrated vehicle for Arctic zone of the Russian Federation, which will be subsequently used for the design and construction of the roadway and calculations in the field of traffic management.

Keywords: traffic flow, saturation flow, heterogeneity, design vehicle, geometric parameters

1 INTRODUCTION

Arctic zone of the Russian Federation (AZ RF) is the northern territories of the European and Asian parts of the Russian Federation located along the coast of the Arctic Ocean seas. It occupies the largest area of the Russian Federation land part (4,774.02 thousand km2), having the longest maritime border of Russia. The AZ of the Russian Federation includes 9 regions: 4 of them are constituent territories of the Russian Federation: Chukotka Autonomous Region, Yamalo-Nenets Autonomous Region, Nenets Autonomous Region, Murmansk Region and 45 municipal districts of 5 constituent territories of the Russian Federation: The Republic of Karelia, the Komi Republic, Arkhangelsk Region, Krasnoyarsk Territory, the Republic of Sakha (Yakutia).

The transport system of Arctic zone is developing slowly and unevenly. In the western part of the AZ of the Russian Federation, motoring highways connect only large settlements and industrial centers of Murmansk and Arkhangelsk Regions with the center of the European part of the Russian Federation. Distinctive features of RF AZ transport system include the following: relatively low density of land routes or their absence; seasonal nature — in particular, transportation is possible by water transport during the navigation period — from June to September, by road transport during the winter season — from December to March; in some regions, aviation or sea transport is the basis of life support.

Due to its vast territories, each region of Arctic zone of the Russian Federation has its own economic zone, which differs from any other zone by distinctive properties and characteristic features. Transport is the prime factor in maintaining the competitive ability of industrial enterprises of AZ of the Russian Federation, it performs the main social function — ensuring life quality and population mobility of the Russian Federation AZ. The functioning, economic growth and development of the entire region, country including Arctic zone depend on the transport system [1-3]. The basis of the economy of Arctic zone of the Russian Federation is the mining industry, while in separate regions of AZ of the Russian Federation various areas of industry prevail, for example: transport and defense complex in Murmansk Region, forest industry in Arkhangelsk Region, etc. Various types of activities and industries have an impact on the formation of the transport system, which as a result forms a heterogeneity of vehicles types of used in a particular region of the AZ of the Russian Federation.

The purpose of the study is to determine the parameters of a designed – calibrated vehicle for performing calculations in the field of traffic management and design of highway crossings, junctions.

2 METHODOLOGY

When assessing the heterogeneity of the traffic flow in the classical way, cars, trucks and buses are distinguished. On the basis of Article 30 of the Federal Law No. 257 dd. 08.11.2007 "On roads and road activities in the Russian

Federation and on amendments to certain legislative acts of the Russian Federation", as well as the Rules of Road Traffic, trucks traffic along the central streets of cities, as well as entry into the city itself is prohibited. Therefore, passenger and fixed-route vehicles predominate in traffic flows in cities [4, 5].

The analysis of official statistics confirms the heterogeneity of vehicle types and reflects data on the distribution of the main types of vehicles in the traffic flow. The growth in the number of automobile parks in the Russian Federation is increasing every year, and the share of light vehicles in the flow is about 87% of the total number of vehicles (Fig.1).

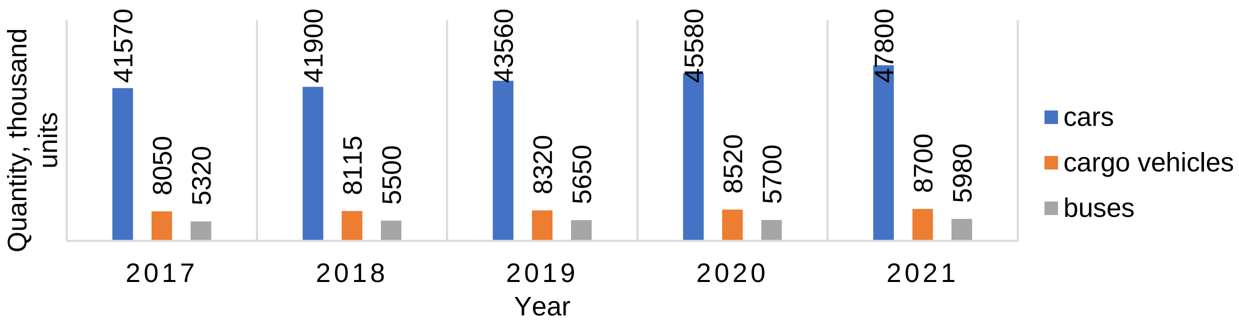

Figure 1: Distribution of the main types of vehicles in the Russian Federation

It is known, that the design and construction of roadway widenings, crossings and junctions, and subsequently, the organization of traffic is impossible without taking into account the geometric data of the design vehicle, which is taken on the basis of the analysis of the traffic flow composition [6-10]. In Russia, for calculation of mandatory control, constant reduction coefficients of the design vehicle are used, developed based on the geometric characteristics of the first domestic cars, such as: Moskvich 407, Microlitre M-21 "Volga", M-20 "Pobeda", ZIL-11. However, every year the level of world and Russian vehicle fleets increases, both technical and geometric parameters of vehicles change, which have a direct impact on design of transport system and traffic management [11, 12]. In this regard, it is necessary to monitor the development and modification of vehicles and periodically update the reduction coefficients of the design vehicle.

Within the framework of this study, the tasks are to perform analysis of statistical data, that includes indicators of the best-selling light vehicles in individual subjects of Arctic zone of the Russian Federation and Russia as a whole. Consideration of how the light vehicle fleet of Arctic zone of the Russian Federation differs from Russia as a whole and determination of the geometric parameters of the design vehicle for AZ of the Russian Federation.

Having conducted a statistical analysis of vehicle brands sold in the Russian Federation (Fig.2) 5 most popular brands were identified. The leader in sales in Russian market are domestic Lada cars, for the period from 2017 to 2021, about 1,738,558 cars were sold. The sales leaders of the foreign automotive industry are: Kia, Hyundai, Renault and Volkswagen.

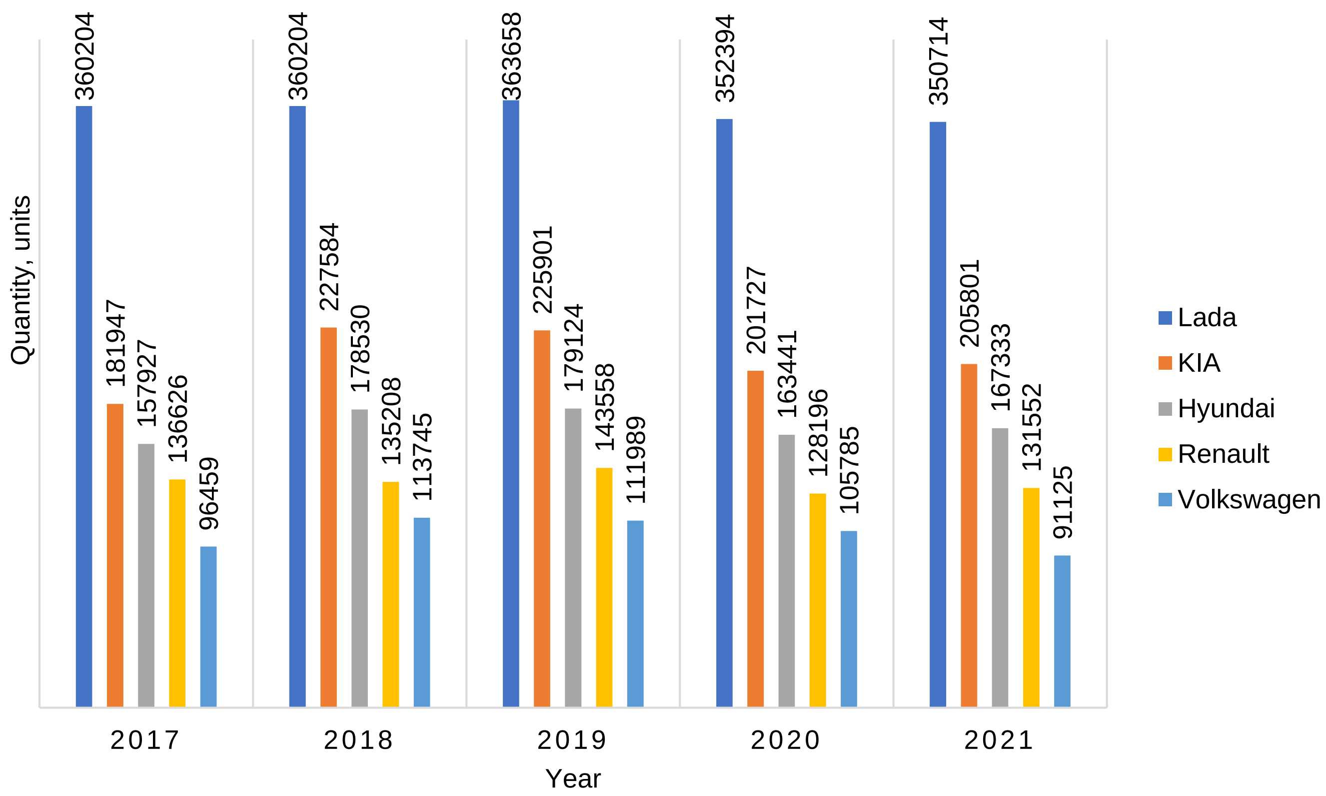

Figure 2: The best-selling vehicle brands in the Russian Federation for the period of 2017-2021

Statistical analysis of the brands of vehicles sold in Arctic zone of the Russian Federation was also carried out (Fig.3).

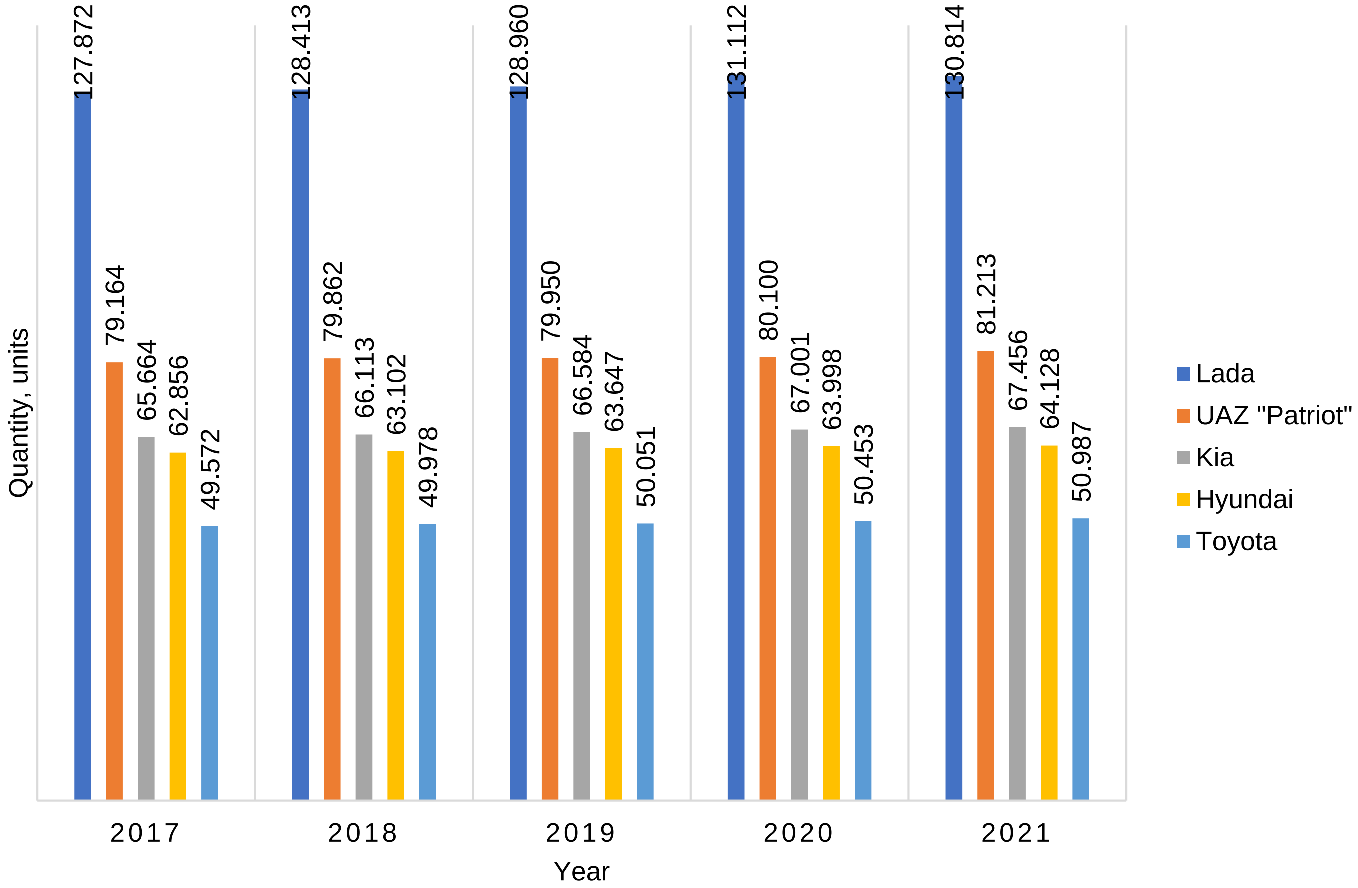

Figure 3: Popular vehicle brands sold in the RF AZ over the past 5 years

The most popular vehicle brands in Arctic zone of the Russian Federation are both domestic and foreign cars (Table 1). For example, in the Arkhangelsk and Murmansk regions, Lada cars are in great demand; in the Nenets Autonomous Region, the Yamalo-Nenets Autonomous Region and the Krasnoyarsk Territory – Hyundai; in the Republic of Komi – Kia; in the Republic of Yakutia – UAZ; in the Chukotka Autonomous Region– Toyota.

Table 1. Sold models of popular vehicle brands in Arctic zone and the Russian Federation

Year	Arctic zone of the Russian Federation		Russian Federation	
	vehicle model	Quantity, units	vehicle model	Quantity, units
2017	Lada Granta	52 360	Lada Granta	94 976
	UAZ "Patriot"	49 715	Kia Rio	96 689
	Kia Rio	48 796	Hyundai Solaris	68 614
	Hyundai Solaris	48 123	Renault Duster	43 828
	Toyota Hilux	38 514	Volkswagen Polo	48 595
2018	Lada Granta	52 980	Lada Vesta	108 364
	UAZ "Patriot"	50 819	Kia Rio	100 148
	Kia Rio	49 215	Hyundai Creta	67 588
	Hyundai Solaris	48 971	Renault Duster	41 409
	Toyota Hilux	38 998	Volkswagen Polo	59 450
2019	Lada Granta	53 120	Lada Granta	137 232
	UAZ "Patriot"	51 400	Kia Rio	92 475
	Kia Rio	50 597	Hyundai Creta	71 487

Year	Arctic zone of the Russian Federation		Russian Federation	
	vehicle model	Quantity, units	vehicle model	Quantity, units
	Hyundai Solaris	49 714	Renault Duster	39 031
	Toyota Hilux	39 800	Volkswagen Polo	56 102
2020	Lada Granta	53 415	Lada Granta	127 781
	UAZ "Patriot"	51 896	Kia Rio	88 064
	Kia Rio	50 900	Hyundai Creta	73 537
	Hyundai Solaris	50 223	Renault Logan	32 628
	Toyota Hilux	40 132	Volkswagen Polo	58 455
2021	Lada Granta	53 879	Lada Granta	99 914
	UAZ "Patriot"	52 050	Kia Rio	70 203
	Kia Rio	51 456	Hyundai Creta	58 487
	Hyundai Solaris	50 897	Renault Duster	32 702
	Toyota Hilux	41 130	Volkswagen Polo	42 455

Having analyzed the best-selling brands of light vehicles in the AZ of the Russian Federation and the Russian Federation over the past five years, their most popular and best-selling models were determined. In Arctic zone, such models of light vehicles of various cross-country capacity as Lada Granta, UAZ Patriot, Kia Rio, Hyundai Solaris and Toyota Hilux are in great demand. As for Russia, the most common are: Lada Granta, Kia Rio, Hyundai Creta, Renault Duster, Volkswagen Polo.

3 EXPERIMENT

Within the framework of this research, the next task is to determine the geometric parameters of the design vehicle for Arctic zone of the Russian Federation. In consequence of the statistical data analysis of sold cars in the AZ of the Russian Federation and Russia, it is possible to determine the difference in the geometric parameters of vehicles, namely, the finding of overall parameters that will be taken into account in the design vehicle when performing transport calculations in the field of traffic management [13, 14].

The geometric parameters of the best-selling light vehicles in the AZ of the Russian Federation and Russia were determined (Table2).

Table 2. Vehicle modification of the best-selling vehicles in Arctic zone and the Russian Federation

№	Модификация транспортного средства	Dimensions					
		Length, mm	Width, mm	Base / distance between axles, mm	Front overhang, mm	Rear overhang, mm	Turning radius, m
	Arctic zone of the Russian Federation						
1	Lada Granta	4268	1700	2476	804	980	5,5
2	UAZ "Patriot"	4750	1900	2760	793	719	5,62
3	Kia Rio	4240	1750	2600	845	795	5,2
4	Hyundai Solaris	4115	1700	2570	820	725	5,2
5	Toyota Hilux	5260	1760	3085	890	1285	6,2
	Russian Federation						
1	Lada Granta	4268	1700	2476	804	980	5,5
2	Kia Rio	4240	1750	2600	845	795	5,2
3	Hyundai Creta	4270	1780	2590	840	840	5,3
4	Renault Duster	4315	1804	2673	822	820	5,5
5	Volkswagen Polo	4483	1706	2602	877	1004	5,4

As a result of a complete analysis of the technical characteristics of light vehicles, the difference in the overall vehicle parameters is clearly visible. The overall dimensions of vehicles in Arctic zone vary in length of the vehicle within 4115 mm - 5260 mm, width of 1700 mm - 1900 mm, and turning radius is 5.2 m — 5.62 m, for the Russian Federation: vehicle length is within 4268 mm - 4483 mm, width of 1700 mm - 1804 mm, and turning radius is 5.2 m — 5.5 m. As we can see, the overall parameters of vehicles operating in Arctic zone differ from the overall parameters of Russia vehicles. Taking into account the existing fluctuations in overall parameters indicators, we will determine the main characteristics of design vehicle for the AZ of the Russian Federation and Russia by finding the arithmetic mean value.

The arithmetic mean is calculated according to the formula:

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \tag{1}$$

where xi - individual values of the variable feature, so-called variants; n - is the number of units of the population.

In consequence of the arithmetic mean calculation, the main values of design cars parameters were obtained (Table 3).

Table 3. Main geometric characteristics of the design vehicle

Design vehicle type	Dimensions					
	Length, mm	Width, mm	Base/distance between axes, mm	Front overhang, mm	Rear overhang, mm	Turning radius, m
Calibrated vehicle for Arctic zone						
Light car	4527	1762	2698	830	901	5,5
Calibrated vehicle for other zones of the Russian Federation						
Light car	4315	1748	2588	838	888	5,4

There is a difference in the readings of the geometric characteristics of desigh vehicles for Arctic zone and Russia, amounting to a deviation of 6%.

4 ANALYSIS

As a result of the research, it is possible to develop an algorithm that allows determining the geometric parameters of the design vehicle for Arctic zone of the Russian Federation, which will be taken into account in the design and construction of roadway widenings, crossings and junctions, as well as subsequent calculations in the field of traffic management and accident examination [15-21] (Fig.4).

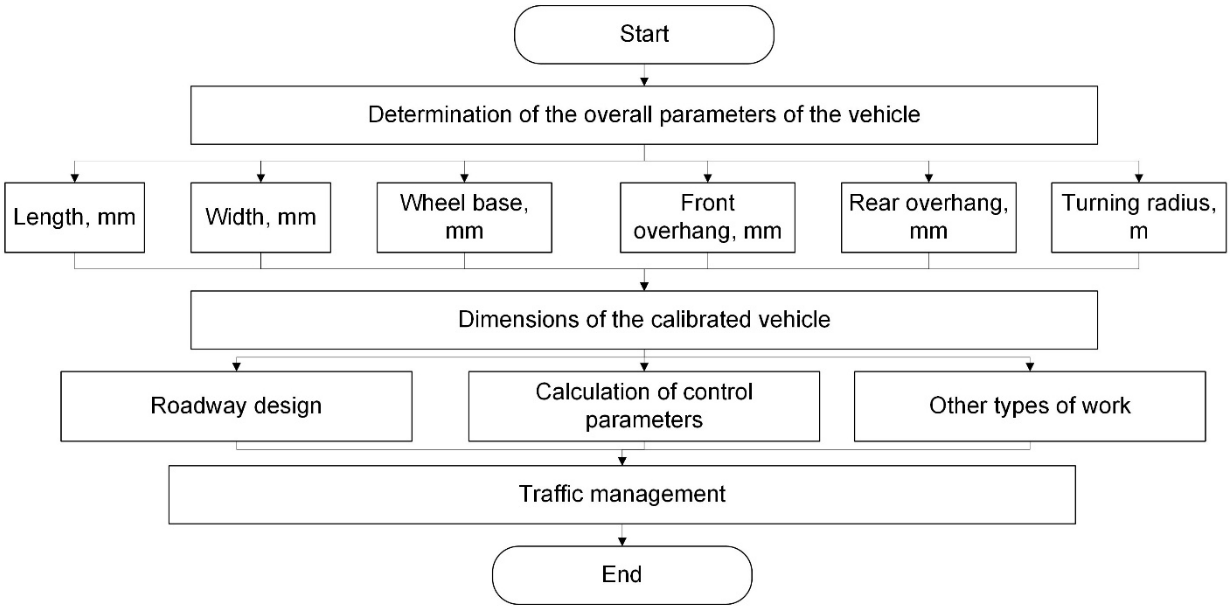

Figure 4: Scheme of the algorithm for determining the settlement vehicle for the Arctic zone of the Russian Federation

Thus, when performing organizational work to improve the transport situation and contributing to improving service quality, one of the necessary measures is to establish the main parameters of cars most often encountered in the flow, which makes it possible to increase the accuracy of calculation and minimize costs at the design stage and subsequent organization of traffic.

5 DISCUSSION

Since the design and construction of the roadway, as well as subsequent calculations in the field of traffic management (saturation flows, forced control) are determined on the basis of the parameters of the design vehicle, which is accepted and approved in the main regulatory documents, but the car park is constantly changing - vehicles are being modified, it is necessary to constantly update the basic geometric characteristics of the design vehicle. Also, in different zones of the Russian Federation, depending on the location of the zone and traffic conditions, vehicles in the stream differ from each other, it is necessary to take into account these factors and determine the estimated vehicle for individual zones of the Russian Federation. On the example of the Arctic zone of the Russian Federation, this study shows the difference in the values of the geometric parameters of the design vehicle of this zone from the rest of the zones of the Russian Federation as a whole, the deviation is 6%. For the calculated vehicle of the RF zones, it is proposed to introduce such a concept as a calibrated vehicle - this is a vehicle with average parameters of vehicles that are most often encountered in the traffic flow.

6 CONCLUSIONS

In the course of the study, the following results were obtained:

1. The most common car in the traffic flow is installed - passenger car, which is more than 80%;
2. The main brands of passenger cars most often found in the flow for the Russian Federation and its Arctic zone are identified, which differ depending on the territory, which is explained by the presence of certain economic costs and are associated both with the level of income of the population and the territory itself.
3. One of the distinguishing features of the considered vehicles is concretized - overall parameters and the limits of their change are determined.
4. A mathematical model has been developed for calculating the parameters of a calibrated vehicle both for the Russian Federation and for the Arctic zone, as a result of which a difference of 6% has been determined, which must be taken into account when performing survey work - construction, reconstruction, reorganization and organization.
5. An algorithm for calculating the parameters of a calibrated vehicle has been developed and promising ways for further research have been identified.

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