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INVESTIGATION INTO TRAFFIC FLOWS ON HIGH INTENSITY STREETS OF VILNIUS CITY

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Abstract. The measurements and analysis of traffic intensity were performed in the capital city – Vilnius, the largest urban area in Lithuania. Vilnius is a centre of business, industry and tourism, and therefore traffic intensity remains the highest in this part of the country. The intensity of vehicle traffic is not only generally calculated but also simultaneously classified which means is divided predefining vehicles into beforehand established categories. Data on traffic flows are used in a road maintenance program for calculating and assessing air pollution, ensuring traffic safety, regulating traffic flows etc. The article presents the methods for measuring traffic intensity which are and were used for calculating traffic intensity not only in the streets of Vilnius but also across Lithuania. Data on vehicle intensity and classification are collected either using technologies (loop and tube detectors, counters and video detectors) or expressing them visually. The article presents the dynamics of changes in the traffic volume on the roads of Lithuania for the period 2000–2009. Also, this article examines traffic intensity of all transport means, including trucks in the permanent traffic volume measuring stations that were installed near the roads in Vilnius zone (data on traffic for the period 2005–2009) and the streets of Vilnius city (data on traffic for the period 2007–2009). Data on traffic intensity were obtained by the Road Research Laboratory of the Road Department of Vilnius Gediminas Technical University in cooperation with the State Enterprise Transport and Road Research Institute (TRRI).

Keywords: vehicle classification, traffic intensity, trucks, visual method, loop detector, tube detector, counter-classifier, video detector.

1. Introduction

Road transport is one of the essential factors to determine the social and economic development of Vilnius and the whole Lithuania. Vilnius city is and will remain the largest attraction point and a source of urban, suburban and international transportation. In recent years, the major problems of road maintenance and condition have been related to an increase in a number of transportations by heavy vehicles and insufficient financing allocated for the road sector and the required road maintenance and repair programs. The earlier built roads and streets are not able to carry increased loads and growing traffic volume. In Vilnius city, traffic counts are carried out every year. For this purpose, stationery and mobile automatic counters are used.

Vehicles are divided into 6 classes:
- motorcycles;
- passenger cars, minibuses;
- passenger cars with a trailer;
- light trucks, heavy weight vehicles without trailers or semi-trailers (three-axle);
- heavy weight vehicles (four-axle, five-axle);
- buses.

The division of vehicles is made according to the number of vehicle axles and the distance between the axles which is not a very accurate process.

The main factor of vehicle traffic is definitely vehicle wheel loads directly affecting road pavement and street/road pavement structure (Čygas *et al.* 2008; Sivilevičius and Šukevičius 2007; Gopalakrishnan 2008; Gopalakrishnan and Khaitan 2010). This impact depends on vehicle weight, the number of axles, a type of wheels, tire pressure and even on a type of suspension. The dynamics of vehicle-generated loads on the pavement and their distribution are determined by traffic volume, traffic flow composition, its speed and the distribution of vehicles in time (Čygas *et al.* 2008; Lee *et al.* 2005; Hugo *et al.* 2007; Zavadskas *et al.* 2008; Beljatynskij *et al.* 2009; Junevičius and Bogdevičius 2007, 2009; Gopalakrishnan 2008; Paslawski 2008; Šliupas 2009; Gopalakrishnan and Khaitan 2010).

Vehicle load directly transferred to the road pavement depends on:

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– axle load,
– the number of wheels on the axle (usually – 2 or 4),
– air pressure in tires.

The axle load of an unloaded vehicle depends on the mark of a vehicle and its weight, the weight of transported goods, the number of axles and configuration. In Lithuania, the maximum permissible axle load is 11.5 tonnes and is regulated by the Law on the Financing of Road Maintenance and Development Program. However, in reality, due to a lack of effective control, heavy weight vehicles are frequently overloaded; axle load is exceeded and can reach even 20 tons or more.

Single wheels make a larger negative effect on the road pavement compared to double wheels. Based on certain estimations, this effect is larger by 1.2 to 4 times. Air pressure in vehicle tires can vary within large limits (can reach up to 950 kPa). The higher is air pressure the higher is wheel pressure transferred to the road pavement, the stronger is an impact on the road pavement (Salama *et al.* 2006) and the faster is pavement degradation.

One of the main criteria describing the impact of a vehicle on the road pavement is the number of equivalent standard axle loads (ESALs) which is one of the basic indices when applying the road pavement management model used for the economic justification of roads.

Pavement degradation processes are especially accelerated by the traffic-related factors:
– for earlier designed pavements, lower limit axle loads were applied which do not already meet the axle loads of heavy weight vehicles;
– the number of heavy weight vehicles within traffic flow has increased;
– axle loads of heavy weight vehicles have been continuously increasing;
– heavy weight vehicles are used to be overloaded.

2. Methods for Measuring Traffic Volume

Traffic volume on city streets is measured by the following State Enterprise Transport and Road Research Institute (TRRI) created methods:
– visually;
– with the help of measuring devices (loop and tube detectors, counters and video detectors (Ozkurt and Camci 2009), see Fig. 1.

A visual traffic volume determination method is the most accurate way enabling to attribute each passing vehicle to the appropriate vehicle class. This method is also the cheapest one since it is not necessary to buy or install any additional equipment to carry out measurements. However, visual recording of vehicles is not convenient at high-speed on the main streets of Vilnius and other large Lithuanian cities with the most intensive traffic flows. Vehicles are classified into 11 classes.

When the measurements of traffic intensity are in short-term variations (individual or periodic measurements), annual average daily traffic intensity (AADTI) is calculated applying the methodology of data on the annual average daily traffic intensity of short-term measurement (TRRI methodology). This methodology is used when a single measurement period is not longer than 12 hours or when measurement time is one week. Having traffic intensity data on short-term measurements, we can calculate the traffic intensity of the day, the traffic intensity of the week and annual average daily traffic intensity. The daily traffic intensity (DTI) is calculated by Eq (1):

$$I_D = N \cdot K_D, \tag{1}$$

where: I_D is the DTI of the measured day, car/day; N is the number of cars moved during the measured period, car; K_D is the coefficient of the measured day traffic intensity.

If traffic intensity was measured over a week without interruption, then, average weekly daily traffic intensity (AWDTI) is calculated by Eq (2):

$$I_W = \frac{1}{7}\sum_{i=1}^{7} I_{Di}, \tag{2}$$

where: I_W is AWDTI, car/day; I_{Di} is the traffic intensity of the *i-th* day of the measured week, car/day.

If traffic intensity lasted less than one week, then, AWDTI is calculated by Eq (3):

$$I_W = \frac{1}{n}\sum_{i=1}^{n} I_{Di} \cdot K_{Wi}, \tag{3}$$

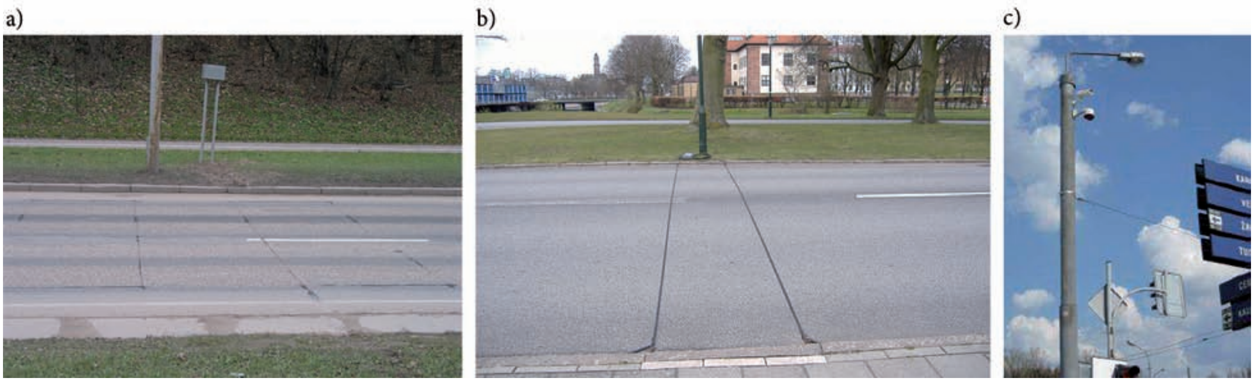

Fig. 1. Traffic volume measuring devices: a – loop detectors; b – rubber tubes; c – video detectors

where: I_{Di} is the traffic intensity of the *i-th* day of the week, car/day; K_{Wi} – the coefficient of week daily traffic intensity, *n* – the number of the measured days.

Annual average daily traffic intensity is calculated by Eq (4):

$$I_Y = \frac{1}{n}\sum_{i=1}^{n} I_{Wi} \cdot K_{Yi}, \quad (4)$$

where: I_Y is AADTI, car/day; I_{Wi} is week average daily traffic intensity of the *i-th* measured week, car/day; K_{Yi} is the coefficient of the traffic intensity of the week in a year, *n* is the number of the measured weeks during the year.

A loop detector is an inductive loop buried in a 6 mm wide and 40–70 mm deep groove cut into asphalt concrete pavement and covered with bitumen. During operation, a frequency signal of 100 kHz is transferred through the loop. With any vehicle passing over the loop, it functions as a metal cord of the loop and, thus, produces changes in the inductive resistance of the loop. Change in resistance is a signal for the detector about the passing vehicle. In order to detect not only a number of vehicles but also their speed and driving direction within vehicle classification regime, it is necessary to install 2 loops in each traffic lane at a certain fixed distance (usually 2 m) from each other. The use of loop detectors requires stationery traffic counting sites. At present, the counters with inductive loops 'Marksman 660' dividing vehicles into 6 classes (EUR6) and 'C&A loop profiler' with signal form analysis dividing vehicles into 10 classes are used for traffic count.

A rubber tube is an elastic one laid across the street. One of his ends is blocked, whereas the other is put on a metal tube taken out in front of the device. With a vehicle passing over the tube, containing air pressure increases and this is the signal for a counter to register the passing vehicle. Counters with rubber tubes are usually used as easily transported devices for a short-term traffic count. Rubber tubes give a possibility of dividing vehicles into 13 classes according to GRO3 – EUR13 classification the criteria of which include the length of a vehicle, the distance between the axles and the number of axles. At present, traffic counts are carried out using 'Marksman 400' counter-classifier dividing vehicles into 13 classes.

Another group of the currently used counters is those with microwave sensors. These are mobile counters used on the sites making difficulties with installing other types of counters and traffic count is carried out for more than 1 day. They are mainly used on regional and low-volume national roads. A counter sends a microwave beam across the road and receives its reflections from vehicles. A microwave counter is installed close to the road at a height of 1.5–6 m above the pavement on a round post (usually on traffic sign). At present, traffic counts are carried out by SDR microwave counter.

Video detectors (Fig 1 c) are mainly installed and used at street intersections. Using video detectors makes possible not only to detect traffic volume but also by monitoring a real situation to analyze flows, their speed and loading of traffic lanes (Gao *et al*. 2009; Ozkurt and Camci 2009). Traffic flows are recorded using a method of video detection or laying induction loops on the asphalt pavement. Video detectors are mounted at a 6–8 m height over the carriageway. Using special software with the help of a personal computer, virtual loops are created on traffic lanes where the passing vehicles are detected and summed up. Virtual loops are created on each lane, i. e. 8 virtual loops are created on 4 traffic lanes. Information about traffic flows is collected 24 hours a day.

3. Receiving and Processing Data on Traffic Intensity

To collect data on transport intensity applying the visual method, each vehicle is recorded at its predefined class. Using the visual method, transport is classified into 11 classes. All cars crossing a measuring post are noted and later summed up calculating daily traffic intensity (DTI) Eq (1), average weekly daily traffic volume (AWDTI) Eq (2, 3) or average annual daily traffic intensity (AADTI) Eq (4).

While using loop or tube detectors, data on transport intensity are fixed and recorded into the memory of an automatic counter-classifier connected to the detector. These devices (counters) work on an electronic chip inside a microprocessor with a specific program. Every crossed car is not only taken over the counter but also put into a certain class. Classification criteria cover length bands and chassis level (the height between the pavement surface and the vehicle floor). Vehicle classification into classes (6 classes, 11 classes, 13 classes) depends on the use of a counter (Chapter 2). All management of information determination for a counter-classifier is done connecting a personal computer, because the counter-classifier has no any controls. After scanning data on transport intensity from the counter, they must be processed, summed up and only then used for the needed purpose (in a road maintenance program, for calculating and assessing air pollution, traffic safety by directing traffic, etc.).

When using video cameras, data on the intensity of the crossed transport is send to the central computer where all information is summed up. In this way, recorded passing traffic is not classified receiving only vehicle intensity.

4. Measurements of Traffic Volume on High-Speed and Main Streets of Vilnius City and in Vilnius Region

Traffic volume on all main, national and partly regional Lithuanian roads is counted every year. For this purpose, stationary or mobile automatic counters are used. With the increasing number of the registered vehicles in the Republic of Lithuania, traffic volume on the roads of national significance has been also increasing. Traffic counts on the roads of national significance are carried out by the TRRI. Accounting for traffic intensity on the main, national and regional roads was carried out in stationary permanent measurement posts (continuous mode) and stationary periodic measurement posts (for 1 week 2 times a year, sometimes for 1 week 4 times a year, for 3 hours 2 times a year or once a year for 3 hours).

Fig. 2 provides changes in traffic volume on the roads of national significance since 2000. The graph shows that for the period from 2000 to 2008, the volume of traffic was growing. In 2009, it became lower, though, if compared to 2000, has increased by 59%.

Data on traffic volume in Vilnius region (Fig. 3), i.e. on roads A1 Vilnius–Kaunas–Klaipėda (the distance of 15.10 km was measured), A2 Vilnius–Panevėžys (the distance of 8.05 km was measured), A3 Vilnius–Minsk (the distance of 7.91 km was measured), A4 Vilnius–Varėna–Hrodna (the distance of 14.50 km was measured), A14 Vilnius–Utena (the distance of 10.86 km was measured), A15 Vilnius–Lida (the distance of 10.01 km was measured), A16 Vilnius–Prienai–Marijampolė (the distance of 16.37 km was measured), 101 Vilnius–Shumsk (the distance of 8.09 km was measured), 102 Vilnius–Švenčionys–Zarasai (the distance of 16.80 km was measured), 103 Vilnius–Polotsk (the distance of 15.23 km was measured) is collected by TRRI.

The measurements of traffic volume in the above mentioned measuring stations showed that for the period 2005–2009, the total average traffic volume was increasing on all roads as indicated in Fig. 4.

Variation in traffic intensity measuring posts during the measured period in Vilnius region is indicated in Table 1.

In 2006–2007, Road Research Laboratory of the Road Department of Vilnius Gediminas Technical University installed stationery traffic volume measuring stations on 11 high-speed and main streets of Vilnius city. In total, 12 permanent traffic volume measuring stations were installed (Fig. 5). The stations were erected on 2 sections in Laisvės avenue.

Measurements were started straight after their installation on 25 April 2007. Counter-classifier 'Marksman 660' is maintained for one week in each stationary installed measuring post. After a week of collecting data

Fig. 3. Traffic intensity measurement posts installed on the roads of Vilnius region: 1 – road A1; 2 – road A2; 3 – road A3; 4 – road A4; 5 – road A14; 6 – road A15; 7 – road A16; 8 – road No. 101; 9 – road No. 102; 10 – Road No. 103 Lithuanian roads for the period 2000–2009

about passing transport vehicles, they are loaded into a personal computer and then a counter-classifier transports them into another stationary installed measuring post. Data on traffic intensity in one stationary post (there are 12 stationary posts in Vilnius city) is measured 4 times per year (once per season). The results of measurements carried out in 2007–2009 are given in Fig. 6.

Estimations have showed that on average traffic volume has not increased in all street sections as in some sections it has significantly decreased Table 2.

Investigations by (Seo and Kang 2006; Park *et al.* 2005, 2008; Sivilevičius and Petkevičius 2002; Romero and Lozano 2006; Butkevičius and Petkevičius 2005; Salama *et al.* 2006) have showed that vehicle wheel pressure on the road pavement and pavement structure is

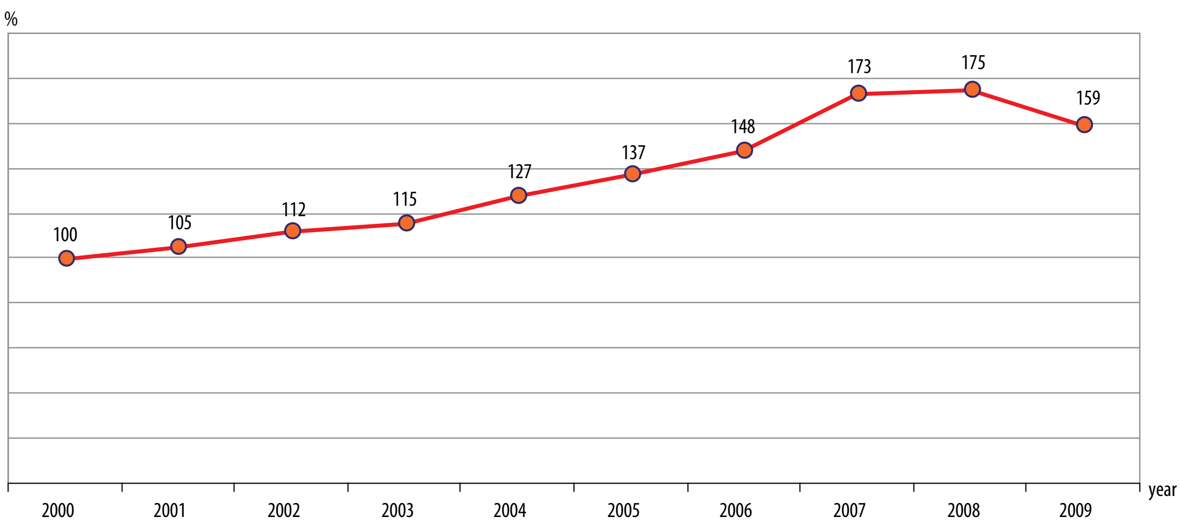

Fig. 2. The dynamics of changes in traffic volume on all main, national and partly regional Lithuanian roads for the period 2000–2009

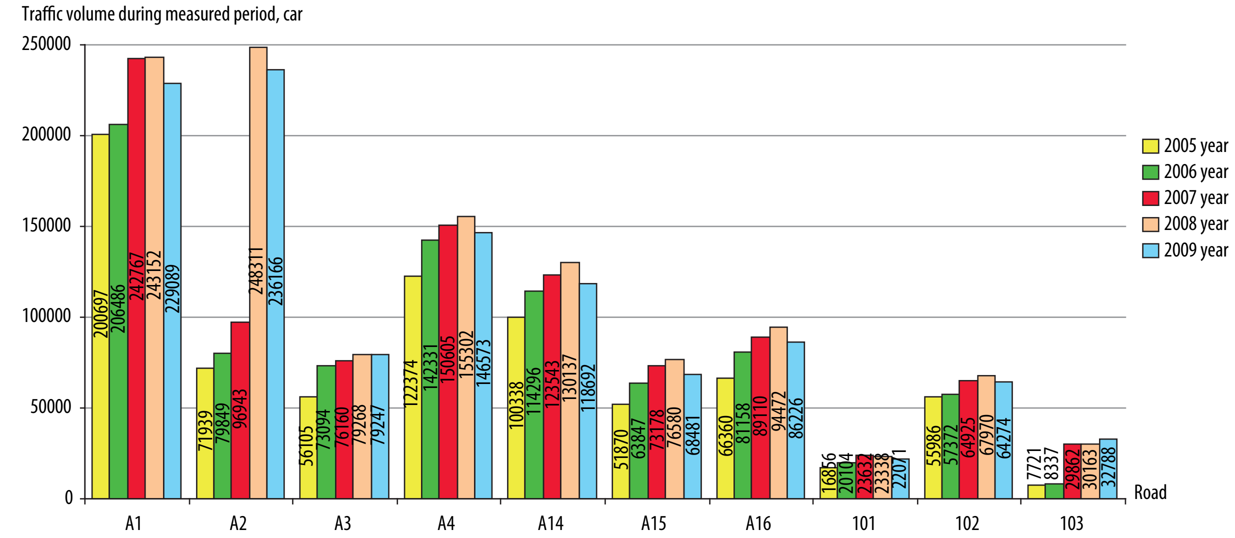

Fig. 4. Traffic volume measured for the period 2005–2009 in the stationery stations installed in Vilnius region

Table 1. Variation in traffic volume for the period 2005–2009 on the roads of Vilnius regio

Roads of Vilnius zone	Consideration period 2005–2009		Consideration period 2007–2009	
	Increase, %	Decrease, %	Increase, %	Decrease, %
A1 (measuring post in 15.10 km)	14.15	–	–	5.63
A2 (measuring post in 8.05 km)	228.29	–	143.61	–
A3 (measuring post in 7.91 km)	41.25	–	4.05	–
A4 (measuring post in 14.50 km)	19.77	–	–	2.68
A14 (measuring post in 10.86 km)	18.29	–	–	3.93
A15 (measuring post in 10.01 km)	32.02	–	–	6.42
A16 (measuring post in 16.37 km)	29.94	–	–	3.24
No.101 (measuring post in 8.09 km)	30.94	–	–	6.61
No.102 (measuring post in 16.80 km)	14.80	–	–	1.00
No.103 (measuring post in 15.23 km)	324.66	–	9.80	–

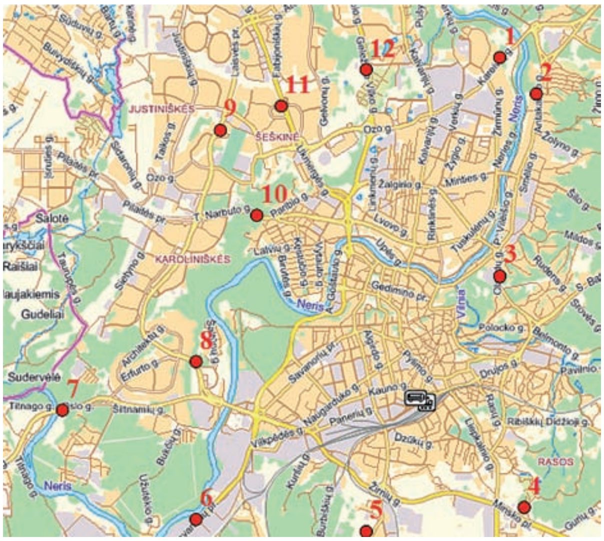

Fig. 5. Traffic intensity measurement posts installed on the streets of Vilnius city: 1 – Kareivių str.; 2 – Antakalnio str.; 3 – Olandų str.; 4 – Minsk Road; 5 – Dariaus and Girėno str.; 6 – Savanorių ave; 7 – Oslo str.; 8 – Laisvės ave (1); 9 – Laisvės ave (2); 10 – T. Narbuto str.; 11 – Ukmergės str.; 12 – Geležinio Vilko str.

the most important load to be considered in road design. Calculating traffic intensity in this article, truck intensity is separated and summed up due to their higher axle loads. Data on truck intensity is used for making tests on truck impact on the road surface and its construction. Fig. 7 shows that for the period 2005–2009, truck intensity amounted from 3% to 19% of total traffic intensity in stationary posts in Vilnius region and in Vilnius city stationary posts. Fig. 8 indicates truck intensity for the period 2007–2009 varying from 7% to 23%.

The estimation and analysis of truck intensity shows it is higher on the streets of Vilnius city than that measured in the stations on the roads of Vilnius region. The researched situation of traffic intensity in Vilnius is higher due to the increased frequency of public transport (busses, trolley busses) which is included in the total amount of heavy traffic intensity. When choosing road A1, Vilnius city can be accessed through Savanorių ave. During the measured periods in 2007–2009, truck intensity in the station on Savanorių ave was 43% higher in 2007, 40% in 2008 and 56% in 2009 than that recorded in the station of road A1 (installed in 15.10 km). When driving on road A2, Vilnius city can be reached through Ukmergės str. where truck intensity in the post was 48% higher in

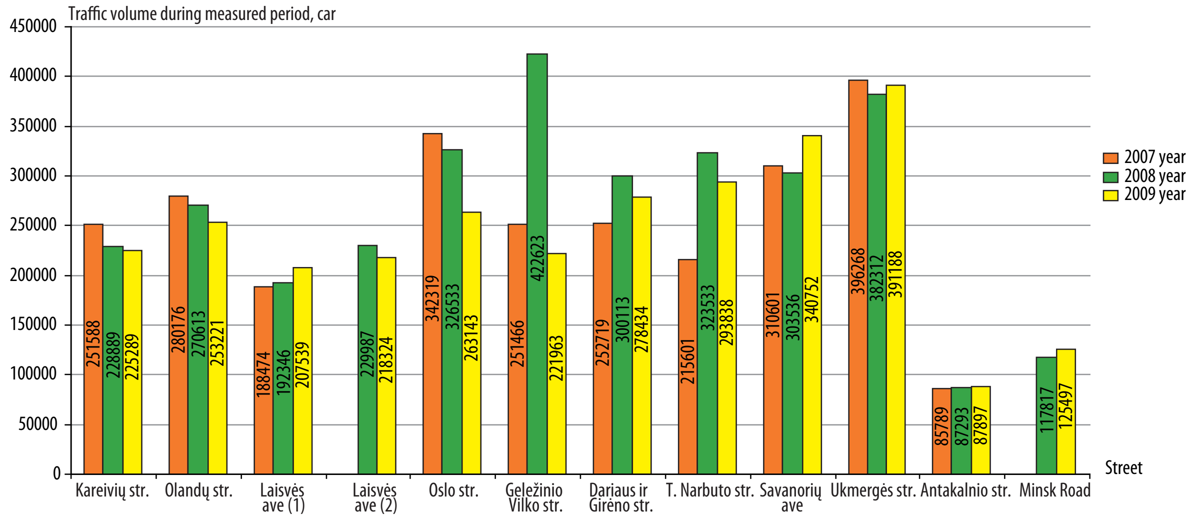

Fig. 6. Traffic volume measured in 2007–2009 in the stationery stations installed on high-speed and main streets of Vilnius city: Kareivių str., Olandų str., Laisvės ave (1), Laisvės ave (2), Oslo str., Geležinio Vilko str., Dariaus and Girėno str., T. Narbuto str., Savanorių ave, Ukmergės str., Antakalnio str., Minsk Road

Table 2. Variation in traffic volume for the period 2007–2009 **o**n the streets of Vilnius city

Streets of Vilnius city	Consideration period 2007–2009	
	Increase, %	Decrease, %
Kareivių str.	–	10.45
Olandų str.	–	9.62
Laisvės ave (1)	10.12	–
Laisvės ave (2)	–	5.07
Oslo str.	–	23.13
Geležinio Vilko str.	–	11.73
Dariaus and Girėno str.	10.18	–
T. Narbuto str.	36.29	–
Savanorių ave	9.71	–
Ukmergės str.	–	1.28
Antakalnio str.	2.46	–
Minsk Road	6.52	–

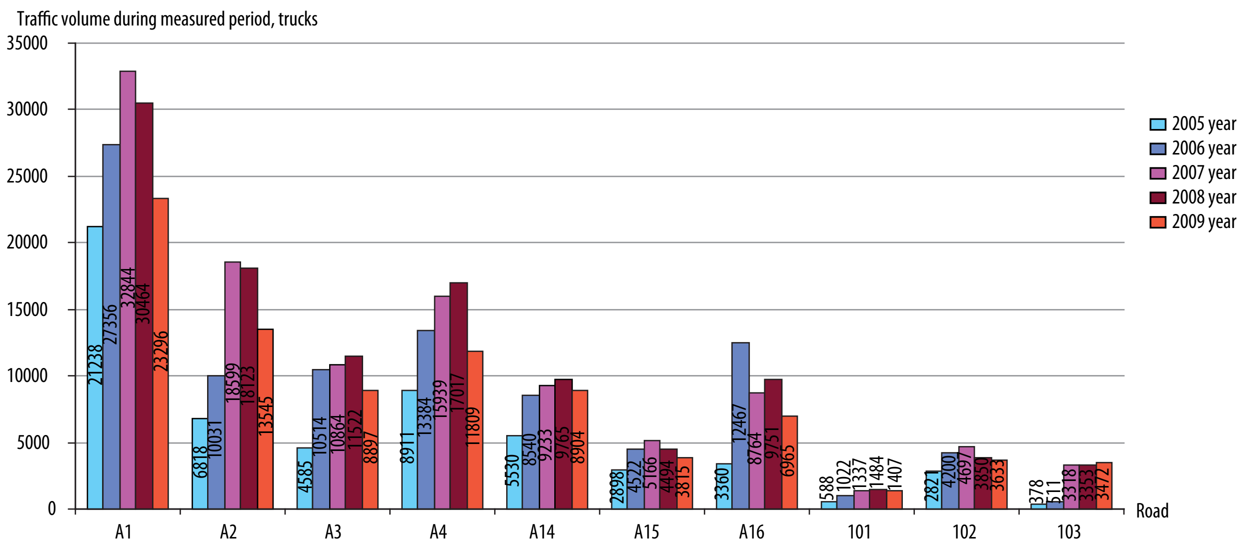

Fig. 7. Truck intensity in stationary posts in Vilnius region for the period 2005–2009

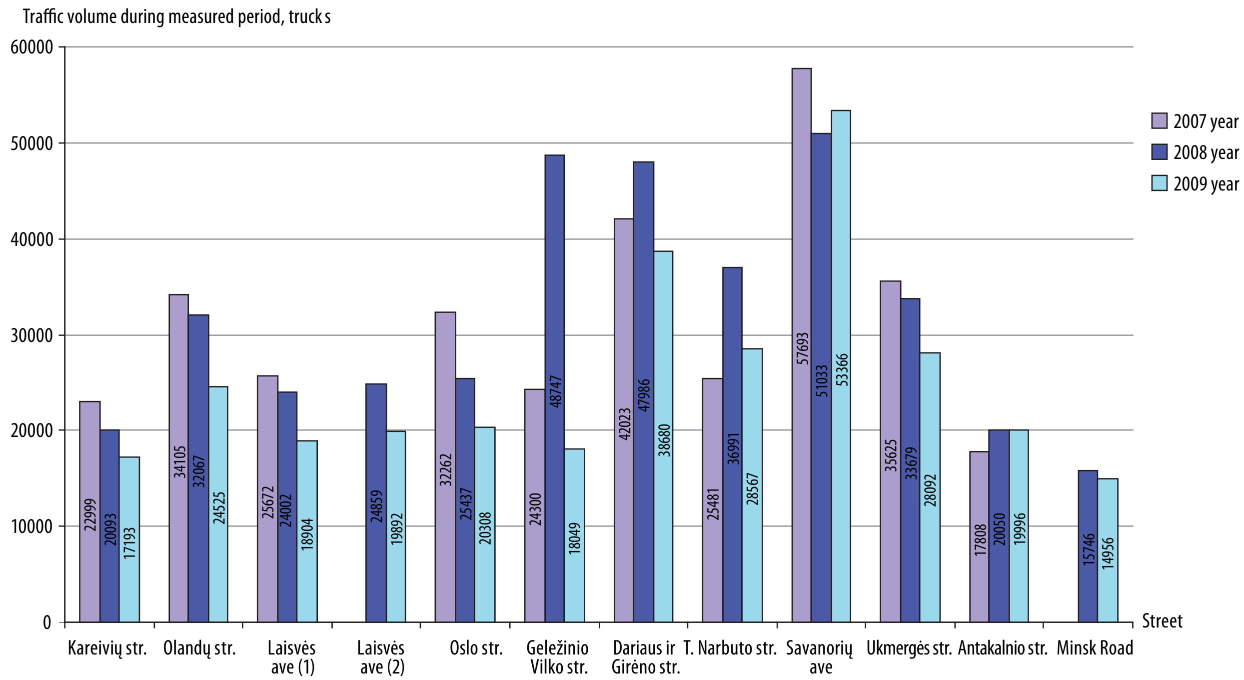

Fig. 8. Truck intensity in stationary posts on the streets of Vilnius city for the period 2007–2009

2007, 46% in 2008 and 52% in 2009 rather than that recorded in the station of road A2 (installed in 8.05 km). When driving on road A3, Vilnius city can be reached through Minsk Road where truck intensity in the post were 27% higher in 2008 and 41% in 2009 than that recorded in the station of road A3 (installed in 7.91 km). If driving on road A14, Vilnius city can be reached through Geležinio Vilko str. where truck intensity in the post were 62% higher in 2007, 80% in 2008 and 51% in 2009 rather than that recorded in the station of road A14 (installed in 10.86 km). While driving on road No.102 Vilnius city can be reached through Kareivių and Antakalnio streets where average truck intensity in the posts were 77% higher in 2007, 81% in 2008, 80% in 2009 than that recorded the station of road No.102 (installed in 16.80 km).

5. Conclusions

Data about traffic volume and traffic composition is very important for the design, estimation and determination of repair priorities of city street pavements, and therefore must be as accurate as possible. Since traffic volume on Vilnius streets is very different, it is not recommended to use only one of the above described methods for measuring traffic volume. A visual measuring method is not suitable for the streets with a high traffic volume as it would be too expensive to install loop detectors and to erect stationery measuring stations on all city streets. Therefore, for the measurements of traffic volume on the streets of Vilnius city, all measuring methods are used.

The analysis of investigations on traffic volume showed that the total traffic volume in 2000–2008 was increasing in the whole territory of Lithuania as well as in Vilnius region (on the roads entering Vilnius city). However, in 2009 compared to 2008, traffic volume was decreasing on the roads of national significance, in Vilnius region and Vilnius city. The conducted investigations showed that in 2007–2009, changes in traffic volume on Vilnius city streets were very different: on some streets it decreased from 1.28% to 23.13% (Ukmergės str., Laisvės ave (2), Olandų str., Kareivių str., Geležinio Vilko str., Oslo str.), whereas on the other streets, it increased from 2.46% to 36.29% (Antakalnio str., Minsk Road, Savanorių ave, Laisvės ave (1), Dariaus and Girėno str., T. Narbuto str.). Changes in traffic volume in Vilnius region were not that big: traffic volume on roads No.102, A4, A16, A14, A1, A15, No. 101 decreased from 1.00% to 6.61% and on roads A3, No.103, A2, increased from 4.05% to 143.61%. The total decrease of traffic volume was influenced by the continuing economic crisis and changed directions to transit and local traffic flows.

Since truck traffic causes degradation on the road pavement and its structure because of repetitive high axle loads, traffic intensity was analyzed as a separate case. The analysis of truck intensity showed it was higher in measuring posts on the streets of Vilnius city rather than in the posts on the roads of Vilnius region in 2007–2009. However, while examining truck intensity in separate measuring posts for the same period (on the roads of Vilnius region and streets of Vilnius city), truck intensity decreased. Changes in traffic volume in Vilnius region were not that big: traffic volume in the post on road A1 decreased to 29% and on Geležinio Vilko str. (in Vilnius city) – to 26%. The total decrease of truck traffic volume like total traffic was influenced by the same reasons – continuing economic crisis and changed directions to transit and local traffic flows.

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