ISSN 1822-427X print
ISSN 1822-4288 online

THE BALTIC JOURNAL
OF ROAD AND BRIDGE ENGINEERING

http://www.bjrbe.vgtu.lt

2007, Vol II, No 2, 81–87

ANALYSIS AND EVALUATION OF THE EFFICIENCY OF ROAD SAFETY MEASURES APPLIED TO LITHUANIAN ROADS

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Abstract. Road traffic safety has become a priority field in the integration process of the state road network into the European road network. Due to the Lithuanian integration into the economy of Western Europe, the state transport system has been rapidly changing. Road traffic safety has become one of the major factors describing the present transport system and its positive and negative changes.

The article presents the road safety problems in Lithuania and gives an analysis of road accidents according to the data of the Traffic Police as well as their types and main causes. The analysis of the most important measures for improving traffic safety is presented. The second task is focused on the analysis of the methodology for calculating losses of accidents.

Keywords: road traffic safety, road safety improvement measures, accidents.

1. Introduction

Due to Lithuanian integration into the European Union (EU) and the development of economic relations with the EU countries, the transit flows, also the number of vehicles on Lithuanian roads, have been rapidly increasing. This is related not only to a large benefit to the public, but also to some undesirable social and economic effects. The first one – a huge number of traffic accidents.

Nearly half a million people are killed each year in road traffic accidents all over the world and approx 15–20 million are injured. During the last 15 years more than 12 000 people died on Lithuanian roads and more than 90 000 were injured.

During last 3 years the traffic volume on Lithuanian roads has been rapidly increased. In 2003–2015 the average change in the traffic volume on E-category roads made 20 %, the change in the traffic volume of heavy vehicles – 37,4 %. In a two-year period the heavy traffic volume on the road VIA BALTICA has increased even by 62 % and on all Lithuanian roads by 25–27 % on average. The volume of international heavy traffic has been growing especially rapidly: in the year 2004, if compared to 1993, the number of trucks, crossing the Lithuanian border, has increased by nearly 3 times. Such a rapid growth of heavy traffic negatively affects the structure of Lithuanian road pavement, causes a faster pavement deterioration, failure and defects, decreases its structural strength etc.

Most of the earlier constructed road pavement structures were calculated for the axle load of 10 tonnes. At present a permissible axle load on the main roads is 11,5 tonnes. Heavy traffic causes a negative impact on pavement evenness and initiates ruts in pavement structure. The ruts with the depth of more than 20 mm cause a serious danger for road safety.

At present the road traffic safety situation in Lithuania is the worst, if compared to the other EU countries. Lithuania takes the last place among all the EU countries according to the number of deaths in road accidents per 1 million inhabitants. Therefore the current Road Maintenance and Development Programme for 2002–2015 outlines the following priority goals: road traffic safety assurance, road maintenance, road development, implementation of the principles of the national sustainable development strategy [1].

The existing number of accidents shows that all the measures and methods, currently used to improve road safety, are insufficient. Comprehensive studies and a successive analysis of their results are necessary not only on a national level but also on a regional and city level. It is an urgent task to make the evaluation of the existing situation as a whole, which would show the effect and the benefit of the road safety measures implemented.

Today the standard and well-known road safety measures are not sufficient. It is necessary to implement the road traffic safety programmes and to introduce the new road safety technologies on EU scale [2].

The subject of this paper is the black spots, occurring on Lithuanian roads. The paper analyses and evaluates the efficiency of the road safety improvement measures after their implementation. The results obtained are compared to the forecasted ones.

2. Road safety situation in the European Union

In 2003, the Transport Ministers of EU countries adopted Verona Declaration, where they committed to reduce the number of people killed in road accidents by 50 % until 2010. The countries one after another approved these commitments on a national level. The study, conducted by the European Commission at the beginning of this year, showed that the number of people killed in road accidents in the EU has decreased by 17–18 %. Such countries as Portugal, Sweden, Netherlands, Denmark, Germany and partly Italy are on the right way in achieving their goal. By 2005, all these countries succeeded to reduce the number of victims of road accidents by more than 20 %. Lithuanian neighbours Estonia and Latvia have taken a number of important decisions for improving road safety situation in their countries. Estonia started to pay a large attention to children and drivers education, Latvia since 2001 has been implementing measures to reduce the number of drivers under the influence of alcohol. In 2004 the penalty point system was introduced for the violators of traffic rules [3]. However, Lithuania has the worst situation in the EU countries, since the number of deaths has not decreased but even increased by 8 % (Table 1, Fig 1) [4].

Table 1. Change in the number of accidents, killed and injured people since 2001

	2001	2005	Change	
			+/–	%
Road accidents	5972	6790	+ 818	14
Killed	706	760	+ 54	8
Injured	7103	8497	+ 1394	20

Based on international accident statistics data, Lithuania is one of the few European countries where more than 200 people are killed every year per 1 million inhabitants (in 2005 – 223 deaths). This number in 2005 was the worst among the EU countries and it is twice as many as the average in the European Union. The main objective of the road safety assurance activity is to plan the measures, which would help to avoid painful consequences of road accidents and to reduce the cases of wrong behaviour by the road users.

3. Road safety situation on Lithuanian roads

The growing traffic volume on Lithuanian roads and streets inevitably causes road accidents. In 2005, 6790 road accidents took place in Lithuania, where 760 people were killed and 8497 injured. During the period of 11 years (1995–2005) in the Republic of Lithuania 63 837 road accidents occurred, where 7905 people were killed and 76 419 injured (Fig 2). This means that every year Lithuania lost nearly 719 of its citizens, 6947 people suffered from serious traumas, which revealed itself long after the period of

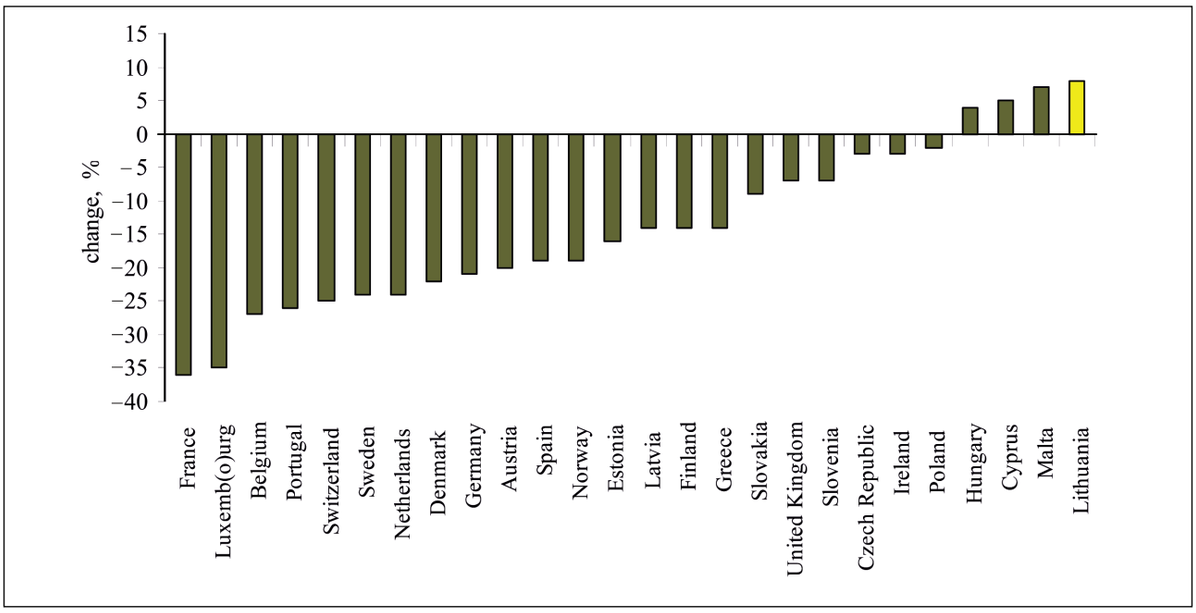

Fig 1. Change in the number of people killed in road accidents in the EU countries during 2001–2005

Table 2. Change in the number of road accidents, people killed and injured, 1995–2005

	1995	2005	Change	
			+/–	%
Number of road accidents	4144	6790	+2646	64
Number of road accidents per 1 thousand vehicles	4,7	3,8	–0,9	–19
Number of the killed	672	760	+88	13
Number of the killed per 1 thousand vehicles	0,77	0,43	–0,34	–44
Number of the injured	4508	8497	+3989	89
Number of the injured per 1 thousand vehicles	5,1	4,8	–0,3	–6

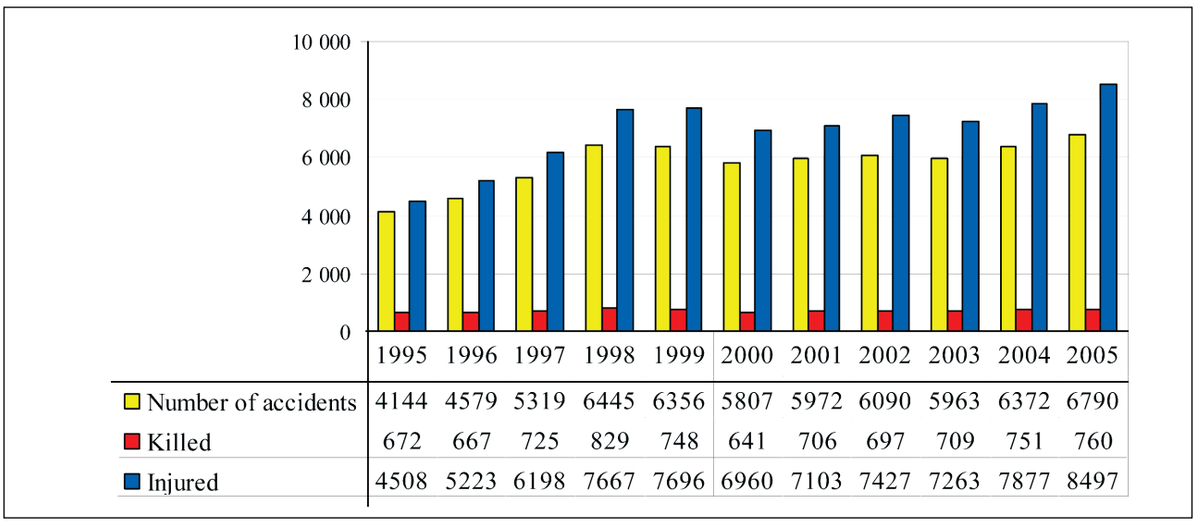

Fig 2. Dynamics in the number of fatal and injury accidents, people killed and injured, 1995–2005

the medical treatment or even caused disability [5].

From 1995 to 2005, the number of accidents in Lithuania has increased by 64 %, the number of people killed – by 13 %, injured – by 89 % (Table 2). This is not solely the statistical data – these numbers embrace the tragedies for families and relatives, increase the number of disabled people, since the number of the disabled due to the road accidents is three times larger than that of the killed people.

4. Methodology for the justification of road safety measures on Lithuanian roads

A proper selection of road safety improvement measures, corresponding to the concrete situation, results in the reduction in the number of accidents, as an objective to be achieved. In order to select the suitable measures, it is necessary to determine accident causes and the risk factors, contributing to the road accidents [6]. This task is the most important for the traffic safety specialists and efforts are made throughout the whole EU to strategically solve it by creating a common methodology. The basis of this methodology is an identification of the risk factors and implementation of the corresponding road safety measures on an accident concentration site.

Each EU country makes different evaluation of the risk factors; however, all the countries agree on the significant interaction between the factors. A very important link is „Road user – Vehicle – Road (infrastructure)". The road accident could be caused by a negative effect of one factor of this link or by the interaction of several factors, but very seldom – by all the factors together [7] [Fig 3].

The main measures, used to assure road traffic safety on Lithuanian roads and streets, are as follows: construction of pedestrian and bicycle tracks, sidewalks and guardrails, reconstruction of intersections by giving a priority to roundabouts and grade-separated intersections, illumination of road sections, construction of grade-separated pedestrian crossings, removal of trees from the edge of the carriage-

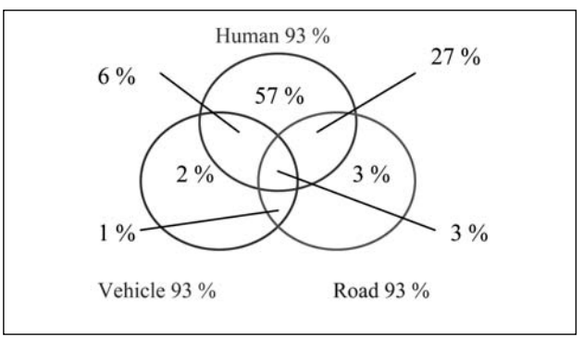

Fig 3. The role of the risk factors and their interaction during the accident

way on the main, national and high-volume regional roads, installation of traffic lights in the intersections where it is complicated to implement another measures, erection of speed-reduction engineering measures etc.

The road safety measures are implemented on those road sections where a regular recurrence of accidents was noticed. Before the implementation a detail analysis is necessary to define the main risk factors, contributing to the accidents. After making the identification of accident causes the corresponding measures are selected to improve road safety.

The road sections, having a regular recurrence of accidents, are divided into two groups for further evaluation:

1. accident concentration site – a road section where the safety indicators are still lower than the limit values, though it is already necessary to take preventive measures and to avoid the black spot;
2. black spot – a road section where the safety indicators had already exceeded the limit values and where urgent measures are required to improve the safety situation.

Each year, more than 200 accident concentration sites and black spots are identified on Lithuanian roads of state significance.

The safety situation of a study road section is assessed by estimating the accident rate:

$$AR = \frac{N \cdot 10^6}{365TLm}, \quad (1)$$

where AR – accident rate, characterising the number of accidents per 1 million vehicles passing through 1 km road section per year; N – number of accidents on a study road section in the period of 4 years; T – annual average daily traffic, vpd; L – length of a study road section, km; m – number of years ($m = 4$).

According to the currently used Lithuanian methodology, the black spot is the road section with a length of 500 m where in the period of 4 years 4 or more road accidents occurred and the accident rate is: $AR_{min.} = 0{,}5$ for roads with a double carriageway (AM and I category roads); $AR_{min.} = 0{,}8$ for roads with a single carriageway (II and V category roads);

The main safety indicators, describing the safety situation of a road section, are: accident density (AD), indicating the number of accidents per 1 km long section per year; accident rate (AR).

The economic analysis of road safety measures is carried out by using the upgraded Lithuanian version TARVAL of the software TARVA, developed at the Finnish Road Technical Research Centre. This version of the software has been installed in the Road Survey Division of the State Enterprise "Transport and Road Research Institute" (TRRI). The software calculates the forecasted reduction of recorded accidents per year, taking into account the accident rate, traffic volume and the proposed road safety improvement measures in the period of 4 years.

For each road safety measure the impact coefficient has been determined, showing the expected change in the number of accidents after a certain measure is implemented. TARVAL coefficients for the homogenous road sections are determined taking into account the following groups of improvements: road improvement (widening, marking etc); road infrastructure improvement (illumination, marker posts etc); intersection improvement; speed restriction; other measures.

The methodology of calculating accident losses was developed by the TRRI in 1995. This methodology was elaborated according to the Report XIII of the European Commission General Directorate. This report presents the findings of the research carried out in 14 European countries. Software to calculate the losses of accidents in the Lithuanian Republic has been developed according to this methodology. When analysing accidents, two groups of losses are pointed out: direct (primary) and indirect (secondary) losses. Direct losses are the losses incurred by vehicle owners, road maintenance units, expenses of traffic police and other organisations, investigating accidents, as well as medical institutions [8].

5. Analysis and evaluation of the efficiency of road safety improvement measures implemented on Lithuanian roads

In 2006, the Dept of Roads of the Vilnius Gediminas Technical University started the evaluation of the efficiency of road safety improvement measures on Lithuanian roads. For this purpose, data on the effect of road safety measures had been collected and analysed for the road sections where the measures were implemented.

One implementation stage was analysed for determining the effect of the road safety improvement measures after their implementation. 28 black spot sections were selected where the improvements were implemented in 1999 [9]. A comparison of the efficiency of road safety measures and the forecasted reduction of accidents with the real situation 4 years after their implementation enabled to assess the accuracy of the currently used efficiency evaluation methodology. The road safety measures and their impact coefficients in the TARVAL software are in Table 3.

It was determined that in 15 road sections the implemented measures have justified themselves. In the remaining 13 sections the expected road safety results were not achieved (Table 4). Therefore the repeated detail analysis of these road sections is necessary, also, implementation of the more effective safety measures and development of methodology for the justification of road safety improvement measures.

Table 4 gives the road sections where, after implementation of a certain road safety measure, the safety situation

Table 3. The impact coefficients of road safety measures in the TARVAL software

No	Measure description	The impact coefficients *		
		For accidents with vehicles	For accidents with pedestrians and bicyclists	For accidents with wild animals
	Existing situation	1	1	1
101	Setting up pedestrian and bicycle ways	1	0,7	1
103	Traffic island on zebra crossing	1	0,8	1
105	Zebra crossing arrangements	0,95	0,9	1
106	Improving pedestrian and bicycle way	1	0,85	1
203	Road widening in country side	0,9	0,9	0,9
204	Overtaking line	0,9	1	1
206	Lines widening	0,9	1	1
209	Building a central island	0,8	0,9	1
401	Building a roundabout	0,7	0,85	1
407	Channelisation of a 4-arm crossing	0,9	0,9	1
409	Channelisation of a 3-arm crossing	0,95	0,95	
412	New traffic lights in a 4-arm crossing	0,7	0,7	1
604	Marking new middle and side lines	0,9	0,9	0,9
608	Improving crossing markings	0,95	0,95	1
702	Humps, bumps etc and speed limits	0,7	0,7	0,7
703	Traffic arrangements on streets	0,9	0,9	0,9
704	Measures supporting speed limit obedience	0,95	0,95	0,95
901	Installation of guard rails	0,8	0,95	1

* The road safety measure's impact coefficient shows the expected change in the number of accidents after a certain measure is implemented

became worse. Table 4 shows the accident data before the road safety measure implementation and after it. The numbers in red emphasise a negative change in the number of accidents after the measure was implemented. On several road sections the safety situation became significantly worse, ie the number of fatal accidents has increased by 2, 3 or even 4 times per year:

- Road A4 Vilnius–Varėna–Grodno, 15,00–15,50 km. In the period 1995–98 on this road section 8 injury and fatal accidents took place where 2 road users were killed and 9 injured. There are only two types of accidents: running on a pedestrian and collision of vehicles. In 1999, the intersection was equipped with traffic lights. The number of fatal accidents has decreased by 0,5 accident/year. The type of road accidents has changed: the number of pedestrian-involved accidents has decreased and the number of vehicle collisions has increased; therefore the number of injury accidents has increased up to 2 accidents/year.
- Road A7 Marijampolė–Kybartai, 38,70–40,80 km. In the period 1995–98, on this section of the main road 6 accidents occurred where 2 people were killed and 4 injured. The main type of accidents – running of a cyclist. In 1999 the guardrails were erected on this road section which had no effect on the reduction of accidents number. Due to the absence of any additional road safety improvement measures, the number of fatal and injury accidents on this road section has been constantly increasing (0,5 and 3,25 accidents/year, respectively).
- Road 130 Kaunas–Prienai–Alytus, 7,60–9,15 km. From 1995 to the end of 1998, on this road section 18 fatal and injury accidents were recorded where 20 road users were injured. The main type of accidents – running on a pedestrian. In 1999 the guardrails were erected here and the pedestrian crossing with a safety island. From the beginning of 2000 to the end of 2003, 28 accidents were recorded where 3 persons died and 35 got injuries. The number of accidents on this road section has been further increasing. The number of injury accidents has increased even by 3,75 accidents/year, of fatal accidents – 0,75 accident/year.

The investigation data obtained enabled to correct the current methodology and it gave a possibility to make a more precise forecast about the economic effect of the road

Table 4. Change in the number of accidents after the road safety improvement measures implemented in 1999

No	Road No	Beginning of section, km	End of section, km	Length of section, km	No of traffic safety measure	Total in 1995–1998			AADT vpd 1995–1998	AR 1995–1998	Total in 2000–2003			AADT vpd 2000–2003	AR 2000–2003	Actual reduction of AR	Number of 1995–1998 accidents/year		Number of 2000–2003 accidents/year		Number of 2000–2003 accidents/year	
						Number of accidents	Number of killed	Number of injured			Number of accidents	Number of killed	Number of injured				Fatal	Injury	Fatal	Injury	Fatal	Injury
1	A1	86,3	87,2	0,9	901	12	3	13	4800	1,903	7	3	6	5017	0,923	0,979	0,75	3,25	0,75	1,5	0	1,75
2	A1	104,38	105,4	1,02	901	4	1	5	8500	0,316	3	0	4	9042	0,194	0,122	0,25	1,25	0	1	0,25	0,25
3	A1	110,4	111,2	0,8	901	9	3	6	9000	0,856	1	1	0	10250	0,073	0,784	0,75	1,5	0,25	0	0,5	1,5
4	A1	120,4	120,9	0,5	101, 901	5	2	3	8500	0,806	1	0	1	8970	0,133	0,673	0,5	0,75	0	0,25	0,5	0,5
5	A1	259,8	260,3	0,5	901	4	2	2	4800	1,142	2	1	7	5121	0,465	0,676	0,5	0,5	0,25	1,75	0,25	–1,25
6	A2	9,05	12	2,95	901	15	3	18	11000	0,317	5	1	6	11670	0,087	0,230	0,75	4,5	0,25	1,5	0,5	3
7	A4	15	15,5	0,5	209, 412	8	2	9	10500	1,044	9	0	17	11040	0,971	0,073	0,5	2,25	0	4,25	0,5	-2
8	A6	7	14,3	7,3	101, 204, 604, 901	55	13	57	8600	0,600	42	9	57	9710	0,353	0,247	3,25	14,25	2,25	14,3	1	0
9	A6	28	28,4	0,4	105, 204, 409	7	1	7	5800	2,067	4	2	2	6150	0,968	1,098	0,25	1,75	0,5	0,5	–0,25	1,25
10	A7	24,22	27,25	3,02	101	6	4	5	4331	0,314	8	3	8	4789	0,329	-0,015	1	1,25	0,75	2	0,25	–0,75
11	A7	38,7	40,8	2,1	101	6	2	4	3528	0,555	14	4	17	3879	1,024	-0,469	0,5	1	1	4,25	-0,5	-3,25
12	A8	57,6	63,9	6,3	604, 608, 702, 703, 704, 901	61	10	66	7500	0,884	5	0	5	8102	0,058	0,826	2,5	16,5	0	1,25	2,5	15,25
13	A8	64	64,4	0,4	401	5	1	6	7200	1,189	0	0	0	7150	0,000	1,189	0,25	1,5	0	0	0,25	1,5
14	A9	54,8	56,3	1,5	101, 901	6	3	5	6500	0,421	6	2	7	6780	0,351	0,070	0,75	1,25	0,5	1,75	0,25	–0,5
15	A9	56,3	57,2	0,9	101	40	1	4	6500	0,468	4	0	8	6780	0,390	0,078	0,25	1	0	2	0,25	–1
16	A9	71,45	72,6	1,15	103, 105, 901	10	1	12	5446	1,094	8	4	4	6478	0,640	0,454	0,25	3	1	1	–0,75	2
17	A11	10,8	12,37	1,57	901	5	2	3	5800	0,376	1	0	1	5970	0,064	0,313	0,5	0,75	0	0,25	0,5	0,5
18	A13	2,05	3,07	1,02	407	7	2	16	5700	0,825	12	1	20	5840	1,200	–0,375	0,5	4	0,25	5	0,25	–1
19	A13	5,6	6,3	0,7	407	5	0	12	5700	0,858	4	1	6	5840	0,583	0,276	0	3	0,25	1,5	–0,25	1,5
20	A13	10,2	10,3	0,1	409	6	0	7	5700	7,210	0	0	0	5840	0,000	7,210	0	1,75	0	0	0	1,75
21	101	17	17,3	0,3	409	5	0	10	5500	2,076	1	0	1	6102	0,325	1,750	0	2,5	0	0,25	0	2,25
22	102	24,7	25,4	0,7	204, 409	6	0	8	2913	2,015	2	2	0	3012	0,565	1,450	0	2	0,5	0	–0,5	2
23	120	14,2	14,8	0,6	101	5	2	4	2600	2,195	1	1	3	2970	0,334	1,861	0,5	1	0,25	0,75	0,25	0,25
24	130	7,6	9,15	1,65	103, 105, 901	18	0	20	5000	1,591	28	3	35	5342	2,014	–0,423	0	5	0,75	8,75	–0,75	–3,75
25	132	2,50	4,45	1,95	209,407, 206,901	8	1	11	4864	0,578	4	0	4	5741	0,213	0,365	0,25	2,75	0	1	0,25	1,75
26	140	6,60	7,40	0,80	106,409	7	1	6	5000	1,199	2	0	2	5100	0,292	0,907	0,5	1,5	0	0,5	0,5	1
27	141	8,65	12,1	3,45	101, 203, 901	15	2	18	7243	0,411	14	1	22	7600	0,318	0,093	0,5	4,5	0,25	5,5	0,25	–1
28	153	0,95	1,90	0,95	101,105	4	2	3	3600	0,801	1	0	2	3756	0,167	0,634	0,5	0,75	0	0,5	0,5	0,25

safety improvement measures to be implemented and for the expected reduction in the number of accidents.

6. Conclusions and recommendations

1. Analysis of the increasing traffic volume and road safety situation on Lithuanian roads shows that the main indicators of road safety in our country are the worst, if compared to the other EU countries. Therefore it is necessary to implement the more effective measures for improving the road traffic safety.

2. Each year more than 200 accident concentration sites and black spots are identified on Lithuanian roads of state significance. Due to insufficient funds, allocated to road traffic safety improvement, the road safety improvement measures are implemented only on 15–30 road sections each year.

3. In Lithuania the efficiency of the road safety improvement measures after their implementation is assessed by using the TARVAL software. The effect of road safety measures on the Lithuanian roads is assessed by applying the impact coefficients. One stage were selected for the evaluation and 28 black spots, where in 1999 the road safety improvement measures were implemented. It was determined that in 15 road sections the implemented measures have justified themselves. In the remaining 13 sections the expected road safety results have not been achieved. Therefore the repeated detail analysis of the study road sections is necessary and the implementation of more effective improvements.

4. To properly evaluate and predict the effect of road safety measures after their implementation, it is recommended:

to correct the currently used impact coefficients of the road safety measures of TARVAL software;

to correct methodology for the economic evaluation of road safety measures;

having a sufficient amount of funds, to carry out the forecast of accident concentration sites and implementation of road safety improvement measures, not waiting until the section becomes a black spot.

5. The records of road accidents after the implementation of road safety measures should also include the damage-only accidents (part of fatal and injury accidents, after the road safety measures are implemented, gets into the category of damage-only accidents).

6. The current evaluation of the efficiency of road safety improvement measures and correction of its methodology in future will give a possibility to make more precise forecasts about the economic effect of the road safety improvement measures to be implemented and on the expected reduction in accident number.

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Submitted 13 March 2007; accepted 20 April 2007