Integrated assessment of methods for calculating harm caused by vehicles in transport of heavy cargoes

R N Saifiullin¹, A S Afanasyev²

¹ Saint-Petersburg State University of Architecture and Civil Engineering, 2-ya Krasnoarmeiskaya St. 4, 190005 St. Petersburg, Russia
² Saint Petersburg Mining University, Saint Petersburg, Russian Federation 2, 21st Line, St Petersburg 199106, Russia

Email: safravi@mail.ru; a.s.afanasev@mail.ru

Abstract. This article presents a comparative analysis of methods for calculating the harm caused by vehicles carrying large-tonnage cargo on roads of regional importance in the North-Western Federal District. An exponential distribution model was used for the analysis. It is revealed that the regions do not have a single methodology for calculating harm, which has brought inconvenience to carriers of large-sized and heavy cargoes. The developed methodology is considered that takes into account the load-carrying capacity and wear of road surfaces.

1. Introduction
The problems of transportation of large and heavy equipment have been aggravated recently due to the increase in their flow, distribution throughout the country with a variety of nomenclature and sizes of large-tonnage cargo, requiring an individual approach to a particular transportation. Violations on the site, non-observance of weight characteristics, insufficient control over the transportation process are at this stage a weak link in the transportation segment. In addition, because of increased loads, the road surface suffers, which collapses much earlier than the estimated time. Therefore, an effective measure will be to strengthen the control of state and supervisory bodies over the implementation of the adopted laws and regulations.

2. Materials and methods
The authors conducted a comparative analysis of the methods of the regions of the North-Western Federal District (Figure 1.) Based on statistical data, it became possible to establish that the magnitude of the harm caused by vehicles (tariffs) in the transportation of heavy cargoes on regional roads has a significant difference compared to the recommended (in %).
For example, according to the recommended methodology, the amount of harm for exceeding the permissible weight from 0% to 10% will be 2709 rubles per 100 km. It is established that unlike Arkhangelsk region, Vologda region and St. Petersburg, the minimum threshold of harm for Leningrad region is 310 rubles per 100 km that is 9 times less.

The results of calculating the harms of the methods used in the regions studied showed that the tariffs in Arkhangelsk region, Vologda region and St. Petersburg are subject to a linear law, and in Leningrad, Novgorod regions, the Republic of Karelia, the Republic of Komi in summer and winter - to exponential law.

As a result of the comparative analysis of the issued permits (%) from the overweight (%), a mathematical model was obtained - \( y = 134e^{-0.8x} \); the coefficient of determination is \( R^2 = 0.9966 \). The greatest number of permits falls at 0% overweight, which is 60%. With the aid of the distribution density, the probabilities of a violation of the preponderance of the total mass for the regions of the North-Western District were obtained:

\[
p(x) = \begin{cases} 
\lambda e^{-\lambda x}, & x > 0 \\
0, & x \leq 0 
\end{cases}
\]

where \( \lambda > 0 \) is a positive constant, called as the parameter of the exponential distribution. In our case it is 0.5.

When calculating the amount of harm caused by vehicles used in the methodologies of different regions in accordance with the accepted conditions (1), the received value of compensation for harm for a certain preponderance, in %, is multiplied by the probability density of falling into this category. The results of calculations of the comparative evaluation, the used methods of harm extent are presented in figure 2.
Figure 2. Comparative evaluation, applied methods of the extent of harm of exceeding the permissible weight (in %) of the new tariff for the regions of the North-Western Federal District.

From figure 2 it can be seen that the tariff rate of harm in the Komi Republic in summer and winter, Novgorod region, Leningrad Region is much less than the tariffs of Arkhangelsk regions, Vologda regions and St. Petersburg. To calculate the average values of harm sizes per vehicle per 100 km according to the adopted methods for calculating the regions of the North-Western District, dependencies were determined for each curve (Figure 3.):

$$S(\text{Saint-Petersburg}) = \int_{0}^{10} \left(189e^{-0.072x}\right) dx = 917;$$

$$S(\text{Arkhangelsk region}) = \int_{0}^{5} \left(4432e^{-0.091x}\right) dx = 2790;$$

$$S(\text{Vologda region}) = \int_{0}^{5} \left(4432e^{-0.091x}\right) dx = 2790;$$

$$S(\text{Komi Republic in summer}) = \int_{0}^{5} \left(524e^{-0.421x}\right) dx = 63;$$

$$S(\text{Leningrad region}) = \int_{0}^{5} \left(1263e^{-0.419x}\right) dx = 155;$$

$$S(\text{Novgorod region}) = \int_{0}^{5} \left(104e^{-0.422x}\right) dx = 133.$$

A comparative assessment of the accepted methods for calculating the amount of harm caused by vehicles during heavy cargo transportation showed that in accordance with the procedure (Decree of the government of the Russian Federation No. 12 of 09.01.2014), the extent of harm amounts to 2790 rubles per 100 km of length on the road of regional significance, which is much higher than the tariffs of accepted methods in St. Petersburg - 917 rubles per 100 km, in Leningrad region - 155 rubles, in Novgorod region and the Komi Republic in winter - 133 rubles, in summer - only 63 rubles per 100 km.
The unevenness of the size of tariffs and the size of harm, based on existing methods, creates additional difficulties for all participants of the transportation process of large-tonnage cargo. One of the ways to improve the process of transportation of large and heavy cargo by road is to develop a variety of methods for optimizing the process of these transportations, from the qualitative and rapid implementation of which the further uninterrupted functioning of this direction depends. The developed technique of definition of the extent of specific harm put by vehicles, transporting heavy-weight cargoes, considering bearing ability and the wear-and-tear of covers of motor roads is offered.

The methodology assumes the determination of the operational coefficient, taking into account the strength criterion of the pavement $K_g$, depending on the capital of the road construction, different categories, as well as the regional conditions, in which the route of transportation is carried out according to the developed dependence:

$$K_o = K_{st} / K_{ed}^{req}$$

where $K_{st}$ - coefficient of strength of pavement; $K_{ed}^{req}$ - required coefficient of strength by the criterion of elastic deflection (MODO 2-2001)).

The results of calculating the operational coefficient, taking into account its carrying capacity, are shown in figure 3.

3. Results and Discussion
The developed technique allowed one to determine the degree of damage to proportional failure. In addition it made it possible to determine the size of the harmful assumption in the form of a transport flow of an additional traffic system, which will take place during the repair service life of the pavement.

4. Conclusion
On the basis of the conducted research, it is established that in order to increase the efficiency of transportation of large-sized heavy cargo. It is necessary to make a single optimal tariff for compensation of damage to roads of regional significance on the basis of the developed methodology. For this purpose there is a need to create a single information field, an information system that will include the data on participants in transportation, the condition and infrastructure of roads, the nomenclature of services rendered during the transportation of large-sized heavy cargo.
Reference

[1] The Government of the Vologda region decree of April 19, 2010 No. 448 on determining the amount of harm caused by vehicles

[2] The Government of the Arkhangelsk region decree of May 26, 2015 No. 161 pn On Amendments to the Decree of the Government of the Arkhangelsk Region of December 22, 2014 No. 555-pp

[3] The Government of the Republic of Komi decree of October 14, 2009 N 295 on determining the amount of harm caused by vehicles carrying heavy cargo when driving on public roads of regional or intermunicipal significance of the Komi Republic (as amended by Government Decrees of 10.02.2010 N 26, from 23.08.2010 N 268, from 31.01.2011 N 4)

[4] The Government of the Leningrad region decree of April 22, 2010. n 97 on determining the amount of harm caused by means of transport carrying heavy cargo when driving on the public roads of regional or inter-municipal significance of the Leningrad Region (as amended by Decree of the Government of the Leningrad Region No. 264 of October 12, 2010)

[5] Republic of Karelia Resolution No. 97 of June 10, 2013 On approval of the Procedure for determining the amount of harm caused by vehicles carrying heavy cargo when moving along public roads of local significance of the Republic of Karelia

[6] Resolution Novgorod region from 02.11.2015 № 220 on determining the amount of harm caused by vehicles carrying heavy goods, while driving on public roads of regional or inter-municipal significance of the Novgorod region

[7] Afanasev A, Panfilov D 2016 Estimating the throughput capacity of intersections taking into account the change in traffic intensity. Transportation Research Procedia. Ser. 12th International Conference “Organization and Traffic Safety Management in Large Cities” (SPbOTSIC)

[8] Safiullin R N, Kerimov M A 2016 Means of photo-video-detection of traffic violations: normative regulation and practice of application: monograph (Moscow: Direct Media)

[9] Safiullin R N 2016 Exploitation of cars. Textbook (Moscow. Ser. 11 Universities of Russia)

[10] Kerimov M A, Marusin AV Evaluation of Functional Efficiency of Automated Traffic Enforcement Systems, 12th International Conference «Organization and Traffic Safety Management in Large Cities», SPbOTSIC-2016, 28-30 September 2016, St. Petersburg, Russia, pp. 288-294.

[11] Ivanivsivky V V, Skeeba V Y, Bataev I A, Lobanov D V, Martyushev N V, Sakha O V, Khlebova I V 2016 The features of steel surface hardening with high energy heating by high frequency currents and shower cooling. IOP Conference Series: Materials Science and Engineering 156(1) 012025

[12] Zverev E A, Skeeba V Yu, Martyushev N V, Skeeba P Yu 2017 Integrated quality ensuring technique of plasma wear resistant coatings. Key Engineering Materials 736 132-137