TRANSPORT
ISSN 1648-4142 print / ISSN 1648-3480 online
2013 Volume 28(1): 97–107
doi: 10.3846/16484142.2013.782895

LITHUANIAN ROAD SAFETY SOLUTIONS BASED ON INTELLIGENT TRANSPORT SYSTEMS

Aldona Jarašūnienė[1], Nijolė Batarlienė[2]

[1]*Transport Research Institute, Vilnius Gediminas Technical University, Plytinės g. 27,*
LT-10105 Vilnius, Lithuania
[2]*Dept of Transport Management, Vilnius Gediminas Technical University, Plytinės g. 27,*
LT-10105 Vilnius, Lithuania
E-mails: [1]aldona.jarasuniene@vgtu.lt (corresponding author); [2]nijole.batarliene@vgtu.lt

Submitted 28 March 2012; accepted 13 June 2012

Abstract. The rapid growth of traffic intensity was predetermined by the dynamic change in the number of cars and the need for carriage. Vehicle congestion and high risk of accidents result in disappointment of many drivers and public transport users, causing psychological tension and increasing the accident rate. The accident rate is one of key indicators that help measuring processes of the transport system and its development. With the help of various road safety solutions, the modern world aims to ensure safe transportation and achieve reduction in the number of traffic accidents. Just as any other country, Lithuania is focusing on these issues as well. Reduction in the number of traffic accidents requires implementation of the national road traffic safety policy, which is one of the most important instruments that specify directions to be taken while implementing road safety solutions for roads with the highest traffic accident rate. The paper presents a methodology for calculating traffic intensity, which can be used while addressing road safety problems. The article describes the importance of Intelligent Transportation Systems (ITSs) for road safety issues and analysis of key traffic safety determinants. The core functions of ITSs are work with information and control of technologies. ITS services can make transport safer. The article examines the use of ITSs for estimation of road safety problems in Lithuania.

Keywords: traffic safety, estimation of traffic safety problems, traffic accident, ITS, information.

Introduction

Transport corridors of international importance and their branches crossing the territory of Lithuania create favourable conditions for local and international transportation of cargos and passengers as well as contribute to development of domestic and international trade. It is important that roads of Lithuania as a transit country were safe. Analysis of data on traffic accidents demonstrated that in Lithuania, accidents often repeat at same places, the so-called accident blackspots. Having analysed causes of traffic accidents, ITSs were used as a traffic safety improvement measure for elimination of such accident blackspots.

ITSs are one of the measures that can reduce the impact of road traffic. ITSs have many functions, including the monitoring of road traffic conditions and supply of such information to traffic participants.

Operation of ITSs is based on systems comprised of a well-developed network of equipment used for monitoring of weather and traffic conditions as well as information centres and means that can be used to inform drivers (various message signs, radio and etc.).

Just as any other computer technology, such as automated systems and optical data transmission, intelligent transport systems (ITSs) are rapidly improving. An intelligent transport system is an integrated system, which includes video surveillance, data transmission, data processing and automated management (Batarlienė 2011).

An intelligent transport system may be defined as an advanced application used by state authorities, the private sector and researchers to solve transport-related problems (Barfield, Dingus 1997).

Intelligent transport systems are the aggregate of information and telecommunication devices that ensure a safe and effective movement of vehicles, cargos and people on roads (Kirikova *et al.* 2003).

ITSs facilitate the management of transport flows by reducing congestion, air pollution, and time spent in traffic jams as well as increasing safety with the help of warnings regarding dangerous situations caused by human or environmental factors (Chowdhury, Sadek 2003).

ITSs are centrally managed information systems used in vehicles and road infrastructure, which can help reducing the duration of a journey and assuring the safety and convenience of drivers; in addition, they can significantly contribute to reduction of energy consumption and environmental pollution (Diebold 1995).

Benefits of ITSs may be grouped into five categories:

- increased safety;
- increased traffic capacity and reduction of congestion;
- increased mobility and convenience;
- reduced environmental pollution;
- boosted economy and increased employment (Ezell 2010).

In the past, road traffic control systems were often installed with the aim to provide one or two services that would function independently as different subsystems (Jarašūnienė 2008).

Use of Intelligent Transport Systems has been analysed by Barfield and Dingus (1997), Bekiaris and Nakanishi (2004), Chowdhury and Sadek (2003), Ezell (2010), Jarašūnienė (2008), Kachroo and Ozbay (2003), McDonald *et al.* (2006), Sussman (2005), Weidmann and Jakubauskas (2009), Hancock and Xu (2005), Anderson and Souleyrette (1998), Li and Miao (2003), Boile (2000), Schneider *et al.* (2007), Marma *et al.* (2005), Miller and Shaw (2001), Kabashkin (1998), Tan and Bowden (2004) and etc.

1. Analysis of the Key Determinants of Traffic Safety

In Lithuania, road safety is regulated by the Law on Road Traffic Safety (Lietuvos Respublikos Saugaus… 2000), international treaties, EU legislation and other legal acts. To ensure traffic safety, stabilize and reduce the number of forecasted accidents around the world, the General Assembly of the United Nations announced 2011–2020 as the Decade of Action for Road Safety. The European Union has adopted a strategy for 2050. The Lithuanian Law on Road Traffic Safety determines legal bases for state and municipal duties related to implementation of the traffic safety policy, traffic safety on roads in the Republic of Lithuania, training of traffic participants, the main rights and responsibilities of people responsible for road maintenance, customs and police officers as well as the main regulations regarding technical condition of vehicles, technical condition verification, registration of vehicles, and requirements for road safety in order to protect the lives of traffic participants and other people.

Reduction of accidents and assurance of road safety are the main tasks of the Road Maintenance and Development Programme (RMDP) – Law on Roads of the Republic of Lithuania (Lietuvos Respublikos Kelių įstatymas 1995; Lietuvos Respublikos Kelių įstatymo ... 2002), Law on the Financing of Road Maintenance and Development Programme of the Republic of Lithuania (Lietuvos Respublikos Kelių priežiūros… 2000, 2004).

An overview of different definitions of intelligent transport systems leads to a conclusion that ITS is a measure helping to effectively solve such transport problems as the accident rate, environmental pollution and congestion; besides, it may improve the mobility of people.

In order to increase traffic safety, it is worth paying attention to determinants that are related to roads, driving modes and etc. Determinants of traffic safety are as follow:

- determinants related to traffic participants;
- relief;
- external determinants.

Every EU country measures determinants of traffic safety differently. However, they all agree on the importance of links between them. A very important link exists between a traffic participant, a vehicle and a road. A traffic accident occurs due to a negative impact of one or two determinants and it is very rare that it is caused by all of them at once (Ezell 2010; Sussman 2005).

Driving under the influence is one of the problems that still exist in Lithuania. Alcohol determines worsening in human physiological indicators as attention is reduced (Barfield, Dingus 1997).

Worsening of physiological indicators is not a problem if traffic participants act carefully. However, alcohol reduces attentiveness by increasing subjective confidence making people think that they can easily deal with traffic safety difficulties (Barjonet 2001).

Research suggests that in a relationship between pedestrians and drivers, mime, gestures and motions play a certain role (Barjonet 2001):

- a driver lets a pedestrian cross a street sooner if the latter expresses his/her intention more clearly and in a more determined way;
- mutual respect between a driver and a pedestrian, such as thank-you signs, encourage traffic participants to engage in such behaviour.

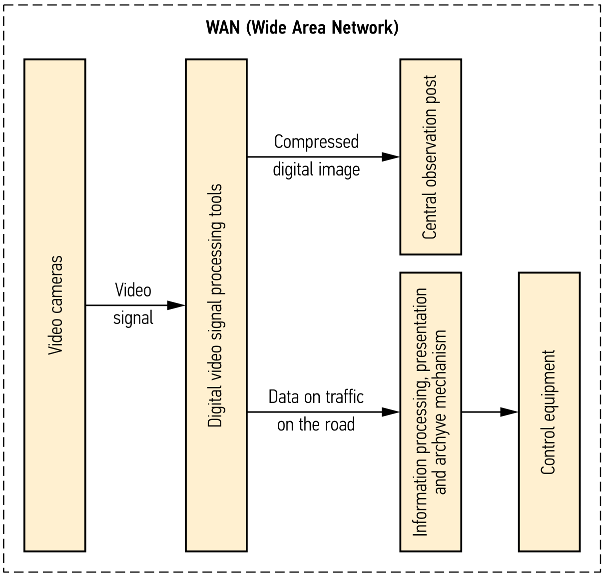

Fig. 1. The principle governing operation of intelligent transport management systems

The age of traffic participants has a great influence on the risk of accidents.

In scientific literature, accidents are classified into different types. The following ones are usually discussed (Ashmarta *et al.* 1997; Zdanavičiūtė 2003):

- a vehicle running over a pedestrian;
- collision of vehicles;
- vehicle overturn;
- vehicle collision with an obstacle;
- falling passengers.

Most often accidents occur due to violation of road traffic regulations by drivers, pedestrians, passengers, motorcyclists; also flagrant violations of technical exploitation regulations by transport sector employees; bad state of roads and road traffic organisation; or animals.

Accidents also occur due to unsafe behaviour of pedestrians on the road. According to the data by the Lithuanian Police Traffic Supervision Service, the following violation of the road traffic regulations by pedestrians are most frequent (Ashmarta *et al.* 1997; Averyanova *et al.* 2000):

- a pedestrian suddenly emerges from behind an obstacle (e.g. from behind a bus that stopped at a bus stop or a car parked along a pavement or roadside);
- a pedestrian suddenly steps in front of a backwards moving vehicle, driving in the same or the opposite direction;
- unpredictable pedestrian behaviour when a driver is given a wrong message by a pedestrian (e.g. a pedestrian who has been waiting for a car to pass, suddenly runs across the street);
- a pedestrian steps onto a road at a place where it is forbidden;
- a pedestrian suddenly emerges from an unlit zone of a road;
- a pedestrian violates regulations regarding street-crossing at marked passages and crossroad zones, etc.

The lack of moral responsibility can be named as an important cause of accidents. Therefore, to ensure traffic safety and solve problems, it is necessary to apply integrated measures that would foster the culture of traffic participants and develop their skills.

2. Methodology for Substantiation of Traffic Safety Improvement Measures Used in Lithuania

Use of road traffic safety measures in sections with high traffic accident rate or at blackspots may result in tangible benefits. However, each planned road safety measure should be assessed for its possible effect before it is implemented. In 1997, experts of the Technical Research Institute of Finland, with reference to the national experience (the Finnish model for assessing the effect of road safety measures TARVA, version 3.10), carried out the analysis of accidents on the Lithuanian highway A1 Vilnius–Kaunas–Klaipėda and suggested coefficients for the effect of traffic safety improvement measures as well as adapted their model to Lithuania, naming it TARVAL (Finnish National Road Administration. 1998. Lithuanian Road Safety Improvement Project. Final Report. Helsinki).

This methodology is still used in Lithuania, though it is evident that during the period of 12 years, it has become morally outdated and no longer conforms to the current road traffic safety situation in Lithuania. During the last period, Finland created more than 10 improved versions of this methodology (currently, they use version 4.10); some other countries have their own systems as well (Jarašūnienė, Miliauskaitė 2011).

Analysis of the methodology, intended for estimation of blackspots and nationally significant road sections with high accident rate was approved by the Minister of Transport and Communications – Order 'Methodology for the Estimation of Sections with High Accident Rate on the Roads of National Significance' (Lietuvos Respublikos Susisiekimo… 2011). The aim of this methodology is to define a road section with increased accident rate and, considering certain traffic parameters, evaluate the degree of possible danger of such sections (Jarašūnienė, Miliauskaitė 2011).

Having estimated blackspots of the entire network of Lithuanian highways and roads, the next step is to implement measures that would help removing such blackspots, i.e. measures that would reduce the number of traffic accidents. In order to reach this goal, a detailed analysis of blackspots is required. Most often, such analysis helps to reveal causes and circumstances of the majority of traffic accidents as well as choose the best measures for improvement of traffic safety, which would minimize an occurrence of a traffic accident.

The methodology for calculation of traffic intensity has been used in solving traffic safety problems on roads. Therefore, next part of this article presents these methods in more detail, providing statistical analysis of traffic intensity changes on roads of national significance, main, national and regional roads.

3. Methods for Calculating Traffic Intensity (TI) Averages

The following calculations were made in relation to all roads of national significance:

- the annual average daily traffic (AADT) of the total transport flow, the freight transport and every vehicle class on road sections, roads and road groups;
- the average daily traffic estimated on a quarterly basis (quarterly TI) of the total transport flow and the freight transport flow;
- the average daily traffic estimated on a monthly basis (monthly TI) of the total transport flow and the freight transport flow;
- the average daily traffic estimated on a daily basis (daily TI) of total transport flow and freight transport flow;
- the distribution of traffic intensity per day (provided by an hour as a percentage of the daily TI).

3.1. The Method for Calculating the Annual Average Daily Traffic (AADT) on a Road Section

Based on the data of stationary permanent traffic accounting posts, AADT was calculated using the following formula:

$$AADT = \frac{1}{365}\sum_{d=1}^{365} DT,$$

where: $AADT$ – the annual average daily traffic; DT – daily traffic; 365 – number of days in a year.

Based on the data of stationary periodical posts, where accounting is undertaken 4 times a week, and temporary posts (except for the ones where measurements are made once a year), $AADT$ was calculated following the Methodology for Calculation of the Annual Average Daily Traffic from Temporary Measurement Data.

Based on the data of stationary periodical posts, where traffic accounting is undertaken 2 times a year for a week, $AADT$ was calculated using the data of the adjacent section with a permanent post. With the help of this method and on the basis of measurements collected during each two weeks, individual $AADT$ estimations were calculated, i.e. $AADT_1$ and $AADT_2$. The final $AADT$ estimation result was calculated using the following formula:

$$AADT = \frac{1}{4}\left(3 \cdot AADT_1 + AADT_2\right),$$

where: $AADT$ – the annual average daily traffic at an examined post; $AADT_1$ – estimation of the average $AADT$ based on the measurement data of the week, which does not fall within the period of June–August; $AADT_2$ – estimation of the average $AADT$ based on the measurement data of the week, which falls within the period of June–August.

The annual traffic accounting is undertaken only at those sections, next to which at one of adjacent road sections the accounting is undertaken periodically or constantly. At those road sections, $AADT$ is calculated following the below-described procedure:

- the proportion of traffic intensities between sections is established;
- based on the data of periodical or permanent post, $AADT$ is calculated;
- at other road sections, $AADT$ is calculated based on the established traffic intensity proportion.

At road sections with traffic unaccounted for the current year, $AADT$ was calculated by multiplying the value of $AADT$ of the previous year by the traffic intensity change coefficient in the road group, to which the road under examination belongs.

The main road section:

$$I_{R_{cur.year}} = p_M \cdot I_{R_{prev.year}i} \cdot$$

The national road section:

$$I_{R_{cur.year}} = p_K \cdot I_{R_{prev.year}} \cdot$$

The regional road section:

$$I_{R_{cur.year}} = p_R \cdot I_{R_{prev.year}},$$

where: $I_{R_{cur.year}}$ – $AADT$ at the road section in the current year; $I_{R_{prev.year}}$ – $AADT$ at the road section in the previous year; p_M, p_K, p_R – traffic intensity change in the main, national and regional roads, accordingly (the current year according to the data by stationary permanent post data: $p_M = 1.088$, $p_K = 1.054$, $p_R = 1.036$).

3.2. The Method for Calculating the Annual Average Daily Traffic on a Road

$AADT$ was calculated for every road based on the data of all traffic accounting posts (also, where traffic accounting was done, and where traffic intensity was calculated). AADT of a road is calculated by evaluating the length of the road section and traffic intensity in that road section:

$$I_K = \frac{1}{L_K} \cdot \sum_{k=1}^{n}\left(I_R \cdot L_R\right),$$

where: I_K – $AADT$ on the whole road (A/N); L_K – the length of the road (km); I_R – AADT on an individual road section (A/N) L_R – the length of the road section (km); n – the number of road sections.

3.3. The Method for Calculating Traffic during a Quarter

Average daily traffic intensities of each quarter ($QADT$) are calculated from monthly average daily traffic intensities $MADT$, considering the number of days in a month:

$$QADT_1 = \frac{1}{D_1 + D_2 + D_3}\left(MADT_1 \cdot D_1 + MADT_2 \cdot D_2 + MADT_3 \cdot D_3\right);$$

$$QADT_2 = \frac{1}{D_4 + D_5 + D_6}\left(MADT_4 \cdot D_4 + MADT_5 \cdot D_5 + MADT_6 \cdot D_6\right);$$

$$QADT_3 = \frac{1}{D_7 + D_8 + D_9}\left(MADT_7 \cdot D_7 + MADT_8 \cdot D_8 + MADT_9 \cdot D_9\right);$$

$$QADT_4 = \frac{1}{D_{10} + D_{11} + D_{12}}\left(MADT_{10} \cdot D_{10} + MADT_{11} \cdot D_{11} + MADT_{12} \cdot D_{12}\right),$$

where: $QADT_1$, $QADT_2$, $QADT_3$, $QADT_4$ – the average daily traffic intensities during quarters 1÷4; $MADT_1$, $MADT_2$, ..., $MADT_{12}$ — the average daily traffic intensities of months 1÷12; D_1, D_2, ..., D_{12} – the number of days of months 1÷12.

3.4. The Method for Calculating Traffic during a Month

Average daily traffic intensities of months are calculated just for the main and national road sections. There traffic accounting is done constantly or periodically – 4 or 2 times per week.

The average daily traffic intensity during a month for stationary permanent traffic accounting posts is calculated based on the following formula:

$$MADT = \frac{1}{d}\sum_{k=1}^{d} DT_k ,$$

where: $MADT$ – the average daily traffic intensity during a month; DT – the daily traffic intensity; d – the number of days in a month; k – running number of the day of the month.

For the road section where traffic intensity was measured for 2 or 4 weeks at different quarters of a year, average daily traffic intensity during a month is calculated based on the following procedure:

- the annual average daily traffic intensity is calculated;
- the average daily traffic intensity for every month is calculated by choosing appropriate month coefficients k_i from Table 1, according to the following formula:

$$MADT_i = AADT \cdot k_i ,$$

where: $MADT_i$ – the average daily traffic intensity of the i-th month; $AADT$ – the annual average daily traffic intensity; i – the running number of the month; k_i – the coefficient of the i-th month, which is chosen taking into consideration the traffic intensity seasonality coefficient k_{seas}.

Table 1. Coefficients used for calculating average daily traffic intensities during a month (MADT) from AADT

Month	Traffic intensity seasonality coefficient k_{seas}		
	< 1.5	1.5÷2.0	> 2.0
	Month coefficients k_i		
1	0.79	0.67	0.61
2	0.88	0.79	0.71
3	0.94	0.88	0.78
4	1.02	0.98	0.84
5	1.07	1.08	0.99
6	1.10	1.19	1.26
7	1.13	1.32	1.71
8	1.14	1.32	1.78
9	1.09	1.07	0.96
10	1.01	0.98	0.81
11	0.97	0.94	0.82
12	0.86	0.77	0.69

3.5. The Method for Calculating Traffic During Weekdays

For calculating traffic intensity on weekdays, only the data of the posts that functioned at least for a week was taken. This intensity is expressed by the following proportion:

$$AWT_{sd} = WDT_{sd} \,/\, ADWT ,$$

where: $AWDT_{sd}$ – the average daily traffic intensity during the weekday; WDT_{sd} – the daily traffic intensity during the weekday; $ADWT$ – the average daily traffic intensity during the week.

3.6. Results of Traffic Intensity and Investigation of Its Change

AADT and transport flows on individual road groups are provided in Table 2.

On main roads, the passenger transport represented 82.6% of total vehicle flow, while the freight transport amounted to 17.4%.

On national roads, the passenger transport accounted for 89.3% of the total vehicle flow, while the freight transport amounted to 10.7%.

On regional roads, the passenger transport represented 89.4%, while the freight transport amounted to 10.6% of the total vehicle flow.

Fig. 2 provides the total traffic intensity change on roads of national significance during the years 2000–2010.

As compared to 2000, traffic intensity during the year 2010 increased by 44%.

4. Estimating the Traffic Safety Problem on Lithuanian Roads with the Help of ITS

An overview of statistics related to traffic safety in Lithuania and Europe allows suggesting that traffic safety is slowly improving in Lithuania. However, compared to other EU member states, it still remains a big problem.

So far, traffic safety has not been sufficiently secured, which can be related to the following problems:

- speed gauges are not always effective;
- the accident rate and its causes have not been studied thoroughly;
- Lithuanian roads do not use modern and effective ITSs, such as variable speed signs or average speed gauge;
- every ITS operates uncoordinatedly.

Table 2. *AADT* for each vehicle class depending on road groups in 2009–2010

Road groups	*AADT*, veh/day										
	2009			2010			Change in AADT in 2010/2009, %			Share of transport types in total flow in 2010	
	Total transport flow	Passenger transport	Freight transport	Total transport flow	Passenger transport	Freight transport	Total transport flow	Passenger transport	Freight transport	Passenger transport	Freight transport
Main roads	7278	6127	1151	7268	6006	1262	99.9	98.0	109.6	82.6	17.4
National roads	1988	1772	216	1931	1725	206	97.1	97.3	95.4	89.3	10.7
Regional roads	357	317	40	359	321	38	101.3	101.3	95.0	89.4	10.6

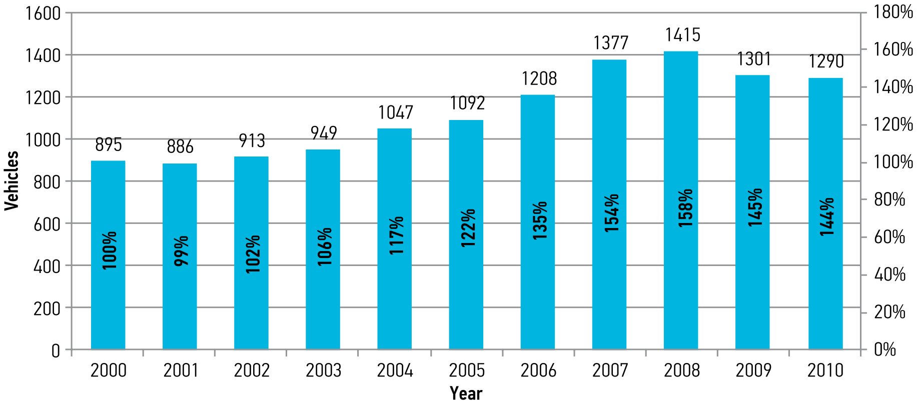

Fig. 2. Change in traffic intensity on roads of national significance in 2000–2010

Approximately 35% of all accidents in Lithuania in 2010 took place on the roads of national significance; however, the number of casualties on national roads was 2 times larger, which represents 71% of all casualties on national roads.

In 2010, 318 accidents were recorded, where 62 people died and 427 were injured. Accidents on highways represented 8.8% of all accidents that took place in the country in 2010. As compared to the year 2009, the number of accidents on highways in 2010 decreased by 2.5% (Table 3).

Every year, the majority of accidents take place on the highway A1 Vilnius–Kaunas–Klaipėda. Large numbers of accidents can be explained by the fact that this road is the longest highway in Lithuania. In addition, a large portion of the road is surrounded by villages, has bus stops and is used by pedestrians and motorcyclists, which increases the risk for an accident on a highway with high speeds allowed.

The greatest number of casualties in 2010 was registered on the highway A5 Kaunas–Marijampolė–Suvalkai. The A5 highway is intensely used by freight transport; besides technical parameters of the road are inadequate for the existing flow of vehicles.

Lithuanian road traffic safety problems could be resolved by the coordination of several measures. Average speed gauges should be used and regularized so that they could function together with variable message signs and the already operating weather observation system KOSIS.

Solving traffic safety problems with the help of ITS. Foreign and Lithuanian practice has revealed that

Table 3. Traffic accidents and victims of highways in 2007–2010

Road No	Traffic accidents*				Number of casualties*				Number of injured*			
	2007	2008	2009	2010	2007	2008	2009	2010	2007	2008	2009	2010
A1	149	92	63	53	47	18	16	6	186	107	73	72
A2	23	20	11	10	3	6	5	2	34	28	9	10
A3	3	1	3	1	1	1	2	0	3	0	1	1
A4	18	15	17	10	3	2	5	1	35	18	19	17
A5	52	46	24	29	11	13	8	10	83	64	29	52
A6	71	48	41	46	17	6	5	2	94	62	45	59
A7	21	16	18	16	5	6	9	4	23	18	26	25
A8	25	13	12	12	13	4	3	4	36	16	14	12
A9	42	27	12	13	5	7	1	2	53	35	15	15
A10	20	17	7	16	8	6	1	6	24	31	6	22
A11	70	48	30	30	10	10	9	5	101	69	46	34
A12	57	33	23	20	14	6	4	6	76	35	30	21
A13	25	17	13	9	6	3	2	1	39	21	14	16
A14	35	19	10	11	8	4	1	3	44	23	12	17
A15	11	15	5	5	7	6	0	1	19	21	6	7
A16	31	19	27	26	H	4	5	5	39	21	40	33
A17	6	5	7	9	1	4	5	4	6	8	12	11
A18	3	1	3	2	1	0	0	0	4	3	3	3
Sum total	662	452	326	318	171	106	81	62	899	580	400	427

Note. *Sections of roads of national significance crossing residential territories are included.

usually speed gauges are not sufficiently effective as drivers slow down for a particular stretch of a road where speed gauges are known to be and once they pass that stretch, they usually continue exceeding the speed limit. Lithuanian roads have only simple road signs that, regardless of the situation, mean the same restrictions, while foreign practice revealed that the use of variable message signs that present restrictions, corresponding to traffic conditions, significantly reduce the number of traffic accidents. The use of information obtained from the system KOSIS would facilitate an effective traffic management as variable message signs would inform drivers about the weather conditions and road coverage; repressive measures could also be used in order to make drivers slow down or warn of dangers.

The survey revealed that the most common cause for traffic accidents is unsafe speed; thus, in order to provide relevant suggestions for use of ITSs and prove their benefit for traffic safety, a Lithuanian road with the greatest car flow and the maximum speed allowed was chosen. The aforementioned road is the highway Vilnius–Kaunas–Klaipėda. Arrangement of speed gauges on the highway Vilnius–Kaunas–Klaipėda presented in Table 4. The statistical analysis of traffic accidents that occurred due to unsafe speed was on this highway was carried out. Relevant measures for resolution of this problem where suggested, indicating locations for the use of the suggested measures (specific places where marked on maps).

Table 4. Arrangement of speed gauges on the highway Vilnius–Kaunas–Klaipėda

No	Kilometre	Distance between speed gauges, km
1.	19.3	
2.	41.3	22
3.	62	20.7
4.	78.9	16.9
5.	87	8.1
6.	95.1	8.1
7.	101.3	6.2
8.	127.1	25.8
9.	161.9	34.8
10.	181.2	19.3
11.	204.7	23.5
12.	222.9	18.2
13.	290.9	68
Average distance between speed gauges, km		22.6

As Lithuanian drivers are best disciplined by repressive measures, on the basis of foreign experience, it is advisable to not only use simple speed gauges but also average speed gauges. In order to achieve a greater benefit and considering the traffic features, it is also advisable to tie in average speed gauges with variable message road signs and road observation system KOSIS, which has not yet been used for this particular purpose in Lithuania.

The study of traffic accidents that occurred on the highway Vilnius–Kaunas–Klaipėda and suggestions for improved traffic safety. According to the selected statistical data, many traffic accidents occurred on the highway Vilnius–Kaunas–Klaipėda and the majority of them were caused by unsafe speed or exceeded speed limit. Table 5 presents statistics about the number of traffic accidents and people killed or injured during those accidents in 2007–2010. This Table also presents the number of traffic accidents that occurred due to the exceeded speed limit.

Table 6 shows the percentage of all traffic accidents that occurred due to the exceeded speed limit. The majority of such traffic accidents were registered in 2010. During the year, the exceeded speed limit was the main reason of injuries caused to people. The largest number of casualties that resulted from the exceeded speed limit was registered in 2007.

Table 5. Statistics revealing the percentage of traffic accidents due to exceeded speed limit

Year	Traffic accidents	Number of casualties	Injuries
2007	149	47	186
2008	92	18	107
2009	63	16	73
2010	53	6	72

Table 6. The percentage of traffic accidents that occurred due to the exceeded speed limit in comparison to all traffic accidents

Year	Traffic accidents	Number of casualties	Injuries
2007	34.65%	37.50%	55.98%
2008	46.04%	22.22%	60.58%
2009	59.72%	31.25%	68.49%
2010	50.24%	11.71%	67.55%

5. Safety of Speed Depending on a Stretch of a Road

In order to thoroughly investigate the frequency of traffic accidents, the highway Vilnius–Kaunas–Klaipėda was divided into stretches of 10 kilometres; the accident rate on each stretch resulting from unsafe speed was studied.

It was identified that the stretch at 90÷100 km was the most dangerous stretch of the road with the largest number of accidents in 2007. This stretch witnessed 40 traffic accidents. The safest stretch was at 170÷180 km. The largest number of injured was in the same stretch where the largest number of traffic accidents occurred, i.e. at 90÷100 km. 13 traffic participants were injured there. The safest stretches of the road without any injured people where at following kilometres: 30÷40, 70÷80, 130÷140 and 160÷180. The majority of accidents that resulted in casualties was at kilometres 290÷300, which claimed lives of 7 people.

The study and statistical data of 2008 revealed the following: 23 traffic accidents occurred at kilometres 90÷100, while the smallest number – 3 accidents – were registered on the stretch between 130÷140 km. The largest number of the injured (10) was also registered on the stretch of 90÷100 km. The safest stretches of the road with no injured people at all were at following kilometres: 40÷50, 70÷80, 130÷180, 210÷220, 230÷240 and 290÷300. The largest number of casualties (2 people) was registered on 190÷200 km stretch.

In 2009, the most unsafe stretch of the road was 80÷90 km, where 30 accidents were registered. In addition, many traffic accidents were also registered on the stretch of 90÷110 km, with 25 accidents in every 10 km of the mentioned stretches. 7 people were injured in the above mentioned 90÷100 km stretch, 2 people were killed in the 140÷150 km stretch. The safest stretch of the road was at 10÷20 km; stretches that had no injured people were at kilometres 50÷80, 120÷130, 200÷210, 220÷240, 270÷280 and 290÷300.

In 2010, the most unsafe stretch of the road was at kilometres 70÷90. In addition, many traffic accidents were also registered at kilometres 90÷100 and 260÷270. The safest stretch of the road was at kilometres 50÷60, 120÷130, 180÷190, 210÷220, 230÷240 and 280÷290.

Having studied the overall statistics of traffic accidents, it was noted that the number of accidents in the stretch of the road at kilometres10÷20 has significantly declined in 2010. A significantly large number of traffic accidents – the largest accident rate in 4 years – was registered at kilometres 190÷200. A significant decrease was registered on the stretches 210÷220 and 230÷240 km. The largest decrease in 2009 was recorded on the stretch 280÷310 km (the dynamics of traffic accidents are graphically presented in Fig. 3).

The largest accident rate resulting from unsafe speed on the right road side of the highway Vilnius–Kaunas–Klaipėda in 2009 was recorded on the following stretches: 10÷20, 30÷40, 40÷50, 80÷90, 90÷100, 100÷110, 140÷150, 160÷170, 180÷190, 190÷200, 240÷250, 250÷260, 260÷270, 280÷290, 300÷310. 124 traffic accidents were registered with 27 injured persons and 3 casualties.

The majority of accidents in 2010 occurred on 90÷100 km stretch, where 28 traffic accidents were registered. The minority of accidents occurred on the following stretches: 50÷60, 120÷130, 230÷240. The largest number of casualties was registered on stretches 90÷100 and 260÷270, while the largest number of injured people (10) was registered on the stretch at kilometres 90÷100.

On the left road side, the first stretch, starting from Vilnius and going to Klaipėda, where 1 person was injured, was at kilometres 20÷30. The total of 5 accidents occurred on the stretch. 11 traffic accidents with 3 people injured were recorded on 80÷90 km stretch; 100÷110 km stretch witnessed 5 traffic accidents with 3 injuries. 3 traffic accidents with 2 injuries were recorded on 110÷120 km stretch. As many as 9 traffic accidents were recorded on 130÷140 km stretch, where 1 person was injured. 4 traffic accidents with 2 injured and 1 casualty occurred on the stretch at kilometres 150÷160. 170÷180 km stretch witnessed 4 traffic accidents with 1 person injured. 1 person was killed and 1 injured at kilometres 190÷200 (6 traffic accidents). 5 traffic accidents with 1 injury were recorded on 210÷220 km stretch. 1 injury was also recorded on 240÷250 km stretch; however, fewer accidents (3) were recorded on the stretch.

The summary of traffic accidents resulting from exceeded safe speed on the highway A1 Vilnius–Kaunas–Klaipėda in 2010 revealed that on the right and on the left sides of the road, 72 people were injured and 6 were killed. The highway was divided into 60 stretches every 10 km. 25 stretches were found to be the most dangerous as they witnessed injuries of casualties.

On the basis of experience in countries that use average speed gauges, the number of traffic accidents was reduced by up to 85%. Lithuania could also install average speed gauges every 10 km to measure the average speed of vehicles. Average speed gauges are effective when installed at a distance of 300 m up to 10 km. The arrangement of gauges is presented in the map, in Figs 4 and 5. The spots for gauges were selected on the basis to the accident rates on stretches of the road.

Having linked the weather observation system KOSIS, which is already in use, with variable message signs, it would be possible to achieve an even greater reduction in the accident rate. Evidence suggests that such systems reduce the number of traffic accidents by 30%. In case of a slippery road surface, this information could be displayed on variable message signs, also reducing the allowed speed. The same thing could be done in case of other dangers: traffic jams, traffic accidents, and etc. In

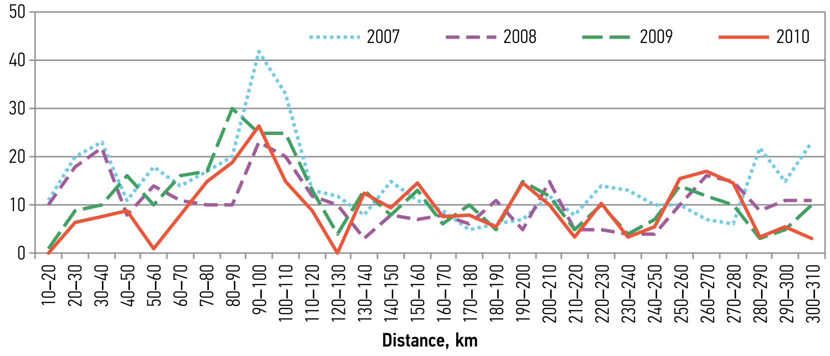

Fig. 3. Fluctuation of traffic accidents of the highway A1 in 2007–2010

addition, variable message signs could be used in order to close one lane and direct all cars to another. Variable message signs should be located behind every bigger entrance to the road. It is necessary to join all ITSs into one system, thus average speed gauges, which respond to speed changes, should be an inseparable part of such system.

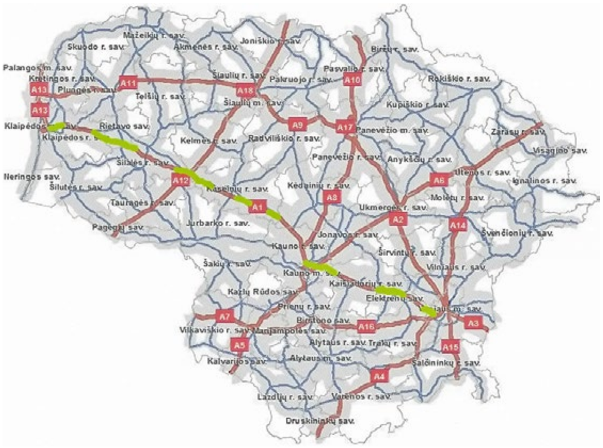

Fig. 4. The arrangement of average speed gauges on the right side of the road

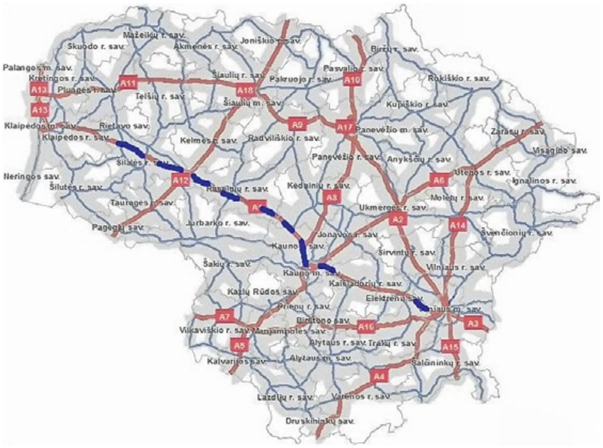

Fig. 5. The arrangement of average speed gauges on the left side of the road

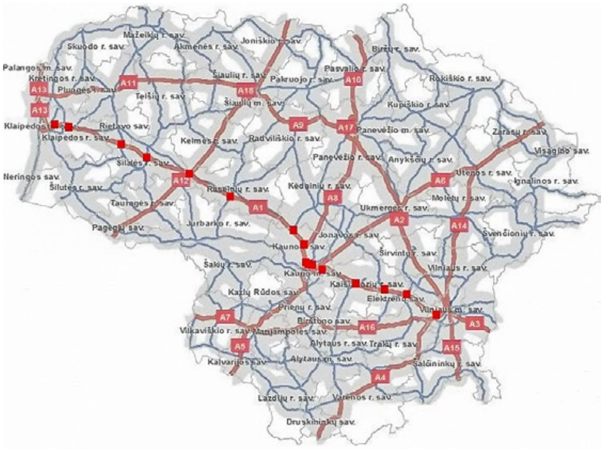

Fig. 6. The arrangement of variable message road signs

Variable message signs are placed next to bigger entrances to the road. On A1 highway, variable message signs should be placed in both traffic directions next to Grigiškės, Vievis, Elektrėnai, Žiežmariai and Rumšiškės. In the territory of Kaunas, 3 variable message signs should be placed by Niveronys, Savanorių pr. and the Western Bypass. Variable message signs should also be placed next to Sitkūnai, Cinkiškiai, Girkalnis, Kryžkalnis, Stungaičiai, Gargždai and the first Klaipėda roundabout. In total, 17 pairs of such signs should be installed (spots are indicated in Fig. 6).

Evaluation of losses incurred by the Lithuanian economy due to traffic accidents. If one system of variable message signs costs LTL 277500 (1 € = 3.45 LTL), 17 such systems would amount to LTL 9435000, while their maintenance would require for an annual amount of approximately LTL 5950000. It might seem expensive. However, on the basis of experience of countries that managed to decrease the number of injuries and casualties by 30%, and having in mind that one person's death costs LTL 1400000 for the country, while an injury amounts to LTL 150000, we may conclude that it is not as expensive as it seems. In 2010, 6 deaths and 72 injuries were recorded on the highway A1. The economic damage for the country amounted to LTL 19200000. In the first year, this system would not bring dividends, but the return on investments would become visible as early as in the second year.

The damage incurred by the state depends on the number of the injured on Lithuanian roads. The average material damage of one recorded accident to the state is estimated on the basis of certain tariffs. The accident tariffs are set using the methodology for calculation of losses incurred due to accidents. The extent of the damage incurred by the state changes depending on the level of the economy and inflation rate of the country.

As compared to 2009, the price per each casualty and injured went up by 2.2% in 2010. The increase in the price was predetermined by national inflation. Although the prices increased, the damage to the state due to accidents was smaller in 2010 than that in 2009.

Each year, collisions as well as injuries and casualties of pedestrians generate great losses to the Lithuanian economy. In 2010, collisions accounted for 33.02%, while injuries and casualties of pedestrians totalled 31.62% of all losses incurred by the state due to accidents.

The greatest damage every year is incurred by the Lithuanian economy due to irresponsible behaviour of 15÷24 year old drivers. In 2010, the damage done by 15÷24 year old youth to the Lithuanian economy amounted to LTL 204.6 million.

Conclusions

1. The analysis of Lithuanian roads suggests that average speed gauges should be used together with variable message signs and weather observation system KOSIS.
2. Traffic safety insurance should be the main priority. It has been proved that traffic safety improvement requires perception and evaluation of the main determinants and possibility to influence them.

3. The removal of blackspots requires both engineering of traffic safety improvement measures and educational activity, which stimulates safe behaviour of road traffic participants. Each implemented traffic safety improvement measure must bring a certain benefit to the public, thus it is necessary to estimate their impact on traffic safety.
4. So far, traffic safety improvement measures have been evaluated using the methodology, which was developed at the Finnish Technical Research Centre and later adapted to Lithuania. This methodology is applied to remove the existing blackspots; however, it cannot be used for the prediction of traffic accidents and their prevention.
5. The methodology for calculation of traffic intensity provided in the article was used while resolving road traffic safety problems.
6. The statistical analysis of the most bustling highway (A1) Vilnius–Kaunas–Klaipėda revealed that approximately more than 45% of road accidents occur due to unsafe speed. 34% of people were killed and 59% of people were injured due to the same reason (A1 highway was divided into stretches of 10 kilometres in order to study all traffic accidents that occurred; stretches of the road with the highest accident rate (people killed or injured) were established).
7. As regards traffic safety problems, it has been recommended to install average speed gauges at stretches of the road with the highest accident rate. The best measures for drivers are punitive rather than informative. The recommended average speed gauges would force drivers to slow down not only before the very gauge, but also in the entire stretch of the road. Currently, drivers slow down only driving by a stationary speed gauge. In addition, variable message signs have also been recommended due to quickly changing traffic conditions. All measures should be used together, so that the maximum effectiveness could be achieved.
8. All recommendations were economically evaluated using the forecasting method. Average speed gauges would pay dividends in the period of one year, while variable message signs – within the period of two years. The economic benefit of both systems during the first year would amount to LTL 11761250.

References

Anderson, M. D.; Souleyrette, R. R. 1998. Simulating traffic for incident management and ITS investment decisions, in *Crossroads 2000 Proceedings,* August 19–20, 1998, Ames, Iowa, 7–11.

Ashmarta, E. M.; Viktorova, E. N.; Viktorova, L. N., *et al.* 1997. *Kriminalistika*. Moskva: Yurist. 760 s. (in Russian)

Averyanova, T. V.; Belkin R. S.; Korukhov, Yu. G.; Rossinskaya, E. R. 2000. *Kriminalistika*. Moskva: Norma–Infra-M. 990 p. (in Russian)

Barfield, W.; Dingus, T. A. 1997. *Human Factors in Intelligent Transportation Systems.* Psychology Press. 480 p.

Barjonet, P.-E. 2001. *Traffic Psychology Today*. Springer. 392 p.

Batarlienė, N. 2011. *Informacinės transporto sistemos*. Vilnius: Technika. 340 p. (in Lithuanian) http://dx.doi.org/10.3846/1217-S

Bekiaris, E.; Nakanishi, Y. J. 2004. *Economic Impacts of Intelligent Transportation Systems*, Vol. 8: Innovations and Case Studies. JAI Press. 666 p.

Boile, M. P. 2000. Intermodal transportation network analysis – a GIS application, in *10th Mediterranean Electrotechnical Conference MELECON 2000*: *Proceedings*, 29–31 May, 2000, Vol. 2. 660–663. http://dx.doi.org/10.1109/MELCON.2000.880020

Chowdhury, M. A.; Sadek, A. W. 2003. *Fundamentals of Intelligent Transportation Systems Planning*. Artech House. 210 p.

Diebold, J. 1995. *Transportation Infostructures: the Development of Intelligent Transportation Systems.* Praeger. 224 p.

Ezell, S. 2010. *Explaining International IT Application Leadership: Intelligent Transportation Systems*. 53 p. Available from Internet: http://www.itif.org/files/2010-1-27-ITS_Leadership.pdf

Hancock, K. L.; Xu, J. 2005. *Modeling Regional Freight Flow Assignment Through Intermodal Terminals*. Project No. UMAR UTC Year 15. 26 p. Available from Internet: http://utc.mit.edu/uploads/files/15Hancock%20UMAR15-6.pdf

Jarašūnienė, A. 2008. *Intelektualiosios transporto sistemos:* monografija. Vilnius: Technika. 200 p. (in Lithuanian). http://dx.doi.org/10.3846/1424-M

Jarašūnienė, A.; Miliauskaitė, L. 2011. The estimation on traffic safety problems in roads on Lithuania using ITS, in *Proceedings of the 11th International Conference 'Reliability and Statistics in Transportation and Communication' (RelStat'11)*, 19–22 October 2011, Riga, Latvia, 327–334.

Kabashkin, I. V. 1998. Main activities in Latvian transport sector of the intelligent transport systems programs, *Computer Modeling and New Technologies* 2: 61–65.

Kachroo, P.; Ozbay, K. 2003. *Feedback Ramp Metering in Intelligent Transportation Systems*. Springer. 328 p.

Kirikova M.; Grundspenkis J.; Wojtkowski W.; Wojtkowski, W. G.; Wrycza, S.; Zupančič, J. 2003. *Information Systems Development: Advances in Methodologies, Components and Management*. Springer. 460 p.

Li, Q.; Miao, L. 2003. Integration of China's intermodal freight transportation and ITS technologies, in *Proceedings of the 2003 IEEE International Conference on Intelligent Transportation Systems*, 12–15 October 2003, Vol. 1. 715–719. http://dx.doi.org/10.1109/ITSC.2003.1252044

Lietuvos Respublikos Kelių įstatymas. 1995 m. gegužės 11 d. Nr. I-891. Vilnius. Available from Internet: http://www3.lrs.lt/pls/inter3/dokpaieska.showdoc_l?p_id=412054 (in Lithuanian).

Lietuvos Respublikos kelių įstatymo pakeitimo įstatymas. 2002 m. spalio 3 d. Nr. IX-1113. Vilnius. Available from Internet: http://www3.lrs.lt/pls/inter3/oldsearch.preps2?a=188756&b= (in Lithuanian)

Lietuvos Respublikos Kelių priežiūros ir plėtros programos finansavimo įstatymas. 2000 m. spalio 12 d. Nr. VIII-2032. Vilnius. Available from Internet: http://www3.lrs.lt/pls/inter3/dokpaieska.showdoc_l?p_id=334712&p_query=&p_tr2= (in Lithuanian).

Lietuvos Respublikos kelių priežiūros ir plėtros programos finansavimo įstatymo pakeitimo įstatymas. 2004 m. lapkričio 9 d. Nr. IX-2546. Vilnius. Available from Internet: http://www3.lrs.lt/pls/inter3/oldsearch.preps2?a=245864&b= (in Lithuanian)

Lietuvos Respublikos Saugaus eismo automobilių keliais įstatymas. 2000 m. spalio 12 d. Nr. VIII-2043. Vilnius. Available from Internet: http://www3.lrs.lt/pls/inter3/dokpaieska.showdoc_l?p_id=440305&p_query=&p_tr2=2 (in Lithuanian).

Lietuvos Respublikos susisiekimo ministro įsakymas dėl avaringų ruožų nustatymo valstybinės reikšmės keliuose metodikos patvirtinimo. 2011 m. birželio 7 d. Nr. 3-342. Vilnius. Available from Internet: http://www3.lrs.lt/pls/inter3/dokpaieska.showdoc_l?p_id=401193&p_query=&p_tr2=2 (in Lithuanian).

Marma, A.; Eidukas, D.; Žilys, M.; Valinevičius, A. 2005. Intelektualiųjų transporto valdymo sistemų efektyvumas, *Elektronika ir elektrotechnika* (6): 61–66. (in Lithuanian)

McDonald, M.; Hall, R.; Keller, H. 2006. *Intelligent Transport Systems in Europe: Opportunities for Future Research*. World Scientific Pub Co. 326 p.

Miller, H. J.; Shaw, S.-L. 2001. *Geographic Information Systems for Transportation: Principles and Applications*. Oxford University Press. 480 p.

Schneider, W.; Asamer, J.; Mrakotsky, E.; Toplak, W. 2007. Influence of environment conditions on traffic flow, in *Proceedings of the 2007 IEEE Intelligent Transportation Systems Conference (ITSC 2007)*, September 30–October 3, 2007, 302–307. http://dx.doi.org/10.1109/ITSC.2007.4357630

Sussman, J. M. 2005. *Perspectives on Intelligent Transportation Systems (ITS)*. Springer. 246 p.

Tan, A. C.; Bowden, R. O. 2004. *The Virtual Intermodal Transportation System (VITS)*. Final Report. 130 p. Available from Internet:
http://ncit.msstate.edu/PDF/VITS_Project.pdf

Weidmann, U.; Jakubauskas, G. 2009. Multimodalinės privataus ir viešojo transporto sąveikos didinimo galimybių panaudojant intelektines transporto sistemas ir paslaugas tyrimas, *Mokslas – Lietuvos ateitis = Science – Future of Lithuania* 1(6): 81–86. (in Lithuanian)
http://dx.doi.org/10.3846/mla.2009.6.17

Zdanavičiūtė, I. 2003. Baudžiamosios atsakomybės už transporto eismo saugumo taisyklių pažeidimus problemos pagal naująjį Lietuvos Respublikos baudžiamąjį kodeksą, *Jurisprudencija* (45): 116–122. (in Lithuanian)