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THE ANALYSIS OF TRAFFIC ACCIDENTS ON LITHUANIAN REGIONAL GRAVEL ROADS

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Abstract. A great number of serious road accidents occur all over the world every year. In spite of some progress in this area, road traffic safety has remained an acute problem in recent years. Traffic accidents on the road depend on the following factors: road traffic volume, road traffic speed, road condition, weather conditions for traffic, driving experience and driving culture. All these factors are related to traffic safety, human lives and health. The main goal of this work is to provide a statistical analysis of traffic accidents and investigate the causes, structure, dynamics and seasonal character of traffic accidents on Lithuanian regional gravel roads. It has been established that seasons play an important role for traffic accidents on regional gravel roads in Lithuania. Rates for traffic accidents increase from spring to autumn. The number of traffic accidents on Lithuanian roads decreased considerably in 2008 and 2009.

Keywords: road, gravel road, gravel pavement, traffic accident, traffic volume, traffic speed, accident rate, dynamics, traffic, traffic safety.

Introduction

The Republic of Lithuania possesses the road network of National Significance (NS) with a total length of about 21300 km. Gravel roads make a large part of the total road network in some countries. The current situation in Lithuania shows there are 7604.08 km of gravel roads (GR) covering 35.8% of the NS road network (Lithuanian Road Administration... 2012). The neighbouring Baltic countries point out that GR make a major part of NS road networks. Latvia has 11823.66 km of GR, which makes 58.68% of the whole road network while Estonia counts 6018 km of GR, which makes 36.4% of that (Latvian State Roads 2012; Estonian Road Administration 2012). GR in Finland covers 28000 km of the national territory (35.9% of the network) while in Sweden it makes 19700 km (20% of the network) (Finnish Transport Agency 2012; Centre for Economic Development… 2012; Swedish Transport Administration 2012).

The construction, operation and maintenance of GR are vital issues. Since 1998, Lithuania has been implementing the Gravel Roads Paving Programme, which is a part of the maintenance and development programme of NS roads. The programme focuses on improving transport links between settlements, reduction in traffic accidents, dust level and road maintenance costs as well as is aimed at increasing traffic safety. The surface of GR having high traffic density is rapidly wearing, and therefore cannot protect the base layer and subgrade from environmental and other harmful effects.

A number of countries worldwide, including Lithuania, have conducted investigations establishing conditions for roads (roughness, noise, etc.) and pointing to the influence of various factors (changes in seasons, weather conditions, traffic intensity and technical state). Climate and an increase in traffic are supposed to affect not only traffic safety on GR but also comfortability and communication time.

Road traffic safety depends on many factors, one of which is road surface texture. Large quantities of moving heavy vehicles deform the pavement surface and cause rutting. Field observations on damage to unpaved roads disclose that spring warming is a critical period for the formation of ruts, and the washboard effect of roughness having a strong impact on traffic safety can be formed both in the wet and dry periods of time (Shoop *et al.* 2006). Climatic winter conditions also make a significant impact on road safety. In winter time, sleet and snow on the road increase the number of traffic accidents up to 50% in the United Kingdom (Andersson, Chapman 2011).

Investigations into gravel material used for the shoulder pavement of low-volume roads in Lithuania

indicate that such material is unsuitable and cannot be compacted due to its grading. The authors proposed using proper material for increasing the structural strength of the shoulders of low-volume roads thus preventing them from damage (Vorobjovas, Žilionienė 2008).

Design solutions to the Gravel Roads Paving Programme in terms of traffic safety were examined by Gintalas *et al.* (2008). Dangerous road sections on the reconstructed or being reconstructed sections were identified, and the analysis of real or predictable accident rates on these sections was carried out.

When implementing the Gravel Road Paving Programme in Lithuania in 1998–2005, the mathematical model KAMIS for economic feasibility evaluation of gravel road paving was used for developing investment projects proved to be an effective tool for justifying gravel road paving (Skrinskas, Domatas 2006).

The analysis of statistical data on the rate for traffic accidents in Lithuania was performed by Prentkovskis *et al.* (2010a, 2010b). In 2008–2009, the number of traffic accidents registered by the Highway Patrol Police in Lithuania decreased approximately 1.3÷1.6 times. In 2009, collisions with vehicles made the largest portion of all traffic accidents (33.4%) and drivers were the main perpetrators of traffic accidents (73.6%).

Most of traffic accidents recorded in Turkey include the age groups of drivers of 30÷39 and 20÷29 years, weekdays from Friday to Sunday and road users without any or only basic education level (Sari *et al.* 2009). The study on young drivers who committed traffic accidents in the United States of America revealed the following factors of higher risk: low driving experience (age) of road users, the irregular use of safety belts and driving impairment under extreme conditions (Vachal, Malchose 2009).

High priority is given to the prevention of drunk-driving or driving under the influence of various psychoactive substances. Alcohol is related to nearly a half of all traffic accident deaths in the city of San Paolo (Ponce *et al.* 2011). The odds for involvement in fatal road traffic accidents in Norway for different substances or a combination of substances were in an increasing order: single drug < multiple drugs < alcohol only < alcohol + drugs; for using single substance: medical drug or THC < amphetamine/methamphetamine < alcohol (Gjerde *et al.* 2011).

Traffic flow on a straight road segment was examined by Junevičius *et al.* (2011). Two different cases were simulated. Relationships between traffic volume, traffic speed and traffic emissions were examined.

To evaluate the importance of the interaction levels of transportation process parameters, Sivilevičius (2011) recommended the method of Analytic Hierarchy Process (AHP).

Road traffic safety in the Baltic States was reviewed by Lama *et al.* (2006). Different methods chosen by transport policy makers for improving traffic safety in every state were compared, and some positive trends were described.

Road traffic safety in the main road network of Latvia was assessed by Lazda and Smirnovs (2009). The methods based on the accident rate and accident frequency were used.

Sokolovskij *et al.* (2007) investigated interaction between automobile wheel and road border.

Prentkovskis *et al.* (2010a, 2012) investigated deformation state of metal road guardrailss.

Kapski and Leonovich (2006) evaluated accident rates using the same probability of the method used for predicting intersection accidents. With the help of the method for potential danger, Kapski *et al.* (2007) forecasted traffic accidents in the conflict areas of the street.

The study performed by Karlaftis and Golias (2002) was aimed at determining the effects of road geometry and traffic volumes on the rates for rural roadway accidents. By using a rigorous non-parametric statistical methodology known as hierarchical tree-based regression, the authors made a conclusion that traffic accidents could be influenced by the average daily traffic volume, road width, road stretch servicing and maintenance parameters as well as by the type of the friction of the road surface and pavement type.

The number of traffic accidents on GR can be decreased by widening the carriageway, improving roadside infrastructure (carriageway smoothness and visibility in the overall plan), reducing the number of crossroads (Zegeer *et al.* 1994), increasing pavement width (Sulistio 2010), introducing criminal responsibility for a dangerous behaviour of road users (Novoa *et al.* 2011), as well as by employing active and passive speed control measures, directing traffic away from residential areas, increasing the number of pedestrians and cyclists, providing relevant information to the public (Short, Pinet-Peralta 2010) and applying traffic control elements.

The risk of driving on the roadway with the posted speed limit of 80 kilometres per hour was reviewed by Dhungana and Qu (2005). The study allowed the authors to conclude that higher risks of deaths and serious injuries in crashes on 80 kmh-roads had links with teen drivers, low restraint use rate, alcohol involvement, single-vehicle fixed object and rollover crashes as a result of speeding or driving too fast on two-lane GR.

The criteria for setting speed limits on GR were defined by Dissanayake and Liu (2011). Data on field speed were collected on a number of straight, level sections of GR with sufficient sight distance in Kansas. Several sites located in two adjoining counties using two different criteria for setting speed limits were also specifically selected for comparison purposes. It was determined that the posted speed limit on GR could not always help with improving operational conditions and safety.

The study and evaluation of the effect on taking the land for public needs at the cost of GR reconstruction were made by Gintalas *et al.* (2007). The article gives some recommendations concerning the necessity of correcting the road plan and reducing related costs.

The present study is aimed at providing a statistical analysis of traffic accidents on Lithuanian regional GR. Data on traffic accidents, traffic volume and traffic speed on Lithuanian regional GR for period 2004–2010 provided by Lithuanian Road Administration under

the Ministry of Transport and Communications of the Republic of Lithuania (2012), Lithuanian Department of Statistics (Statistics Lithuania 2012), Transport and Road Research Institute (2012) and the Police Department under the Ministry of the Interior of the Republic of Lithuania (2012) were collected and analysed.

1. Lithuanian Road Network of National Significance

Lithuanian road network of national significance consists of the main (1738.5 km), national (4939.3 km) and regional (14590.6 km) roads of the total length of 21268.4 km (Fig. 1).

Within the investigated period from 2004 to 2010, the dynamics of Lithuanian road network of national significance remained almost unchanged, except for regional roads paved according to Lithuanian Gravel Roads Paving Programme (*Lietuvos žvyrkelių asfaltavimo programa*) (Fig. 2).

The most important factor influencing the rate for traffic accidents is the parameter of traffic volume. The average of annual daily traffic volume (further AADT) on each road calculated based on road data obtained from traffic accounting posts (the places traffic volume was measured and calculated) is presented in Fig. 3.

The road AADT is calculated evaluating the length of each segment of the road and traffic volume on the considered road segment (Transport and Road Research… 2012):

$$I_R = \frac{1}{L_R} \cdot \sum_{R=1}^{n} \left(I_S \cdot L_S \right), \quad (1)$$

where: I_R is the road AADT (veh./day); L_R is road length (km); I_S is the AADT of the road segment (veh./day); L_S is the length (km) of the road segment; n is the number of road segments.

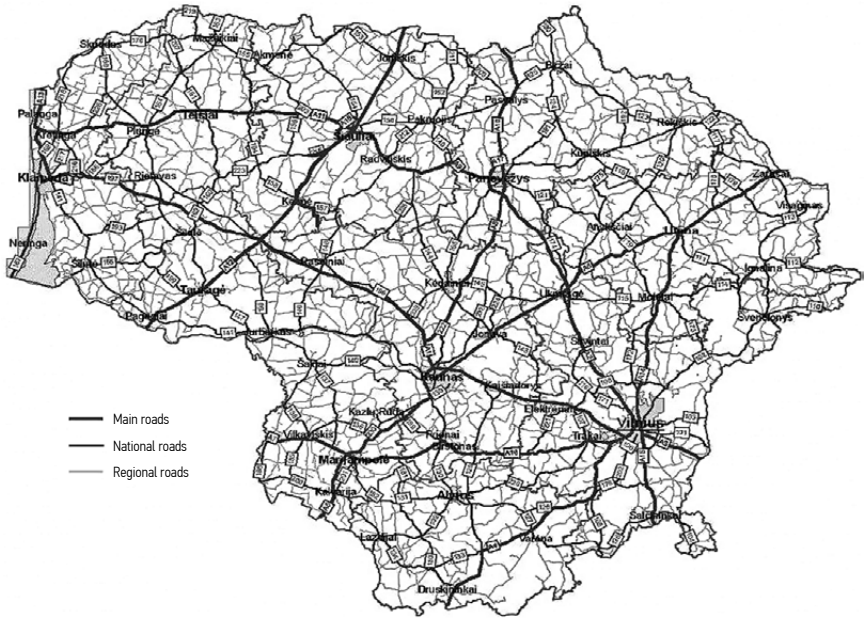

Fig. 1. Lithuanian road network of national significance (Lithuanian Road Administration… 2012)

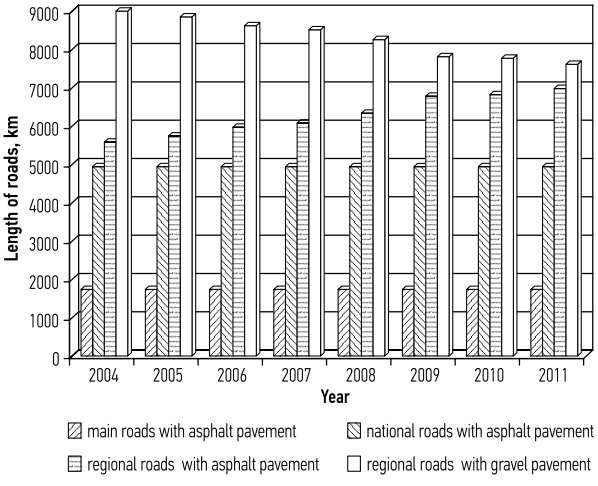

Fig. 2. The dynamics of Lithuanian road network of national significance (Lithuanian Road Administration… 2012)

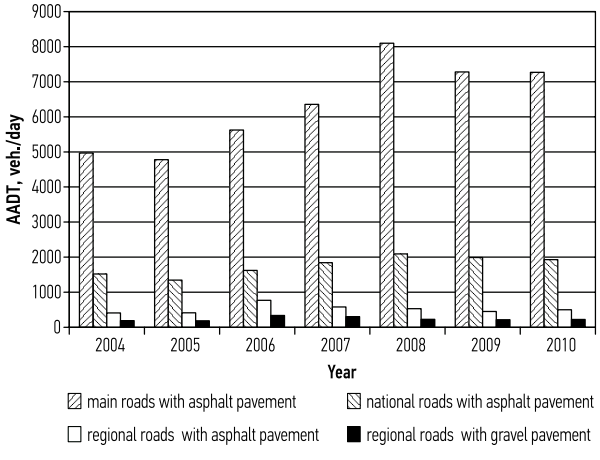

Fig. 3. The average annual daily traffic volume on Lithuanian roads of national significance (Transport and Road Research… 2012)

Based on accounting data on stationary permanent traffic volume, AADT is calculated applying the formula (Leduc 2008; Transport and Road Research… 2012):

$$AADT = \frac{1}{365}\sum_{d=1}^{365} DT, \quad (2)$$

where: *AADT* is the average annual daily traffic volume; *DT* is daily traffic volume; 365 is the number of days per year.

Another important factor influencing the rate for traffic accidents is vehicle speed on the road. The average speed of vehicles is related to the maximum permissible speed on a road segment and depends on the speed limits of a particular road segment (for example, road works) and different traffic conditions (for example, different periods of winter weather, high traffic volume or permanent traffic jams). The average speed of vehicles according to accounting data on stationary permanent traffic volume (based on accounting data for GR with mobile constant traffic volume) is as follows (Fig. 4).

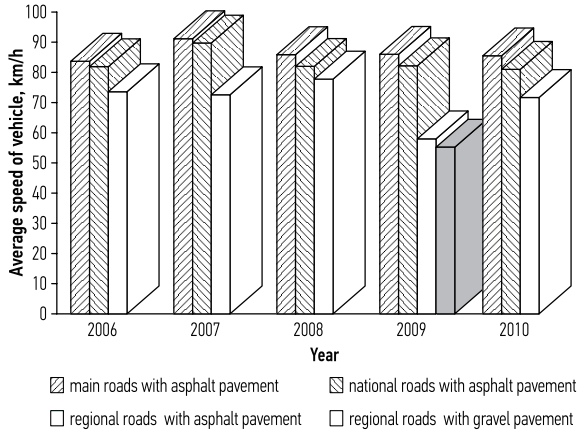

Fig. 4. The average vehicle speed on Lithuanian roads of national significance (Transport and Road Research… 2012)

There are no data on traffic speeds on regional gravel roads, except for 2009.

2. Evaluating Traffic Accidents on Lithuanian Roads of National Significance

Evaluating traffic accidents in absolute terms is not always correct. To compare the rate of traffic accidents of various regions or countries considering a different traffic volume, traffic speed, the number of vehicles and population, relative traffic accident rates, including the number of traffic accidents per 1 million population, the number of traffic accidents per 1000 km of roads and the number of traffic accidents per 1000 vehicles are used. The number of victims (injured or killed) in traffic accidents is also taken into account (Fig. 5).

The length of Lithuanian gravel roads is 7604.08 km, which makes 35.8% of the national road network. The number of traffic accidents on GR does not reach 10% of the total number of traffic accidents on all roads (Fig. 6). A low level of accidents that involve motor vehicles on GR compared to the total amount of traffic accidents

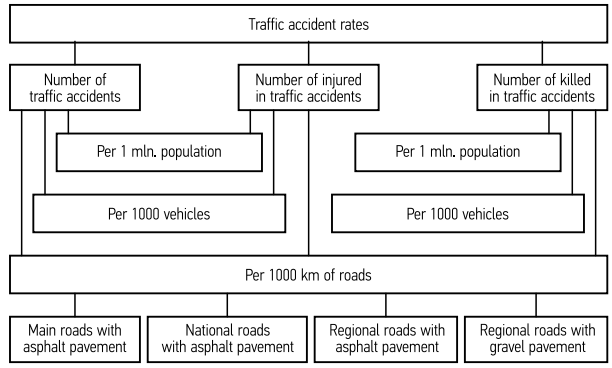

Fig. 5. The parameters used for calculating the accident rate on Lithuanian roads of national significance

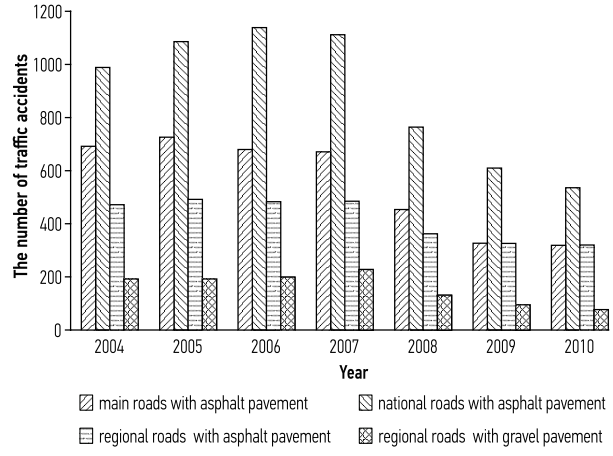

Fig. 6. The dynamics of traffic accidents on Lithuanian roads of national significance (Police Department under… 2012)

can be explained by the fact that GR are only regional Lithuanian roads of national significance.

In general, national roads having asphalt pavement have statistically the highest traffic accident rate. However, they have the lowest traffic volume compared to the main roads and are followed by regional roads having asphalt pavement and regional roads having gravel pavement. They also have a lower traffic volume compared to the main roads and national roads while the amount of traffic accidents on these roads is not high (Fig. 6).

A significant decrease in traffic accidents from 42% in 2008 and to 27% in 2009 can be explained by the implementation of the Gravel Roads Paving Programme. A decrease in the total length of GR due to their paving causes a decrease in the number of traffic accidents. However, this does not mean that the number of traffic accidents on GR per road kilometre is decreasing (Gintalas *et al.* 2008). Based on the analysis of statistical data on traffic accidents, an opposite trend can be observed. The number of traffic accidents on the newly asphalted GR segments has increased. This negative trend is explained by the improved technical condition of the above road segments and the wrong behaviour of road users. When road traffic parameters are improved, road users usually increase driving speed on these segments of the road.

Road segments with frequent traffic accidents are included in the list of blackspots the number of which on Lithuanian roads of national significance is constantly decreasing (247 in 2007, 240 in 2008, 195 in 2009, 145 in 2010). Based on data obtained in 2011, there are 87 blackspots on Lithuanian roads of national significance (Table 1).

Table 1. Blackspots on Lithuanian roads of national significance (Lithuanian Road Administration… 2012)

Type of road	Number of blackspots
main roads having asphalt pavement	36
national roads having asphalt pavement	43
regional roads having asphalt pavement	7
regional roads having gravel pavement	1
total:	87

Blackspots, in accordance with the approved methodology (Lietuvos Respublikos Susisiekimo… 2011), should be determined based on the number of traffic accidents on the road segment of 500 meters. If, during the four running years, more than three traffic accidents are recorded on the road segment, the segment is considered to be a blackspot.

Traffic accidents on different roads having different road surfaces can be compared based on the rate for traffic accidents evaluating the number of traffic accidents on the considered road segment, AADT and the length of the road segment. Therefore, the considered rate is more useful than the relationship between traffic accidents and traffic volume (World Road Association 2012; Lazda, Smirnovs 2009):

$$AR = \frac{A \cdot 10^6}{365NLm}, \quad (3)$$

where: A is the number of traffic accidents on the considered road segment per year; N is AADT on the considered road segment (veh./day); L is the length of the considered road segment (km); m is the number of years.

The highest traffic accident rates are found on regional roads having asphalt pavement, except for the year 2006. They reached maximum values in 2004 and 2005. Rates for traffic accidents on regional roads that have gravel pavement ranged from 0.31 in 2004 to 0.12 in 2010. According to this index, regional roads having gravel pavement are lagging behind the main roads but passing ahead of national and regional roads having asphalt pavements (Fig. 7).

The dynamics of those injured and killed in the accidents that occurred on Lithuanian roads of national significance is presented in Fig. 8 showing that the number of the injured and killed in the accidents on the roads had been decreasing since 2008 and reached the lowest values in 2010.

National roads having asphalt pavement hold the highest rate of the injured and killed in motor vehicle accidents, while regional roads having gravel pavement retain the lowest rate of those.

The expenses covered by the government depend on the number of victims on Lithuanian roads. The amount of losses varies with reference to the national level of economy and inflation (Fig. 9).

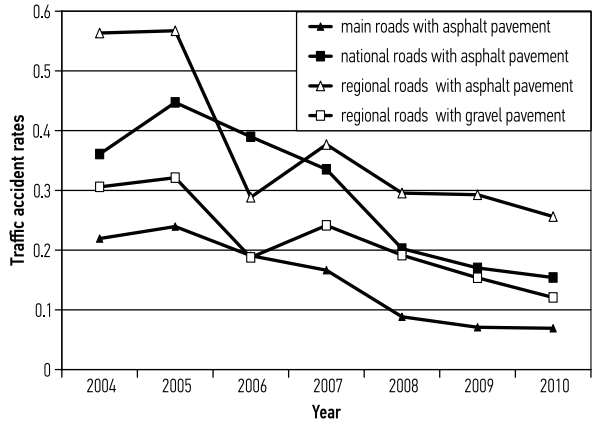

Fig. 7. Rates for traffic accidents

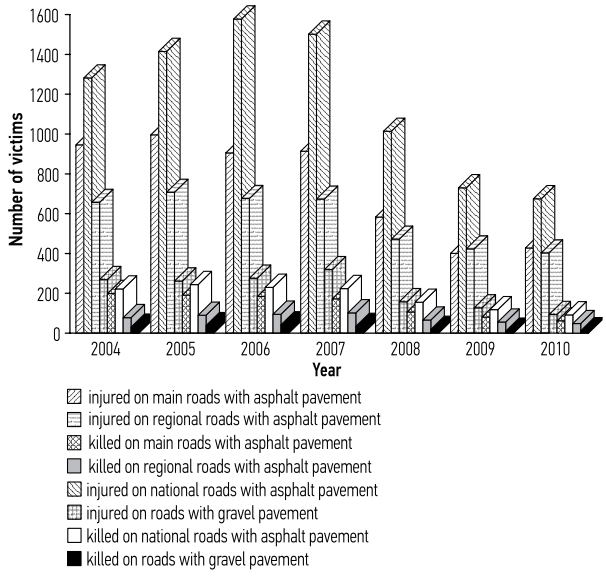

Fig. 8. The number of the injured and killed in motor vehicle accidents on Lithuanian roads of national significance (Police Department under… 2012)

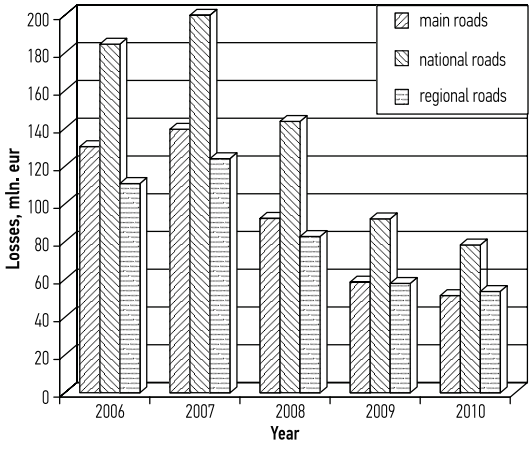

Fig. 9. Economic losses caused by traffic accidents in Lithuania (Transport and Road Research… 2012)

3. Evaluating Traffic Accidents on Lithuanian Gravel Roads of National Significance

For evaluating traffic accidents on Lithuanian regional GR, the parameters of the road should be considered (Fig. 10).

Most of these interrelated parameters directly affect the number of traffic accidents on GR. Traffic accidents on GR depend on the following factors: road condition, road traffic, vehicle speed, climatic and weather conditions, driving experience and driver's behaviour, time of the day and vehicle condition.

Table 2 shows the dynamics of changes in various types of roads. Regional roads having gravel pavement and included in the Lithuanian Gravel Roads Paving Programme (*Lietuvos žvyrkelių asfaltavimo programa*) became regional roads having asphalt pavement. Data on the completed projects of paving GR with asphalt are presented.

The length of GR paved with asphalt each year varied from 373 kilometres in 1999 reaching the minimum of 5 and 40 kilometres in 2001 and 2009 respectively, and the maximum 446 kilometres in 2008, to the planned 61 kilometres in 2011.

The total length of the roads paved with asphalt per year is calculated by summing up the length of the roads paved with asphalt per month of the current year:

$$ARS_Y = \sum_{M=1}^{12} ARS_M, \quad (4)$$

where: ARS_Y is the length of the roads paved with asphalt per year, km; ARS_M is the length of the roads paved with asphalt per month, km.

Road traffic accidents classified according to the nature of the event are shown in Fig. 11 indicating that all types of traffic accidents decreased since 2008 to the lowest number in 2010 with the exception of collisions with moving and parked cars.

Table 2. The dynamics of paving Lithuanian regional gravel roads with asphalt

Year	The length of gravel roads paved with asphalt, km	Left gravel roads, km
1999	373	10141.09
2000	397	9768.09
2001	5	9371.09
2002	112	9366.09
2003	247	9254.09
2004	157	9007.09
2005	231	8850.09
2006	107	8619.09
2007	256	8512.09
2008	446	8256.09
2009	40	7810.09
2010	159	7770.09
2011	61	7611.09
total:	2591	

Road traffic accidents, depending on the nature of the event, are calculated summing up the annual values:

$$TA_{iY} = \sum_{M=1}^{12} TA_{iM}, \quad (5)$$

where: TA_{iY} is the number of traffic accidents of a particular type per year; TA_{iM} is the number of traffic accidents of a particular type per month (Fig. 12).

The distribution of traffic accidents by months is calculated by summing up all types of traffic accidents for a particular month:

$$TA_M = \sum_{i=1}^{7} TA_{iM}, \quad (6)$$

where: TA_M is the number of traffic accidents per month.

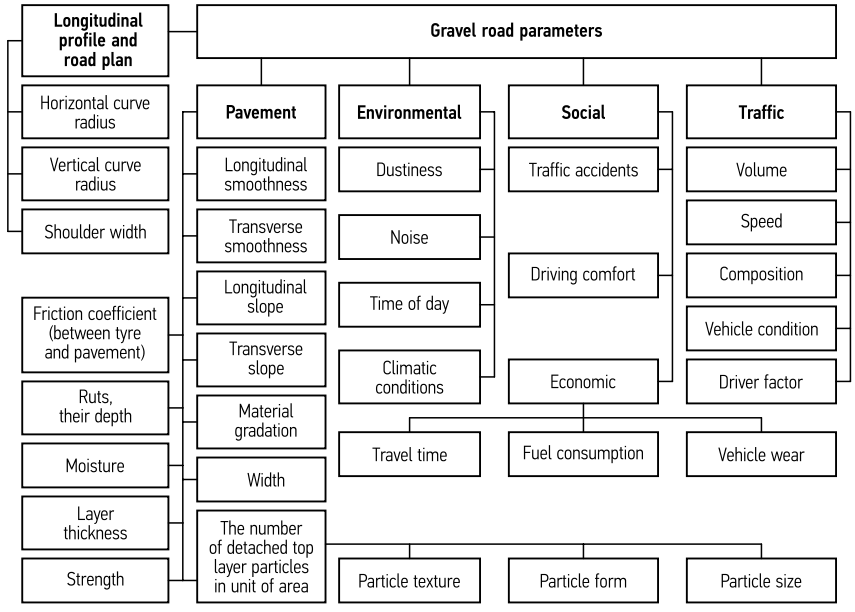

Fig. 10. Parameters affecting traffic safety on gravel roads

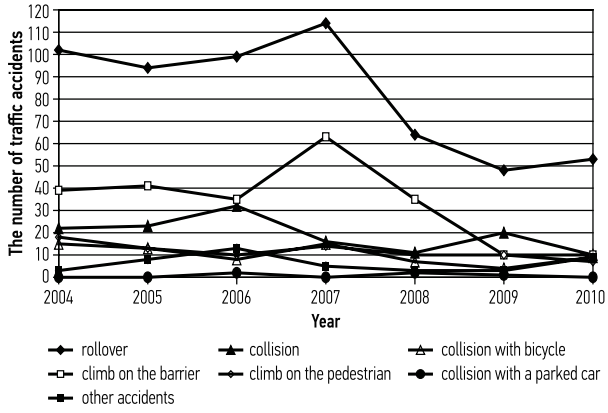

Fig. 11. The types of traffic accidents on Lithuanian regional gravel roads (Police Department under… 2012)

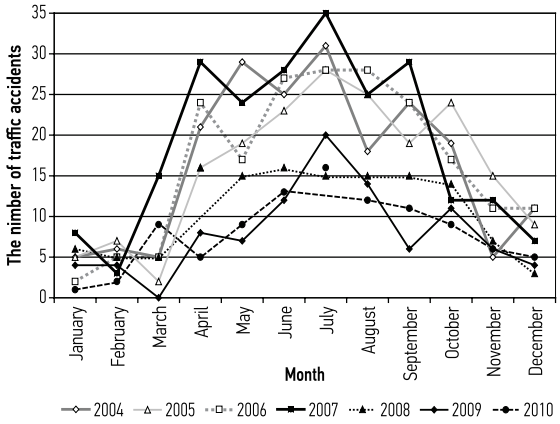

Fig. 12. Traffic accidents on Lithuanian regional gravel roads considering the months of the year (Police Department under… 2012)

Summing up traffic accidents in a particular year according to their type, the following total annual number of traffic accidents is obtained:

$$TA_Y = \sum_{i=1}^{7} TA_{iY}, \quad (7)$$

where: TA_Y is the rate for traffic accidents.

Most of road accidents occur from April to November with a peak in July. This can be explained by an increased traffic volume in spring and summer, i.e. the time when traffic conditions are sufficiently good. A smaller number of traffic accidents between December and March can be explained by a decrease in traffic volume and speed as well as by a safer behaviour of road users in winter conditions.

Conclusions

1. Traffic accidents on the road depend on a particular season. The rate for traffic accidents increases from April to November because of the increased traffic volume due to better traffic conditions with peaks in July. The rate decreases within the period from December to March as a result of lower traffic intensity due to worsening traffic conditions and a safer behaviour of road users.
2. The number of traffic accidents on Lithuanian roads decreased considerably in 2008 and 2009.
3. The analysis of traffic accidents on regional roads having gravel pavement shows that a decrease in the permitted maximum speed from 90 km/h to 70 km/h in 2007 led to a decrease in traffic accidents. However, to prove this, a more extensive study is required.
4. Further research should be a helpful tool for assessing the influence of the economic crisis that sparked off in 2008 and is still in progress and for evaluating the effects of traffic volume and surface roughness on the rate for traffic accidents.

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