EXTERNAL COSTS OF TRAFFIC ACCIDENTS ON SLOVENIAN ROADS

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Abstract. Traffic safety can be viewed from different aspects. In this paper we assess traffic safety in Slovenia from the costal point of view. Slovenia is a small country on a crossing of important European routes, which provides good developmental possibilities, but at the same time poses threat to traffic safety as the inland infrastructure does not seem to be ready to accommodate the increasingly high traffic flows.

We have created a time series for several traffic safety and traffic workload indicators and analysed those with simple descriptive statistics. Then we have provided an assessment of the costs arising from road accidents.

We found out, that despite the large improvement in traffic safety records it seems that improvement trends could come to an end soon due to heterogenization and growth of traffic flows as well as of deterioration of national and municipal roads.

Keywords: external costs of transport, road traffic safety, road traffic flows, traffic workload, traffic flow structure, road condition

Introduction

One of the most important elements that describe the functioning of transport system is traffic safety. Traffic safety is commonly expressed in terms of number of accidents and severity of their consequences, and this problem is primarily present in road transport. An estimation of the World Health Organization is that approximately 1.24 million people die every year on the world's roads, and another 20 to 50 million sustain nonfatal injuries as a result of road traffic crashes (WHO, 2013a). Apart from the human suffering, traffic accidents, in particular injury accidents, cause significant costs.

Road traffic injuries cause considerable economic losses to victims, their families, and to nations as a whole, so the economic costs of traffic accidents can be divided into internal and external costs, though in some calculations of traffic costs, all costs due to accidents are classified as external costs (ECMT, 2001). By other classification, the external costs of accidents are those social costs of traffic accidents, which are not covered by risk oriented insurance premiums(Button, Vega, & Nijkamp, 2010). These usually include productivity loss, income taxes loss and spending loss due to lost lives or working disability or decreased quality of life, medical treatment, as well as travel delays, congestion and extra pollution caused by the accidents.

In total, the external costs of road accidents are estimated at roughly 1% of gross national product (GNP) in low-income countries, 1.5% in middle-income countries and 2% in high income countries (Armigol *et al*., 2008).

Traffic impacts our living environment in many different ways. Besides accidents, it causes congestion, noise, air pollution, climate changes, road wear etc. These impacts change with the changes in traffic volume and traffic structure. In past decades several studies dealing with the negative impacts of transport have been created (for example INFRAS/IWW, 2000, 2004, 2014; HEATCO, 2005; GRACE, 2008; IMPACT, 2009; CE/INFRAS/ISI, 2011). So far, only one comprehensive assessment of the external costs of transport in Slovenia was created. The study created by Lep and others dates back to 2004. This study follows the methodology applied in INFRAS/IWWE studies. As it is the only such study in Slovenia, it is used as a base for the analysis on external costs presented in this paper.

The goal of the paper is to provide the estimation of external costs of traffic accidents on Slovenian roads. To achieve it and to make the results udnerstandible, we firstly introduce the reader to the developmental process of Slovenian inland transport system with the focus on the factors that influence traffic safety. This is followed by descriptive statistics on road traffic safety in Slovenia. The used methodology is decribed in the separate chapter.

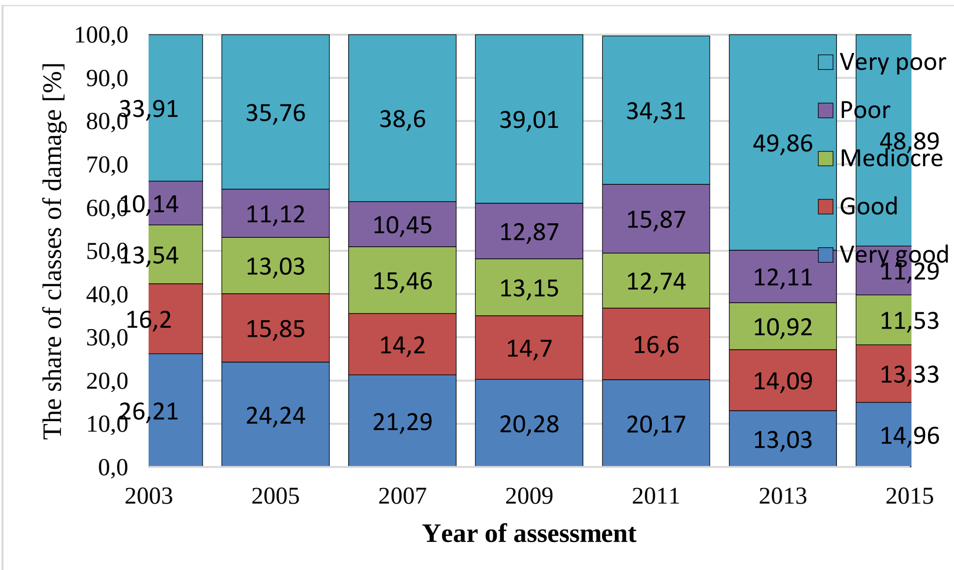
Development of slovenian transport system

Slovenia, a small country on the shores of North Adriatic, became a sovereign state in the beginning of the 1990s, and its excellent geo-strategic position was soon recognized by the European Union. The relation of mutual interest was formalized in 1993 with the Agreement between the European Economic Community and the Republic of Slovenia in the field of transport. With this Agreement Slovenia committed to the realization of projects of common interest as quickly as possible and the European Community agreed to co-finance these projects.

This resulted in the creation of two separate national programs in the mid-1990s; the ambitious National Motorway Construction Programme in the Republic of Slovenia and far less ambitious National Programme of the Slovenian Railway Infrastructure Development. The first integral transport policy was adopted only in 2006. This transport policy emphasizes the importance of Slovenian geographic position as well as the need to retain freight transit flows over Slovenian territory as they bring money. Furthermore, it stresses that these traffic flows should be accommodated by the railways. However, it seems that these two programs have shaped the development of Slovenian surface transportation considerably, much more than the current transport policy, so nowadays, the Slovenian motorways system is pretty much completed, while the railway system has been neglected for many years, and currently cannot meet the modern transportation requirements in terms of capacity, speed, reliability, axle load, train length, radiuses etc. In fact, so far only about 25% of National Programme of the Slovenian Railway Infrastructure Development from 1995 has been realized. Transit freight flows thus cross Slovenia on the roads.

Together with the neglecting of railways also the neglecting of national roads[7], except motorways and highways, was happening. Every year, condition of the pavement on the network of national roads is visually assessed according to the methodology of the Modified Swiss index (MSI). As can be seen from the Figure 1, the condition of state roads is deteriorating very quickly; in 2015 60.2% in comparison to 46.9 % in 2005 of main and regional roads (R3 regional roads excluded)was in poor or very poor condition, while only 28.3% in comparison to 40.1% ten years ago of these roads was in good or very good condition. This can significantly affect traffic safety.

Figure 1: The condition of national roads G1, G2, R1, R2 in Slovenia in the period 2003–2015



Source: *(DI.GOV, 2015)*

In addition, although the Slovenian tolling system for vehicles of maximum permissible mass of more than 3.500 kg (hereinafter trucks) is comprehensive (the differentiation is based upon the distance travelled, number of axes and emissions standard of the vehicle), the toll collection system is outdated and several parts of motorways can be used without payment. The use of motorways is thus tempting and without a suitable alternative in the form of railways, the transit cargo flows are increasing very quickly. This causes the changes in the structure of traffic flows on the motorways which can threaten the traffic safety.

[7] Public roads in Slovenia consist of national roads (motorways, highways, main roads – G1, G2 and regional roads – R1, R2, R3) with total length of 6,645 kilometres and municipal roads (local roads and public paths) with total length of 32,360 kilometres.

Furthermore, disperse settlement pattern in Slovenia (2 million inhabitants live in around 6,000 settlements) makes the organisation and functioning of public transport rather difficult. This consequently encourages the use of private cars more extensively which results in saturated traffic conditions.

The above mentioned caused changes in the shape and functioning of the Slovenian transport system. From the Table 1 it is possible to see that some main roads and highways were upgraded into motorways in the period from 2000 to 2014; in fact, in the analysed period the length of motorways increased by more than 75%. In 2000 the Slovenian motorways accommodated barely 21% of all traffic workload done on Slovenian state roads, while this percentage increased to more than 44 in 2014. Traffic workload actually almost tripled on Slovenian motorways in the analysed period. At the same time the traffic workload of freight vehicles doubled on Slovenian roads; the growth on motorways was almost 530% and only 46% on regional roads. However, as mentioned, the road network expanded, so if we normalize the results by calculating the relative growth according to the length of roads than we can say that freight traffic workload increased by 256% on the motorways and only by 36% on regional roads. This is also due to the fact the Slovenian legislation requires the use of higher category roads for distance transport of freight vehicles wherever such roads exist.

Table 1: Structure of roads' length and traffic work on Slovenian state roads in 2000 and 2014

	2000				2014			
	Length [km]	AADT	Traffic workload	FV traffic workload	Length [km]	AADT	Traffic workload	FV traffic workload
			[mio vkm/year]				[mio vkm/year]	
Motorways	257	20,943	1,968	248	534	29,495	5,751	1,314
Highways	137	16,560	831	119	73	21,603	574	109
Main road	1,012	8,222	3,045	383	811	7,516	2,225	266
Regional roads	4,717	2,060	3,557	290	5,127	2,335	4,369	424
State roads	6,123	4,196	9,401	1,040	6,545	5,408	12,919	2,113

Note: AADT - Annual average daily traffic; FV – Freight vehicles; vkm – vehicle kilometres

Source: *(DI.GOV, 2016)*

Data and methods

Slovenia has a long tradition of traffic accidents data recording; first records on traffic accidents date back to the early 1950s. The current data set is composed of two data bases; the first one including information on the occurrence of accidents and the other one on the participants in these accidents. The two data bases are connected through the accident identification number. These data are provided by the Slovenian Police in raw format.

To determine overall progress in traffic safety we used some simple descriptive statistics. Firstly, we calculated the Average annual growth rate (AAGR) for the period from 2000 to 2015 for several traffic safety indicators, namely the number of accidents, the number of fatalities and severely injured as well as the number of slightly injured people. Then we calculated the Pearson's coefficients of correlation to check if all indicators of traffic safety are moving in the same direction.

After that, we applied Accident Point Weightage – APW method (see e.g. (Mustakim & Fujita); (NorBalkish, Ismail, & Erwan, 2011)) which is usually used to assess traffic safety on road segments and consequently for black spots elimination. However, we used it in a generalized way to assess overall improvement of road traffic safety in Slovenia, and to determine the relations of different categories of the roads in terms of traffic safety.

$$\mathrm{APW} = 6 \times X_1 + 3 \times X_2 + 0.8 \times X_3 + 0.2 \times X_4 \qquad (1)$$

where: X_1stays for number of fatal accidents, X_2number of serious injury accidents, X_3 number of slight injury accidents and X_4 number of damage only accidents.

A common approach to forecast traffic safety is by creation of safety performance function (SPF). SPF is an equation that is used to predict the average number of crashes per year as a function of exposure and in some cases roadway characteristics. The generalized form of models that are used to forecast the number of road accidents takes the following form (Eenink *et al*. 2008):

$$E(\lambda) = \alpha Q^{\beta} e^{\sum y_i x_i} \qquad (2)$$

where estimated expected number of accidents, $E(\lambda)$, is a function of traffic volume, Q, and a set of risk factors, x_i (i = 1, 2, 3, …, n). The effect of traffic volume on accidents is modelled in terms of an elasticity, that is a power, β, to which traffic volume is raised.

It is good to make the selection of explanatory variables that are included in a SPF based on theory; however, data availability is often a limiting factor, thus formula (2) often takes the following simplified form as suggested by Elvik and others (2009):

$$E(\lambda) = AADT^{\beta} \qquad (3)$$

where *AADT* stays for average annual daily traffic, which is a proxy for traffic volume. The presumption of this model is that accidents occur randomly, but at constant rate in regards to traffic activity.

To express the consequences of accidents in monetary terms we used the determined costs of accidents from the study on external costs in Slovenia that was created by Lep and others in 2004. We translated the information on costs from Slovenian ex currency to Euros and adjusted these costs by the inflation rates obtained from the Statistical office of the Republic of Slovenia.

The value of life can be calculated in different ways (see e.g. VTPI, 2013), that is HC=Human capital; WTP=Willingness to pay; PGS=Pain grief suffering or VSI=Value of serious injury. In Slovenian study on external costs of transport, the value of life is calculated as WTPand the external costs of traffic accidents (*TC)* are calculated by the following formula:

$$\mathrm{TC} = A(b + c) \quad (4)$$

where A is the number of traffic accidents, b is the willingness to pay for the accident risk reduction and c represents the systematic external costs including the costs of hospital treatment and the costs of police investigation at the accident scene.

Finally, we obtained data on Gross domestic product (GDP) and Gross nation product (GNP). The data on GNP is provided by World bank in US dollars, so we used historical data on average exchange rates between the two currencies, namely US dollars and Euros. The source for the exchange rates was investing.com. This data was used to determine the share of external costs in Slovenian GDP and GNP.

Limitations of the obtained data

Reporting of road accidents in official statistics is often incomplete and biased (Elvik *et al*. 2009), and even when crashes are well defined in identical terms, there are significant variations in crash data among sources (Shinar, 2007). Even Brvar (2010), a research journalist in Slovenia, expressed doubts on the accuracy of Slovenian official road safety statistics; however, as there is no better publically available data on traffic accidents in Slovenia, we needed to use the official data provided by Slovenian police.

The results

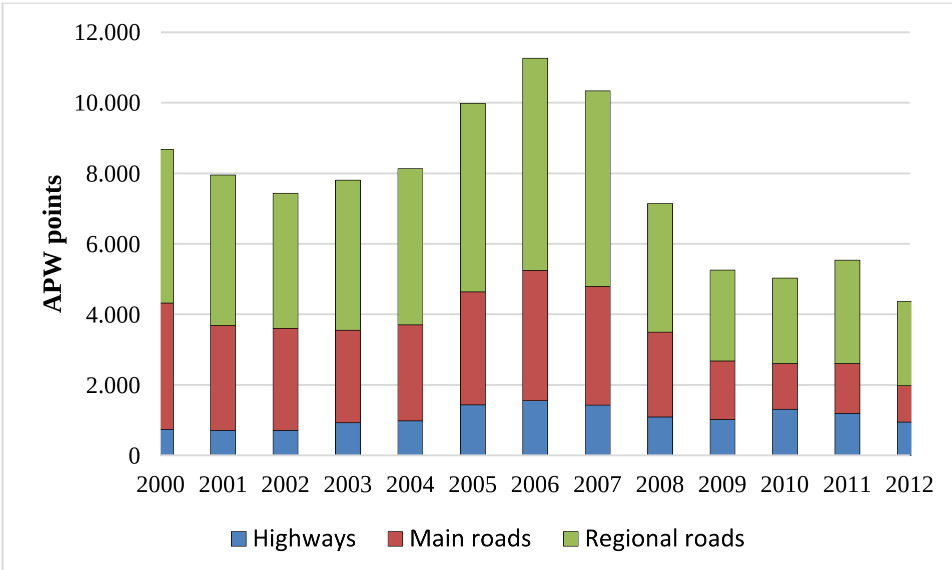
Basic findings

Traffic safety is improving on Slovenian roads. In fact, the calculation of AAGR for the period from 2000 to 2015 shows improvement of all traffic safety indicators, that is in the number of accidents (-4.6%), number of fatalities (-5.5%) and number of severely injured (-6.0%), only a number of lightly injured persons on roads increased (+0.1%).

Generally speaking, in the year 2008 the highest improvement of road traffic safety in Slovenia was registered, with the change of APW being -24.7%. This is the year of the significant expansion of Slovenian motorways network as well as of the introduction of vignette tolling system for personal cars in Slovenia, which resulted in a massive switch of personal passenger traffic flows from regional roads to motorways, which are by theory the safest roads (see e.g.

ETSC, 2008). In fact, according to APW traffic safety improved on all road categories besides the motorways

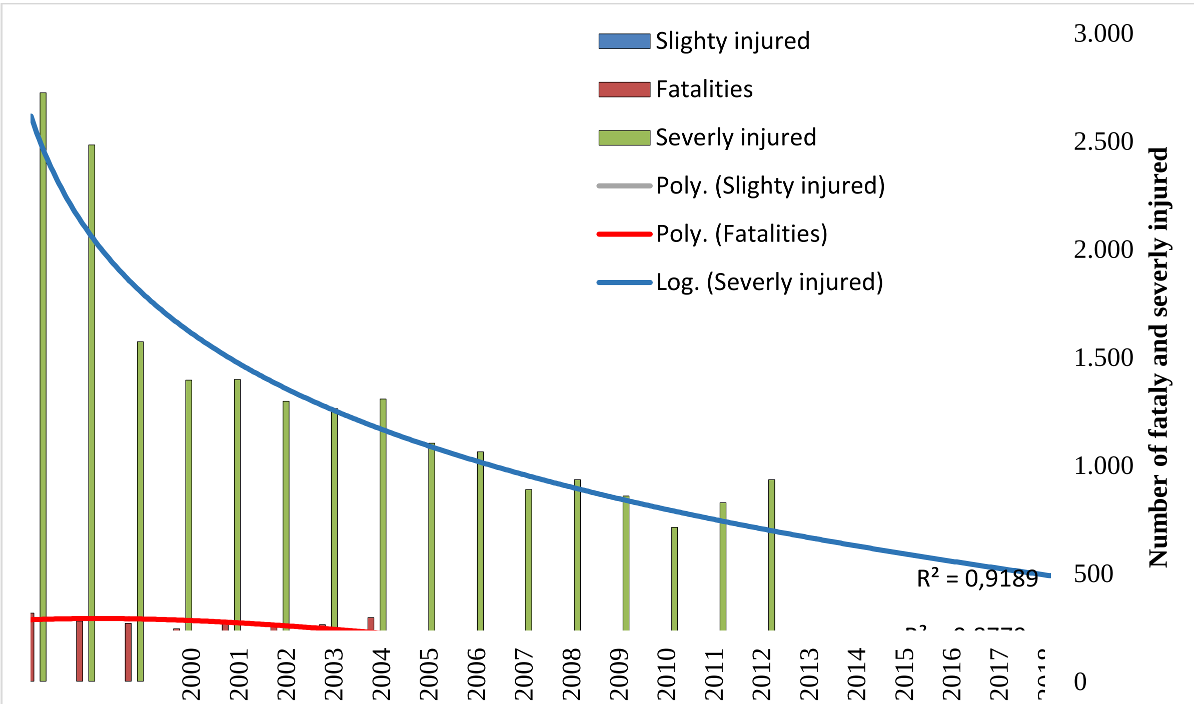
Figure 2: APW points by road type



Although, the proportion of people killed on motorways is growing, the number of accidents relative to traffic workload is dropping; in 2015 almost 3 times less fatalities per billion vehicle kilometres occurred on Slovenian motorways in comparison to the year 2000(calculation based on DI.GOV, 2016). Similar is observed for severely injured people on motorways.Regional roads and main roads still remain the most dangerous categories of Slovenian road network also in the view of traffic workload done.

Regardless of the recorded improvement of traffic safety records, the best fitting approximation with a rather high coefficient of determination suggest that we can expect more accidents (the polynomial approximation with the coefficient of determination being 0.919) and more slightly injured road users in future; however, the number of severely injured road users should further drop and the number of fatally injured should be pretty steady. This is in line with theory which says that the increased volume of traffic flows on a limited transport infrastructure results in lower traffic speeds which consequently result in less severe accidents (see e.g. Button, 2010).

Figure 3: Forecast of traffic safety on Slovenian roads



By using the formula (3) we find that the growth of AADT on national roads by 10% results in increase in the number of road accidents by approximately 11.2% (between 8.7 and 13.8% with a confidence of 95%). The same growth of AADT on motorways causes growth in the number of road accidents by around 7.5% (between 6.5 and 8.5% at a confidence interval of 95%). Furthermore, Zanne *et al.*(unpublished) determined that the increase of share of trucks on Slovenian motorways by 1%, increases the number of accidents by around 2.5 to 3% if AADT remains unchanged.

Costs of traffic accidents on Slovenian roads

The causer of road accident in Slovenia is not reported in almost one fifth of the cases. For that reason, we decided to calculate the costs of accidents as total costs, regardless of the possibilities that the driver was actually also the victim due to his/her own fault. In any case, the economy loses, due to the lost production, lost tax income, lost spending, medical expenses are covered from the governmental funds, suffering is present etc.

From the only existing study on external cost of transport in Slovenia, we retrieved basic values for the year 2002 and then adjusted those values by using the inflation rates. In this study the external costs of traffic accidents are divided into three main groups, namely economic loss, medical treatment and on spot police work. The basic values from 2002and the calculated values in 2015 were rounded as follows:

Economic loss:

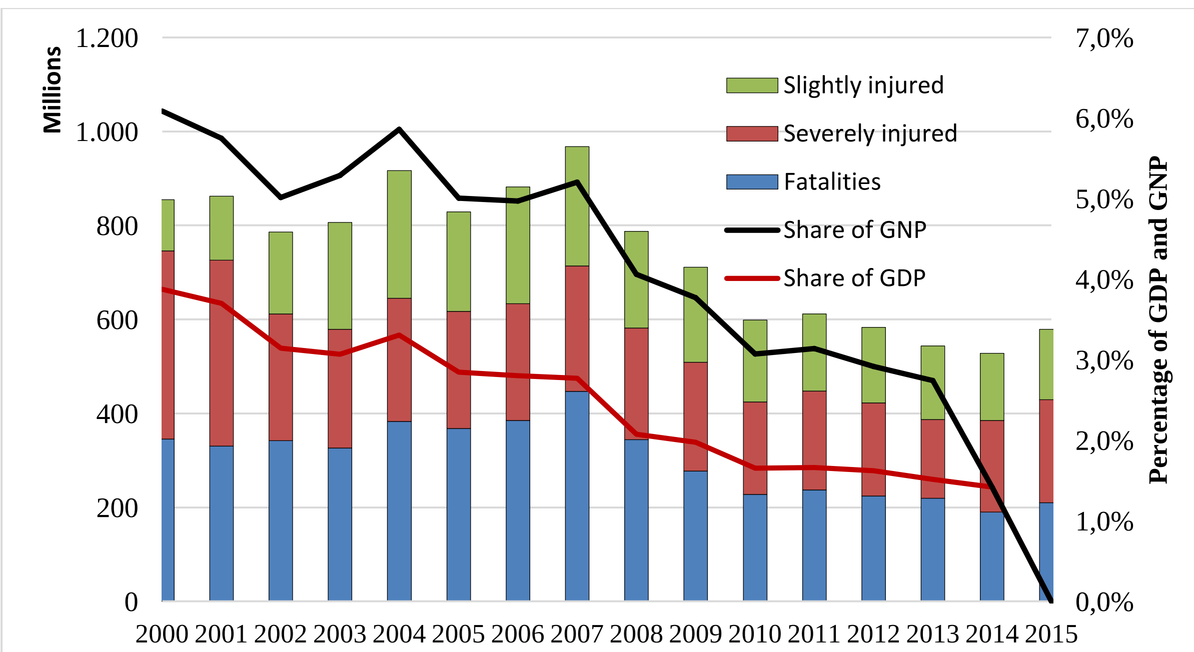
- Death: 1,276,915 EUR / 1,750,000 EUR
- Severe injury: 166,000 EUR / 227,500 EUR
- Slight injury: 12,770 EUR / 17,500 EUR

Medical treatment:

- Death: 242 EUR / 330 EUR
- Severe injury: 5,560 EUR / 7,675 EUR
- Slight injury: 1,295 EUR / 1,775 EUR

Police work: 58 EUR / 80 EUR.

Figure 4: Costs of traffic accidents on Slovenian roads



Source: Own calculation based on Lep et al. (2004), STAT.SI, Policija, World Bank data

In the analysed period the costs of accidents on Slovenian roads accumulated for around 11.85 billion EUR or in average 741 million EUR per year. As can be seen from Figure 4, these costs decreased significantly since 2007, but the best fitting trend (polynomial approximation with the coefficient of determination being 0.814) suggests that we can expect the growth of traffic accidents costs. This is consistent with the findings regardingthe development of road traffic safety in Slovenia. Any road accident causes costs; currently, one fatal injury costs around 90 times more than slight injury, and one severe injury costs around 12 times more than slight injury.

The costs of road accidents also represent dropping share of GDP and GNP; the latest is now in line with the theory my mid-income countries.

Conclusions

In Slovenia the adequate alternative to road transport is not provided for freight movements. In addition, Slovenian tolling system is rather friendly to the trucking companies. On the other hand, the use of public transportation is decreasing as a result of improper settlement policy, and the use of personal cars is in expansion. This results in an unsustainable modal split and growth of road traffic flows as we could see from the Table 1.

Nevertheless, traffic safety was improving in the analysed period and consequently the costs of accidents were decreasing; in fact, the share of GDP and GNP dropped to the average in mid-income countries. This can be mainly attributed to the construction of the motorway network and Slovenian legislation, which requires the use of motorways for freight vehicles wherever possible as well as of switch of personal cars to the motorways that started in 2008. However, the construction of the motorway network is now completed, while other roads are increasingly neglected. Although the motorways are taking an increasing share of traffic flows, regional and other lower category roads represent vital connections that are used on daily basis, and a sum of traffic flows on main and regional roads (without municipal roads) still accumulates for around 25% above the work done on motorways. As proved earlier in this paper, these roads are still the most dangerous ones, and with the expected further deterioration the traffic safety on these roads might me seriously jeopardized.

The limited infrastructure will have to accommodate the increasing traffic workload; only in the last year it increased by 1.6% (AAGR for the entire period was 2.3%) on all state roads and the traffic structure has changed considerably. The first can produce higher number of mostly less severe accidents, while heterogenic traffic structure poses threat to traffic safety in different ways; congestion and induced overtaking on main and regional roads, as well as significant difference between the average speed on drive lane and fast lane, higher density of vehicles on the fast lane than on drive lane resulting in inadequate time headings on fast lane on motorways and highways (Zanne & Groznik, 2015). This can produce more crashes even without the direct involvement of a freight vehicle itself.

This suggests that more focused researches should be performed in order to find adequate solutions to keep traffic safety at relatively high levels and to keep total costs of accidents below 600 million EUR.

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