



## THE ANALYSIS OF IMPLEMENTATION POSSIBILITIES OF SECTORIAL AUTOMATED VEHICLE SPEED CONTROL SYSTEMS ON THE ROADS OF LITHUANIA

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**Abstract.** Excess speed is one of the largest road safety problems causing the increased risk of road crashes. A wide range of safety improvement measures, both educational and engineering, are being implemented to solve this problem. The main objective of those measures is to force vehicle drivers to observe the speed limit requirements and to ensure enforcement of speed requirements. This paper gives an overview of the impact of vehicle speeds on road safety and the effect of safety improvement measures. Possibilities for the implementation of sectorial vehicle speed enforcement system on the roads of national significance of Lithuania are presented. The paper contains criteria for the selection of road sections of Lithuania where the sectorial vehicle speed enforcement system could be installed. The amount of investments is also given necessary for the installation of sectorial vehicle speed enforcement system on the selected road sections as well as their one-year maintenance. Taking into consideration the damage incurred by the country due the people killed on roads a pay-back period of the sectorial vehicle speed enforcement system is determined.

**Keywords:** vehicle speed, sectorial vehicle speed enforcement, expected number of accidents.

### 1. Introduction

Excess speed is one of the most important causes of road crashes and probably the most widely spread violation of Traffic Rules today. Based on data of *Organization for Economic Co-operation and Development*, 40–50% of drivers on the average drives faster than the posted speed limit. High speeds have negative effects on the safety of road users, the efficiency of the traffic system and the environment (air pollution, noise) (Siegrist, Roskova 2001). Many studies show (Elvik *et al.* 2004; Mounttain *et al.* 2004; Pauw *et al.* 2014) that the driving speed influences both the chance to be involved in a crash and the severity of the injuries when a crash occurs. Nilsson (2004) and Elvik *et al.* (2004) described the relationship between speed and road crashes as a power function, which indicates that the crash risk increases more than proportionally with higher speeds.

If the vehicle drivers could freely choose their driving speed many of them would take much higher speed than the posted speed limit. Many drivers mistakenly think that they manage to control their vehicle when driving at a much higher speed than required by the legal acts and road signs. However, they do not take into account all the

factors of a safe journey: road geometry, driving conditions and illumination, traffic volume, personal experience and motivation, crash risk. The actions of the driver, having noticed an unexpected obstacle, can be divided into five components: 1) taking the notice of possible obstacle; 2) identification of obstacle; 3) assessment of personal actions, distance, the speeds of other vehicles and behaviour of other road users; 4) decision-making on personal actions; and 5) execution of actions aimed at avoiding the crash or reducing the negative consequences as much as possible (Kallberg, Luoma 1996). A high driving speed reduces time allocated for the execution of each of the above mentioned issues.

A number of studies were implemented to examine the psychological causes of drivers influencing the speeding. Several models were developed to explain the drivers' behaviour in general and speeding in particular, but none of them has been generally accepted. There is a whole series of explanations as to why the drivers exceed the speed limit. According to Rothengatter (1990), speed appears to be determined by four motivational factors which can be termed: 1) the pleasure of driving; 2) traffic risk; 3) journey time; and 4) driving costs. Speeders and non-speeders differ by all four factors – the drivers

who exceed the speed limit believe that this gives them more pleasure and do not accept that it will increase the risk, and they appreciate time more and costs less than those drivers who observe the speed limit (Siegrist, Roskova 2001).

In 2012, Lithuania, compared to the other European Union member-states, according to the number of people killed in road crashes per million inhabitants took the lowest position – one million of Lithuanian inhabitants represented 101 killed road user. Statistics of the road crashes on the roads of Lithuania shows that the largest part of crashes are taken by the collisions with pedestrians (in 2012 – 35%) and vehicle collisions (in 2012 – 30%). A severity of those crashes is greatly affected by a high driving speed. In Lithuania, due to the excess speed or inappropriate speed 62 drivers were killed and 366 were injured apart from the other road users.

There is no single way to solve the speeding problem, both educational and engineering measures are necessary. The latter are divided into two parts: 1) measures to physically force the drivers to reduce speed, i.e., the raised speed reducing measures (speed humps of trapeze shape, raised pedestrian crossings, speed bumps, speed humps at the junctions), a curved/narrowed carriageway, and 2) measures to control vehicle speed, e. g. stationary and sectorial speed enforcement systems. The above mentioned measures shall act as a long-term educational and teaching measure forcing the driver to continuously think about his behaviour on the road and encouraging him to change his driving habits.

## 2. The vehicle speed enforcement systems

### 2.1. The impact of speed cameras on road crashes

The impact of speed cameras on road crashes are studied by many scientists (Li *et al.* 2013). Literature analysis showed that various methods are used to determine the effect of speed cameras. Most studies use naive before-after methods with control groups (Christie *et al.* 2003; Cunningham *et al.* 2008; Gains *et al.* 2004; Goldenbeld, van Schagen 2005; Shin *et al.* 2009). Other scientists use the empirical Bayes method (Gains *et al.* 2005; Mountain *et al.* 2004, 2005; Newstead, Cameron 2003). Li *et al.* (2013) has summarized all those studies and the results showed that the implementation of speed cameras significantly reduced the vehicle speed and the number of crashes near camera sites. When studying the effect of speed cameras Li *et al.* (2013) came to two essential conclusions. The first relates to the distance on which speed cameras have their largest impact. Li *et al.* (2013) determined that the most effective distance for the operation of speed cameras is 200 m, however, the distance of 500 m is also sufficiently effective. The second conclusion relates to the migration of crash site. The study showed that the drivers' behaviour to voluntarily drive at a permissible speed has not been changing as they only reduce speed when approaching the speed cameras.

### 2.2. Analysis of the effect of stationary speed enforcement systems on the roads of national significance of Lithuania

The first two stationary speed enforcement systems SENSYS SSS were installed in Lithuania in November 2005. Their installation sites were selected based on two criteria: 1) accident data and speeding problems on those roads; 2) high traffic volume. Over the 2-year period the speed cameras have recorded 17 500 violations, however, no injuries or fatalities took place within their impact zone. Following a success of the first speed cameras, until August 2008 on the roads of national significance of Lithuania (the length of road network – 21 242.2 km) 12 stationary PoliScan Speed cameras were installed. In December 2009, 139 stationary speed cameras Multa Radar S580 were put into operation. After implementation of the stationary speed cameras the number of injury and fatal crashes on the roads of Lithuania due to speeding decreased by 32%, the number of people killed – by 33% and the number of people injured – by 36% (Čygas *et al.* 2013). The analysis did not take into consideration the injury and fatal crashes having occurred due to additional factors: drink driving, driving having to right to drive, collisions with animals, other. However, the study of average vehicle speed near the sites with the stationary speed cameras showed that before and behind the site of speed camera the drivers exceed the speed limit and reduce it only within the impact zone of the camera. Based on the study results an assumption was made that the impact zone of the camera is up to 500 m. The same assumption was made after a survey of public opinion in which the majority of drivers who took part in the survey said that having seen a road sign showing the presence of the stationary speed camera they usually slow down, and having passed the camera – speed up again. Taking this into consideration, it could be stated that the stationary speed cameras should be installed at those locations where there is a concentration of road crashes, and since vehicle speed may have the largest effect on the occurrence of road crashes, the assurance of speed limit could determine a reduction in the number of crashes. In order to increase the impact zone of speed cameras the sectorial vehicle speed enforcement system should be introduced which is widely used in foreign countries (Čygaite 2012).

### 2.3. Analysis of the effect of sectorial speed enforcement systems in foreign countries

A sectorial speed enforcement system is based on measuring an average vehicle speed in a certain road section. In the beginning and at the end of the section the speed cameras are installed which detect the entering/departure time of vehicle, the number plate of vehicle and takes picture of the driver (Fig. 1a). This information is enough to calculate an average vehicle speed and in case of violation to identify the vehicle and the driver. In countries where

responsibility for speeding falls on the owner of the vehicle it is well enough to detect the vehicle from the rear (Fig. 1b).

Average speed enforcement was first operated in a trial form in 1997 in the Netherlands and then as a permanent installation in 2002. In England, average speed enforcement has increased considerably since an initial trial of the technology in 1999. The first full implementation of the technology occurred in Nottingham in 2000. In Austria, the first implementation of average

speed enforcement occurred on the motorway A22 in the tunnel near Vienna in 2003. In Italy, an average speed enforcement Tutor system, introduced in 2005, covers approximately 2900 km of the motorway network.

The results of scientific studies show that an average speed enforcement system is an effective enforcement countermeasure for reducing vehicle speeds and improving traffic flow by reducing speed variation through increased rates of compliance with posted speed limits (Table 1). Also, it was determined by scientific investigations

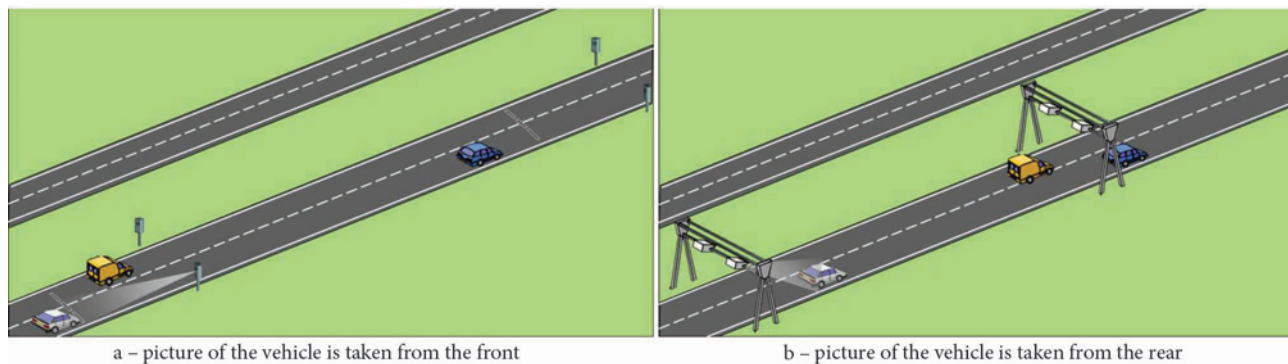


Fig. 1. Basic diagram of an average speed enforcement system

Table 1. Summary of findings related to the effect of average speed enforcement on vehicle speeds and road crashes

| Source  | Location/s and details of system/s  | The effect on vehicle speeds  | The effect on traffic crashes  |
|---|---|---|--|
| Rijkswaterstaat Directie-Zuid-Holland (2003) and Kuratorium fur Verkehrssicherheit (2007) | Netherlands, Rotterdam: A13 (80 km/h – reduced from 100 km/h)               | Offence rates reduced from 4.6% to 0.6% (weekday) and 0.9% (weekend) – estimated traffic volume of 124 000 vpd.   | All crashes reduced by 47%; fatalities reduced by 25% – implementation of system coincided with a reduction in the speed limit from 100 km/h to 80 km/h, thus proportion of the observed reduction attributable to average speed enforcement cannot be reliably determined |
| Stefan (2006)   | Austria, Vienna: A22 tunnel (80 km/h cars and 60 km/h heavy vehicle speeds) | Passenger vehicle speed reduced by 10 km/h during daytime conditions and 20 km/h during night-time conditions; heavy vehicle speeds reduced by 15 km/h during daytime conditions and 20 km/h during night-time conditions | Comparing 3 years prior to 2 years post installation: all injury crashes reduced by 33.3%; fatal and serious injury crashes reduced by 48.8%; minor injury crashes reduced by 32.2%  |
| Galata (2007)   | Italy: A4, A13, A14, A26  | Significant reduction in average speeds of 15% during first 12 months of operation; maximum speeds reduced 25%  | In first year of operation: fatalities reduced by 50.8%; serious injury crashes reduced by 34.8%   |
| Speed Check Services (2010)   | England, Nottingham: A6514 (40 mph), A610 (30 mph)                          | Comparing 3 years prior to 3 years post installation: 85 <sup>th</sup> percentile speeds reduced 9.1% on A6514 and 23.1% on the A610  | Comparing 3 years prior to 7–8 years post installation: across all sites killed and serious injury crashes reduced by 65%; fatalities reduced from 6 to 1 on the A6514 and from 3 to 0 on the A610   |
| Speed Check Services (2010)   | England, South Yorkshire: A616 (40 mph)                                     | Comparing 3 years prior to 3 years post installation: proportion of vehicles exceeding speed limit reduced eastbound 66.6% and westbound 80%  | Comparing 3 years prior to 5 years post installation: killed and serious injury crashes reduced by 82%   |

that an average speed enforcement system has a positive effect on a reduction in the number of injury and fatal crashes, as well as their severity (Table 1).

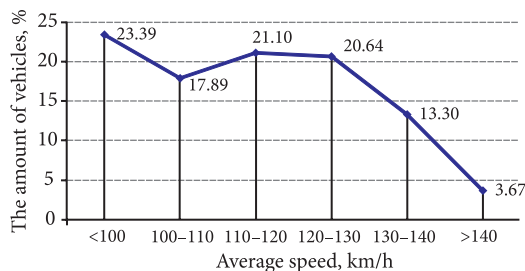
### 3. Adaptation of a sectorial speed enforcement system in Lithuania

#### 3.1. Experimental investigation on sectorial speed enforcement on the roads of Lithuania

In 2008, the Joint Stock Company ATEA made an experimental investigation of sectorial speed enforcement in Lithuania. For an experimental investigation the section of the main road A2 Vilnius – Panevėžys was chosen with a prevailing uniform traffic volume (i.e., no entries and exits) and the maximum speed limit (in summer time) for the motorways in Lithuania – 130 km/h. The investigation was carried out on 26 June 2008 on the test section of



**Fig. 2.** The sectorial speed enforcement devices on the test section of the road A2 (photo: JSC ATEA)



**Fig. 3.** Percentage distribution of vehicles on the road A2 by an average speed

5.641 km long by measuring an average speed of vehicles for 2 hours. The speed measurements were carried out using the stationary *Vitronic Poliscan* Speed cameras installed on a tripod (Fig. 2). One driving direction was measured. The speed cameras were erected on the carriageway.

The investigation data was processed with the *Microsoft Office Excel* software. The results of experimental investigation have determined that even 16.97% of vehicles had exceeded the posted speed limit of 130 km/h. A percentage distribution of vehicles by an average speed is given in Fig. 3.

The results of investigation show that even under the sufficiently high speed limit (130 km/h) on the test section, 1/6 of the drivers exceeded the speed limit. Taking into consideration the fact that Lithuania implies no responsibility for the exceeded average speed, it was assumed that the results of investigation, performed by JSC ATEA on the road A2, show not the impact of sectorial speed enforcement on the assurance of the speed limit but the effect of stationary speed cameras. Based on the results of investigation a conclusion is made that the effect of two speed cameras does not ensure that on a 5.641 km long road section the drivers observe the speed limit. The results of investigation, performed by the JSC ATEA, confirm an assumption made by Čygaite (2012) that on the sections dangerous from the road safety point of view and longer than 500 m the effect of one speed camera is insufficient to ensure that the drivers observe the speed limit.

#### 3.2. Selection of road sections for the installation of a sectorial speed enforcement system on the roads of Lithuania

In 2013, the *Dept of Roads of Vilnius Gediminas Technical University (VGTU)* made the investigation the task of which was to select road sections where a sectorial speed enforcement system could be installed and be effective. When selecting the mentioned road sections, data provided by the *PE Road and Transport Research Institute* and the *Lithuanian Road Administration under the Ministry of Transport and Communications* was used.

The following three criteria were used to select road sections for a further analysis:

- the predicted number of road crashes on the road section;
- traffic volume on the road section;
- speed measurement data on the road section.

Prediction of crashes on the roads of national significance of Lithuania was carried out using the empirical Bayes method (Čygas et al. 2012; Jasiūnienė, Čygas 2013; Jasiūnienė et al. 2012). Elvik (2008) and Hauer et al. (2002) noted that the empirical Bayes method is well-developed and widely used in the field of road safety. This method is based on the assumption that in a similar environment with the prevailing similar traffic conditions the risk of crashes is similar. Using the empirical Bayes method the expected number of crashes is determined by combining two information sources: 1) number of historic crashes on a specific road element, and 2) mathematical accident

prediction model describing crash risk on the road elements similar in their environment. This method is illustrated by the following formulas:

$$E(\lambda) = \alpha\lambda + (1 - \alpha)r, \tag{1}$$

$$\text{Weighting coefficient: } \alpha = \frac{1}{1 + \lambda/k}, \tag{2}$$

where  $E(\lambda)$  – the predicted number of crashes on a specific road section/junction;  $\lambda$  – the general expected number of crashes for the whole group of homogenous sections determined with the help of mathematical accident prediction models;  $r$  – the number of historic crashes on a specific section;  $k$  – the inverse value of the over dispersion parameter. Parameter  $\alpha$  means weight given to the mathematical accident prediction model of homogenous group of roads or junctions by combining it with the number of historic crashes.

For the road sections and junctions the different mathematical accident prediction models are used. Accident prediction model used for road sections is based on the number of crashes per the vehicle travelled distance, whereas, for junctions – on the number of crashes per entering vehicles. It should be noted that mathematical accident prediction model calculates the predicted number of crashes on a road element having certain similar properties. Based on this, the road network shall be divided into groups having similar properties, depending on the selected independent variables. Accident prediction models are not able to assess all the factors influencing the occurrence of road crashes. The main factors having the largest influence shall be distinguished.

Homogenous groups of road sections were classified by the following 4 criteria: 1) road significance; 2) road cross-section; 3) the speed limit and 4) AADT. The road network of national significance of Lithuania (total 21 268.40 km) was classified into 34 homogenous road groups consisting of 13 254 homogenous road sections.

Homogenous groups of junctions were classified by the following 3 criteria: 1) type of junction; 2) road

significance; 3) traffic volume at the junction. The junctions of the road network of national significance of Lithuania were classified into 14 homogenous groups which are made of 1454 junctions.

A very important criterion for the effect of a sectorial speed enforcement system is uniform traffic volume on the whole road section, therefore when selecting road sections it is necessary to take into consideration the number of entries and exits. Aiming to ensure a uniformity of traffic volume on the whole road section, the length of sections suitable for speed enforcement decreases what results in the increase of investment costs due to more densely installed speed cameras.

Another criterion important for the selection of road sections is the problem of excess speed. To determine a percentage of drivers in the whole traffic flow who do not observe the speed limit, the data of speed measurements taken in the stationary periodical traffic measuring posts was used provided by the SE Road and Transport Research Institute.

Based on the above criteria, 10 road sections were selected (Fig. 4, Tables 2–3) the length of which varies from

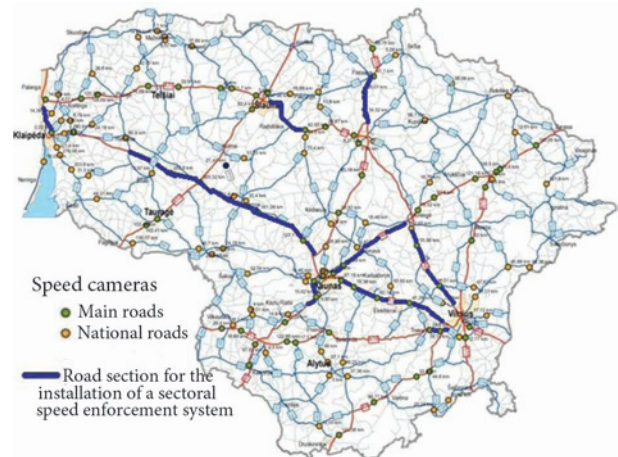


Fig. 4. Road sections suggested for the installation of a sectorial speed enforcement system on the roads of Lithuania

Table 2. Traffic data of road sections selected for the installation of a sectorial speed enforcement system

| Road No. | Sectorial section, km | Length of section, km | AADT <sub>ave</sub> , vpd | AADT change*, % | Speed cameras** | Speeding, % |          |
|----------|-----------------------|-----------------------|---------------------------|-----------------|-----------------|-------------|----------|
|          |                       |                       |                           |                 |                 | ≤10 km/h    | >10 km/h |
| A1       | 17.4–94.0             | 76.6                  | 21 847                    | +18.95          | 4               | 24.0        | 14.3     |
|          | 114.0–253.0           | 139.0                 | 10 232                    | –43.0           | 4               | 22.5        | 13.3     |
| A2       | 11.1–70.0             | 58.9                  | 10 428                    | –32.3           | 2               | 22.0        | 13.9     |
| A5       | 5.5–22.5              | 17.0                  | 17 998                    | –18.1           | 1               | 31.2        | 27.9     |
| A6       | 7.0–14.0              | 7.0                   | 19 151                    | 0               | 1               | 46.6        | 28.0     |
| A6       | 14.0–30.0             | 16.0                  | 10 894                    | +16.8           | 1               | 44.3        | 17.5     |
| A9       | 43.0–70.0             | 27.0                  | 7 715                     | +3.1            | 0               | 44.0        | 48.2     |
| A10      | 10.0–38.0             | 28.0                  | 7 965                     | –15.9           | 2               | 14.7        | 6.6      |
| A13      | 4.0–19.0              | 15.0                  | 11 441                    | –32.5           | 0               | 25.2        | 21.6     |
| A16      | 15.55–25.0            | 9.45                  | 10 006                    | –18.6           | 2               | 15.5        | 6.0      |

Note: \* The difference in AADT between the beginning and the end of section; \*\* - the number of stationary speed cameras on the road section.

**Table 3.** Data of road crashes on road sections selected for the installation of a sectorial speed enforcement system

| Road No. | Sectorial section, km | Historic data of crashes 2007–2011 (5 year) |       | Predicted crashes/year |
|----------|-----------------------|---|-------|------------------------|
|          |                       | Crashes                                     | Fatal |                        |
| A1       | 17.4–94.0             | 145   | 40    | 30.64                  |
|          | 114.0–253.0           | 126   | 36    | 27.68                  |
| A2       | 11.1–70.0             | 44  | 15    | 11.30                  |
| A5       | 5.5–22.5              | 38  | 9     | 11.10                  |
| A6       | 7.0–14.0              | 30  | 5     | 10.5                   |
| A6       | 14.0–30.0             | 52  | 7     | 6.79                   |
| A9       | 43.0–70.0             | 57  | 11    | 12.52                  |
| A10      | 10.0–38.0             | 32  | 12    | 8.38                   |
| A13      | 4.0–19.0              | 39  | 5     | 9.39                   |
| A16      | 15.55–25.0            | 14  | 5     | 3.43                   |

**Table 4.** Investment demand for the installation of a sectorial speed enforcement system in the initial stage

| Type of costs  | Selected road sections for the installation of a sectorial speed enforcement system |                  |                |               |               |                |                |                 |                |                  | Amount of costs | Unit price, EUR | Total price, EUR |  |
|--|---|------------------|----------------|---------------|---------------|----------------|----------------|-----------------|----------------|------------------|-----------------|-----------------|------------------|--|
|  | A1 (17.4–94.0)  | A1 (114.0–253.0) | A2 (11.1–70.0) | A5 (5.5–22.5) | A6 (7.0–14.0) | A6 (14.0–30.0) | A9 (43.0–70.0) | A10 (10.0–38.0) | A13 (4.0–19.0) | A16 (15.55–25.0) |                 |                 |                  |  |
| Cameras, units   | 8   | 8                | 8              | 8             | 8             | 8              | 4              | 4               | 8              | 4                | 64              | 8688            | 556 032          |  |
| Software, units  | Onetime investment into the software of the whole system                            |                  |                |               |               |                |                |                 |                |                  | 1               | 101 367         | 101 367          |  |
| Server, units  | Acquisition of a server for the whole system  |                  |                |               |               |                |                |                 |                |                  | 1               | 57 924          | 57 924           |  |
| Installation of devices                                  | 2   | 2                | 2              | 2             | 2             | 2              | 2              | 2               | 2              | 2                | 20              | 14 481          | 289 620          |  |
| Initial metrological inspection of the section           | 2   | 2                | 2              | 2             | 2             | 2              | 2              | 2               | 2              | 2                | 20              | 2896            | 57 920           |  |
| Monthly maintenance of equipment                         | Two persons and all the related costs   |                  |                |               |               |                |                |                 |                |                  | 2               | 1158·12         | 27 792           |  |
| Annual metrological inspection for one driving direction | 2   | 2                | 2              | 2             | 2             | 2              | 2              | 2               | 2              | 2                | 20              | 579             | 11 580           |  |
| Monthly salary for the staff processing the files        | 3 persons working in the field of processing the files of the whole system          |                  |                |               |               |                |                |                 |                |                  | 3               | 869·12          | 31 284           |  |
| Maintenance of a server                                  | One-year service of the server  |                  |                |               |               |                |                |                 |                |                  | 1               | 3475            | 3475             |  |
| Costs of electricity, data transmission                  | 2   | 2                | 2              | 2             | 2             | 2              | 1              | 1               | 2              | 1                | 17              | 1042            | 17 725           |  |
|  |   |                  |                |               |               |                |                |                 |                |                  |                 | Total           | 1 189 527        |  |

7 km to 139 km. The total length of selected sections was 393.95 km. Taking into consideration the fact that the highest traffic volume in Lithuania is recorded on the main roads, the initially suggested road sections belong to the mentioned group of roads.

### 3.3. Investment demand for the installation of a sectorial speed enforcement system on the selected road sections

Calculations were based on the data obtained from the JSC ATEA. The cost of the installation of a sectorial speed enforcement system in both driving directions of the

two-lane road is 31 136 EUR. Calculations of the investment demand for the implementation of the system on all the selected road sections are given in Table 4. The total amount of investments necessary for the installation of a sectorial speed enforcement system on the selected road sections makes 1 189 527 EUR.

Each year Lithuania incurs large economic losses due to road crashes. Damage caused by road crashes directly depends on the number of people killed and injured. The average material damage of one road crash for the country is determined according to the *Methodology for Calculating*

*Accident Losses.* Based on information, provided by the Lithuanian Road Administration under the Ministry of Transport and Communications, in 2013 the damage to Lithuanian economy caused by one person killed in road crash amounted to 566 591 EUR. When calculating the pay-back period of the installation of a sectorial speed enforcement system on the selected road sections the accident losses of only people killed in road crashes was taken into consideration. On the selected road sections the total predicted number of road deaths is equal to 44.31. The European Commission data shows that 30% of fatal crashes is caused by speeding. Based on foreign experience it is expected that after installation of a sectorial speed enforcement system on the selected road sections the number of drivers exceeding the speed limit will decrease. This would save about 13 lives each year and the country would avoid the economic loss of 7 365 692 EUR. When calculating the pay-back of the system the injury crashes were also taken into consideration as well as fines collected for the excess speed.

Installation of a sectorial speed enforcement system in Lithuania requires urgent changes in the respective legal acts to define the responsibility of vehicle drivers for exceeding an average driving speed.

#### 4. Conclusions

1. For the installation of a sectorial speed enforcement system on the roads of Lithuania 10 sections of the main roads were selected in the initial stage. Three criteria were used for the selection of road sections: the predicted number of crashes on the road section, the traffic volume and the speed measurement data. The length of selected sections varies from 7 km to 139 km. The total length of sections is 393.95 km.

2. The cost of the installation of a sectorial speed enforcement system on the selected road sections and its one-year maintenance would amount to 1 189 527 EUR.

3. Taking into consideration a positive effect of a sectorial speed enforcement system on a decrease in the number of crashes, it is expected that this would help to save about 13 lives each year.

4. Installation of a sectorial speed enforcement system in Lithuania requires urgent changes in the respective legal acts to define the responsibility of vehicle drivers for exceeding an average driving speed.

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