Improving Road Traffic Safety Through the Use of Innovative Technologies

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Abstract*: *The use of innovative technologies is the most effective and promising way to improve the road traffic safety management system. The relevance of the work is expressed in the need for continuous implementation of innovations in the context of growing disproportion between the sharp increase in the number of vehicles, high traffic intensity, and imperfection of road traffic management (problems of existing infrastructure, poor information support for road users, etc.), which results in road traffic injuries and deaths. In the course of the research, it was found that in the context of the Republic of Adygea, using rumble strips installed at the road shoulder reduces the number of run-off-road collisions by 30%, while using centerline rumble strips reduces the number of cross-over incidents and resultant head-on collisions by 15%.

Index Terms*: *carriageway, road traffic accidents, road traffic, Republic of Adygea, rumble strips.

I. INTRODUCTION

In developed countries, the growth and competitiveness of the economy are largely due to the development of new technologies, the production of high-tech goods and services, and their introduction to world markets [1], [2]. Ensuring road traffic safety, and above all the prevention of road traffic accidents (RTA) as a transnational problem of modern times, is relevant to the entire global community. It should be addressed only from the standpoint of various branches of scientific knowledge [3], [4]. The development of road transport and, as a consequence, the improvement of road-traffic management play an important role in overcoming the crisis and other modern problems, contribute to the optimization of legal, financial, organizational, psychological, and other mechanisms aimed at strengthening the socio-economic situation and the rule of law in the country [2], [5]-[7]. The problem of road traffic safety is becoming increasingly important due to the growing disproportion between the sharp increase in the number of motor vehicles, high intensity of road traffic, and the imperfection of the road traffic organization (problems of existing infrastructure, poor information support for road users, etc.), which lead to many negative phenomena on the road, and, above all, to road injuries and deaths [4], [8]-[10]. As in any other area of regional and national politics and economy, innovations in the field of road traffic safety are very important [11], [12]. In general, innovations can be seen as a process of implementations of novelties in a particular activity of an economic entity. Innovations are qualitative changes in the types, forms, and methods of economic activity caused by external causes and internal capabilities. The main purpose, when implementing innovation, is directing them to improve the efficiency of achieving specific goals [9], [13], [14]. In the field of road traffic safety, innovations have certain specifics. Despite a large number of studies dealt with the theory of innovations, there is practically no unified theoretical understanding of science-based innovations in the road traffic safety system.

The aim of the present work is to carry out a comprehensive study of the innovative component of road traffic safety, to propose and justify the effectiveness of using rumble strips for road traffic safety (RTS) for the Republic of Adygea.

The research object is the road traffic safety system.

The research subject is the innovation sector of road traffic safety, namely, the installation of rumble strips.

II. METHODS

A. General description

The methodological and theoretical basis of the study includes the works of Russian and foreign scientists and specialists, devoted to the problems of innovative development of the Russian road traffic safety system; programs, concepts, legislative acts of the Russian Federation, official documents of the Russian Federation Government, as well as other materials related to this issue. In the course of the study of the indicated problem, the methods of economic-technical, financial and marketing analysis were used, as well as planning and forecasting methods along with analysis of statistical materials [7], [9], [10].

B. Algorithm

The length of roads within the territory of the Republic of Adygea equals to 4,757.9 km, including 208 km of

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Federal-aid highway, and 1,374.5 km of republican and intermunicipal roads. Out of the total length of roads, 2,977.4 km have asphalt carpet, while the remaining 1,780.5 km represent gravel roads. The condition of regional and intermunicipal roads can be qualified as satisfactory.

The total number of bridges and bridge structures is 81 units with a total length of 4,503.27 long meters. General information about the roads in the Republic of Adygea is presented in Table I.

Table I. Information on federal roads crossing the territory of the Republic of Adygea

Name of the federal road	Length within the subject boarders, km	Technical category	The main type of road covering	Condition
M-4 Don	21.6	I, II	Asphalt carpet	Meets regulatory requirements
The approach road to Maikop city from R-217 Caucasus	25.9	II, III	Asphalt carpet	Meets regulatory requirements
A-146 Krasnodar-Novorossiysk, south approach road to Krasnodar	8.7	II, III	Asphalt carpet	Meets regulatory requirements
A-160 Maikop-Ust Labinsk-Korenovsk	46.2	II, III	Asphalt carpet	Meets regulatory requirements
A-159 Maikop-Guseripl, the approach road to Caucasian State Nature Biosphere Reserve	77.2	II, III, IV	Asphalt carpet	Meets regulatory requirements

The density of paved roads per 1 thous. km in the territory of the Republic of Adygea is 206.6 km (the eighth position in the Russian Federation). However, the existing mismatch of road transport infrastructure to the needs of the Republic of Adygea in terms of road traffic safety, the lack of efficiency of the road safety system, and the extremely low discipline of road users exacerbate the problem of road accidents. In recent years, road traffic safety has become a very serious problem in the country. The road traffic safety system in the Russian Federation is continuously developing but still does not correspond to the world level. It is important to note that road traffic safety is a system problem, whose successful solution largely depends on the consistency of actions of the federal and territorial executive power bodies, road traffic safety bodies, the enterprises of transport-road complex, educational and medical institutions, and civil society organizations.

III. RESULTS

According to conducted analysis, the distribution of road traffic accidents occurred due to the unsatisfactory road conditions is as follows:

- more than 68% are caused by low road adherence;
- about 10-13% are caused by the improper quality of roadsides and the presence of potholes;
- about 4% are caused by a lack of both information and road signs;
- about 8-9% are caused by insufficient visibility and illumination.

As before, the most common cause of a road accident is entering an oncoming lane and exit to the roadside. Rumble strip is installed in the top layer of asphalt-concrete road covering on those sections of the highway, which are distinguished by the greatest number of road accidents. Rumble strips are perpendicular to the vehicle traffic direction, have certain step and depth, and are functionally designed to create uncomfortable conditions to the driver.

In cases, where the exit from the main lane to the ditch is unexpected, or the car enters an oncoming lane, when contacting the rumble strip, it starts vibrating, creating a noise effect on the driver that results in a sharp increase in the driver's attention to the situation on the road, preventing thereby a possible accident. Rumble strip is a structural element of the road, and determines the total transport and operational characteristics of the section, where it is located, serving as a road element reducing the risk of a possible accident. When driving a motor vehicle at a speed of 60 km/h on a road provided with irregularities on the road surface in the form of a rumble strip with a roughness width equal to 200 mm, the depth of the structural element of the rumble strip should be 20...30 mm, while the width can be taken 150...200 mm. At that, the length of the rumble strip should be selected depending on the longitudinal and transverse profiles of the road. With an increase in the vehicle speed and a decrease in the wavelength of irregularities, no significant effect of the depth of the structural element was observed that allowed taking this parameter equal to 40 mm. At that, vibration acceleration is achieved within 2.1 m/s^2. In practice, rumble strips can be combined with the carriageway marking that allows extending the life of the marking material by reducing the abrasion effect of snow-removers. It was experimentally revealed that when using this innovative solution, after the expiration of the winter operation of the road, the reflective effect of the marking line combined with the rumble strip was almost three times higher than the similar indicators of the usual horizontal marking line. It is recommended to arrange rumble strips on new roads or roads that do not

have defects in roadway and roadside coverage. On existing roads, decisions concerning installation of the rumble strips should be made based on road accident analysis. In practice, there are four types of manufactured rumble strips: milled, rolled, formed, and raised. The disadvantage of rolled and formed rumble strips is that they can be created only during the road construction process (into hot asphalt), while raised rumble strips can be demolished in the winter by snow-removers. For the Republic of Adygea, it is most acceptable and expedient to install milled rumble strips on existing roads with asphalt concrete pavement. Such rumble strip effects as follows: as soon as the wheel of the vehicle gets (even partially) on the rumble strip, a sharp unpleasant sound appears in the car, which is similar to the sound of a washing board, when it is scrabbled by a wooden stick. The main goal of using rumble strips is to awaken sleepy drivers or to focus distracted drivers, even in those places where there is no marking (not updated or not visible due to snow). This severe sound informs the driver about the danger. In case of presence of such rumble strips on the highways with dividing barriers, sleepy drivers will be alerted even from the minor accident and nonhazardous road collisions.

The advantage of applying rumble strip consists in reducing the number of deaths and serious injuries caused by falling asleep or loss of vigilance of the drivers with the subsequent run-off-road car accidents. The estimated accident rate reduction varies from 20 to 65%. The efficiency of the rumble strips is confirmed also by a high benefit to cost ratio that allows drawing the conclusion that they are the most cost-effective means of improving road safety. According to the obtained data, it has been revealed that using rumble strips in the context of the Republic of Adygea

- reduces the number of run-off-road car collisions by 30%, when installed at the shoulder of the road;

- reduces the number of cross-over incidents and resultant head-on collisions by 15%, when installed on the centerlines. Table II gives an approximate cost estimate for the recommended measures and the expected efficiency of their implementation. The information of the head of the Transport Department of the Public Council under the Ministry of Construction, Transport, Housing and Road Economy of the Republic of Adygea presented at the meeting held on April 27, 2017 (Protocol No. 1) is taken as the basis of the cost estimate.

Table II. Cost estimation of recommended measures and calculation of expected efficiency of their implementation

Indicator	Arrangement of rumble strips	Installation of solar-powered traffic signals	Implementation of other effective innovative developments in the road sector (according to item 3.3)
The cost of installation of a single object, thousand rubles	120	45	-
Number of objects recommended for installation, items	20	200	-
The total cost to implement project solution, thousand rubles	1,200	9,000	3,000
Total costs, thousand rubles	13,200		
Expected effect	Reduction of accidents on road sections, modified according to recommendations by an average of 10%.	Cost savings compared to conventional traffic signals powered by electricity, 1.5-2 times	Reduction of accidents on road sections modified according to recommendations by an average of 8%.
Cost evaluation of the project solution effectiveness, thousand rubles	19,502	9,000	15,602
The total valuation of the effectiveness, thousand rubles	44,104		
Effectiveness ratio	3.3		

Damage indicator from road accidents in the Republic of Adygea is calculated based on the average ratios (data retrieved from insurance companies).

L_d - losses associated with deaths due to RTA (9,180.0 thousand rubles/person);

L_i – losses associated with injuries (786.0 thousand rubles);

L_v – losses from damage to vehicles (490.0 thousand rubles);

L_c – damage caused by cargo deterioration (140.0 thousand rubles);

L_{in} – costs of law enforcement agencies to investigate an accident (15.0 thousand rubles);

L_r – damage to road structures (120 thousand);

L_t – damage from loss of time of other vehicles in the traffic flow (6.0 thousand rubles).

Below are calculations of the above indicators carried out with regard to the Republic of Adygea:

1. Losses associated with deaths due to RTA:

L_d= 9180.0* 119 =

1,092,420 (thousand rubles)

2. Losses associated with injuries:

L_i= 786.0* 595 = 467,670 (thousand rubles.)

3. Losses from damage to vehicles:

L_v= 490,.0* 506 = 247,940 (thousand rubles)

4. Damage caused by cargo deterioration:

L_c= 140.0* 506 = 70,840 (thousand rubles)

5. Costs of law enforcement agencies to investigate an accident:

L_{in}= 15.0* 506 = 7,590 (thousand rubles)

6. Damage to road structures:

L_r= 120.0* 506 = 60,720 (thousand rubles)

7. Damage from loss of time of other vehicles in the traffic flow:

L_t= 6.0* 506 = 3,036 (thousand rubles)

In general, the economic losses from the accident in the Republic of Adygea in 2018 amounted to:

L_{RTA} = 1,092,420 + 467,670 + 247,940 + 70,840 + 7,590 + + 60,720 + 3,036 = 1,950,216 (thousand rubles)

1. Assessment of the effectiveness of rumble strips, installation of traffic signals , as well as other above-mentioned innovative developments in the road sector was carried out based on the fact that the implementation of these measures would reduce the cost of eliminating the consequences of accidents in an amount proportional to the expected effect (10 and 8% for the first and third measures, respectively). The sum of expenses on the elimination of consequences of accidents within territorial borders, which are under the responsibility of Road Patrol Service of Federal Authority for Road Traffic Safety of the Main Department of the Ministry of Internal Affairs of Russia in the Republic of Adygea on average makes 1,950,216 thousand rubles per year.

$$\Delta C = C_B - C_A, \quad (3.1)$$

where C_B and C_A are the annual losses from road traffic accidents respectively, before and after the implementation of measures, thousand rubles.

Δ C = 1,950,216 – (1,950,216-44,104) = 44,104 (thousand rubles)

2. Calculation of effectiveness ratio

$$K_e = \Delta C / S_r \quad (3.2)$$

where S_r is the reduced expenditures for the proposed measures, thousand rubles.

K_e = 44,104 /13,200= 3.3

3. The calculation of the payback period

The value, inverse to the effectiveness ratio, in fact determines the payback period of capital investments in specific measures, taking into account its economic efficiency:

$$T_{pp} = S_r / \Delta C \quad (3.3)$$

T_{pp} = 13,200 / 44,104 = 0.3 of the year, or four months.

The total cost to implement the recommended measures will be 13,200 thousand rubles. Cost-effectiveness evaluation amounts to 44,104 thousand rubles.

Thus, each of the measures recommended in the framework of this work makes a certain contribution to improving road safety in the Republic of Adygea.

IV. CONCLUSION

A set of suggested innovative solutions and recommendations in relation to regional conditions of road traffic safety includes the implementation of technical means to ensure RTS (establishing road sections with rumble strips and implementing other effective innovation developments in the road industry (the installation of solar-powered traffic signals). Rumble strip is a structural element of the road, which determines the total transport and operational characteristics of the road section where it is installed. This element is a means to reduce the risk of a road traffic accident. Installation of these elements will allow reducing the accident rate on the roads of the Republic of Adygea, and focusing the attention of drivers on speed enforcement.

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