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EXTERNAL COSTS OF TRAFFIC ACCIDENTS ON SLOVENIAN ROADS

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Abstract. *Traffic safety can be viewed from different perspectives. In this study, we assess traffic safety in Slovenia from the point of view of costs. Slovenia is a small country at a crossroads of important European routes that provides good developmental possibilities, but at the same time faces potential threats to traffic safety because the inland infrastructure does not seem ready to accommodate the increasingly high traffic flows.*

We have created a time series for several traffic safety and workload indicators, and have analysed them using simple descriptive statistics. We have then provided an assessment of the costs arising from road accidents.

We discovered that despite a large improvement in traffic safety records, it seems that such trends could soon come to an end because of the heterogenisation and growth of traffic flows, as well as the deterioration of national and municipal roads.

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

1. Introduction

One of the most important elements that describes the functioning of a transport system is traffic safety. This is commonly expressed in terms of the number of accidents and severity of their consequences, with the problem primarily present in road transport. The World Health Organization estimates that approximately 1.24 million people die every year on the world's roads, and another 20 to 50 million sustain non-fatal injuries as a result of road traffic crashes (1). Apart from the human suffering involved, traffic accidents – particularly injuries – cause significant costs.

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Road traffic injuries cause considerable economic losses to victims and their families, and to nations as a whole. The economic costs of traffic accidents can be divided into internal and external costs, though in some calculations, all costs stemming from such accidents are classified as external costs (2). Under other classifications, external costs of traffic accidents are social costs that are not covered by risk-oriented insurance premiums (3). These usually include productivity, income tax and spending losses generated by lost lives, working disability or decreased quality of life, and medical treatment, as well as travel delays, congestion and extra pollution caused by the accidents.

In total, 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 (Peden *et al.*, 2008).

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

The aim of the study is to provide an estimation of the external costs of traffic accidents on Slovenian roads. To achieve this and aid understanding of the results , we firstly introduce the reader to developmental processes involving the Slovenian inland transport system, with a focus on factors that influence traffic safety. This is followed by descriptive statistics on road traffic safety in Slovenia. The methodology used is decribed in a separate chapter.

2. Development of the slovenian transport system

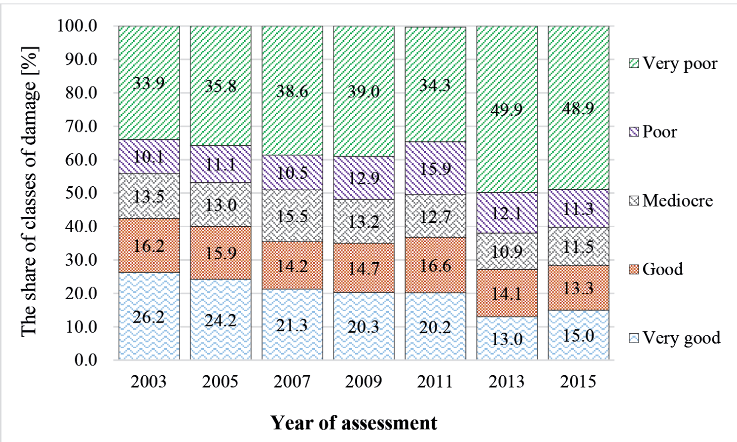
Slovenia, a small country on the shores of the North Adriatic, became a sovereign state at the start of the 1990s, and its excellent geostrategic position was soon recognised by the European Union. A relationship of mutual interest was formalised in 1993, with an agreement between the European Economic Community and the Republic of Slovenia in the field of transport. Under this agreement, Slovenia committed to carrying out projects of common interest as soon as possible, and the European Community agreed to co-finance these initiatives.

This resulted in the creation of two separate national programmes in the mid-1990s – the ambitious National Motorway Construction Programme in the Republic of Slovenia and the far less ambitious National Programme of the Slovenian Railway

Infrastructure Development. The first integral transport policy was adopted only in 2006. This policy emphasises the importance of Slovenia's geographic position and the need to retain freight transit flows over its territory because they bring in money. Furthermore, it stresses that these traffic flows should be accommodated by railways. It seems, however, that the two programmes have shaped the development of Slovenian surface transport much more than the current transport policy – so nowadays the country's motorway system is more or less completed, whereas the railway system has been neglected for many years and cannot currently meet modern transportation requirements with regard to factors such as capacity, speed, reliability, axle loads, train lengths and radiuses. In fact, only about 25% of the National Programme of the Slovenian Railway Infrastructure Development from 1995 has so far been completed. Transit freight thus crosses Slovenia by road.

Alongside the neglect of the railways has also been a neglect of national roads[2] other than motorways and highways. Every year, the condition of the pavement on the network of national roads is visually assessed under the methodology of the modified Swiss index (MSI). As can be seen in Figure 1, the condition of state roads has deteriorated rapidly: a total of 60.2% of main and regional roads (excluding R3 roads) were in a poor or very poor condition in 2015, compared with 46.9% in 2005; and only 28.3% were in a good or very good condition, compared with 40.1% a decade earlier. That situation can significantly affect traffic safety.

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



Source: *(4)*

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

In addition, although the Slovenian tolling system for vehicles with a maximum permissible mass of more than 3,500 kg (namely trucks) is comprehensive (with differentiation based on distance travelled, number of axes and the vehicle's emissions standards), the toll collection system is outdated and several parts of the motorways can be used without payment. The use of motorways is thus tempting, and without a suitable alternative in the form of railways, transit cargo flows are rapidly increasing. This causes changes in the structure of motorway traffic flows, which can threaten safety.

Furthermore, the dispersed settlement pattern in Slovenia (with 2 million inhabitants live in around 6,000 settlements) makes the organisation of public transport challenging. This in turn encourages an extensive use of private cars, resulting in saturated traffic conditions.

The trends cited have caused changes in the nature and functioning of the Slovenian transport system. From Table 1, it can be seen that some main roads and highways were upgraded to motorways between 2000 and 2014, and the length of motorways increased by more than 75% in the period analysed. In 2000, Slovenian motorways accommodated barely 21% of the total traffic workload on state roads, a figure that increased to more than 44% in 2014. In total, the traffic workload almost tripled on Slovenian motorways during the period analysed. Over the same period, the traffic workload of freight vehicles doubled on the country's roads, with growth on motorways of almost 530%, compared with only 46% on regional roads. However, as noted, the road network expanded. If we therefore normalise the results by calculating the relative growth in relation to the length of roads, we can say that freight traffic workload increased by 256% on motorways and only 36% on regional roads. This is also because Slovenian legislation requires the use of higher-category roads for distance transport by 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 (mil. vkm/year]	FV traffic workload (mil. vkm/year]	Length (km)	AADT	Traffic workload (mil. vkm/year)	FV traffic workload (mil. 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 roads	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: *(5)*

3. Data and methods

Slovenia has a long tradition of data recording for traffic accidents, with its first records dating back to the early 1950s. The current data set is comprised of two databases – one that includes information on the occurrence of accidents and the other on those involved in these accidents. The two databases 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) between 2000 and 2015 for several traffic safety indicators – namely the number of accidents, the number of fatalities and the number of people severely injured, as well as the number of slightly injured people. We calculated the Pearson's coefficients of the correlation to see whether all indicators of traffic safety are moving in the same direction.

After that, we applied the accident point weightage (APW) method (see e.g. (6); (7)), which is usually used to assess traffic safety on sections of road and in turn to help eliminate black spots. However, we used this in a generalised way to assess overall improvements in road traffic safety in Slovenia, and to determine the relations of different categories of roads in terms of traffic safety.

$$APW = 6 \times X_1 + 3 \times X_2 + 0.8 \times X_3 + 0.2 \times X_4, \quad (1)$$

where X_1 is the number of fatal accidents, X_2 the number of serious injury accidents, X_3 the number of slight injury accidents, and X_4 the number of damage-only accidents.

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

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

where the 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 this volume is raised.

It is good to select explanatory variables included in the SPF based on theory. However, data availability is often a limiting factor, so formula (2) often takes the following simplified form, as suggested by Elvik and others (2009):

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

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

To express the consequences of accidents in monetary terms, we used the costs of accidents determined from a study on external costs in Slovenia by Lep and others in 2004. We translated the information on costs from the 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, for example, VTPI, 2013), that is HC = human capital, WTP = willingness to pay, PGS = pain grief suffering, or VSI = value of serious injury. In the Slovenian study on the external costs of transport, the value of life is calculated as WTP, and the external costs of traffic accidents (*TC*) are calculated using the following formula:

$$TC = A(\text{b+c}), (4)$$

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

Finally, we obtained data on gross domestic product (GDP) and gross national product (GNP). GNP data is provided by the World Bank in US dollars, so we used historical data on average exchange rates between that currency and euros. The source for exchange rates was Investing.com. This data was used to determine the share of external costs in Slovenian GDP and GNP.

3.1. Limitations of the data

The 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 between sources (Shinar, 2007). Even Brvar (2010), a research journalist in Slovenia, expressed doubts about the accuracy of the country's official road safety statistics. However, given that there is no better publicly available data on traffic accidents in Slovenia, we needed to use the official data provided by the country's police.

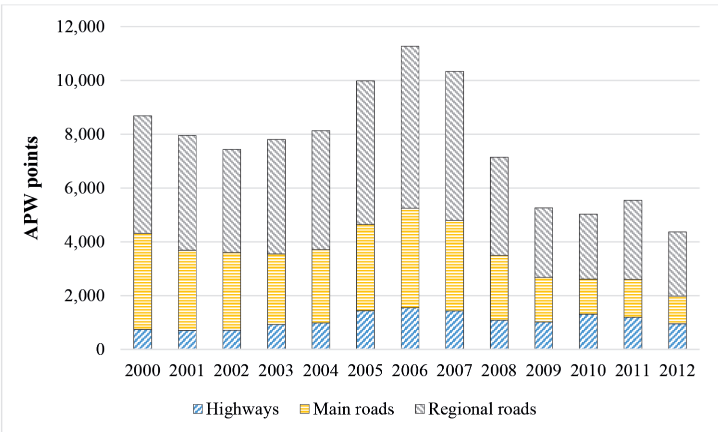
4. Results

4.1. Basic findings

Traffic safety is improving on Slovenia's roads. A calculation of the AAGR between 2000 and 2015 shows an improvement in all traffic safety indicators – that is, in the number of accidents (-4.6%), number of fatalities (-5.5%) and the number of people who were severely injured (-6.0%). Only the number of people who were slightly injured on roads increased (+0.1%).

Generally speaking, the largest improvement in road traffic safety in Slovenia was registered in 2008, with a change in APW of -24.7%. That year saw a significant expansion of the Slovenian motorway network, as well as the introduction of a vignette tolling system for personal cars in Slovenia. As a result, there was a massive switch in flows of personal passenger traffic from regional roads to motorways, which are in theory the safest roads (see e.g. ETSC, 2008). In fact, according to the APW data, traffic safety improved in all road categories aside from motorways.

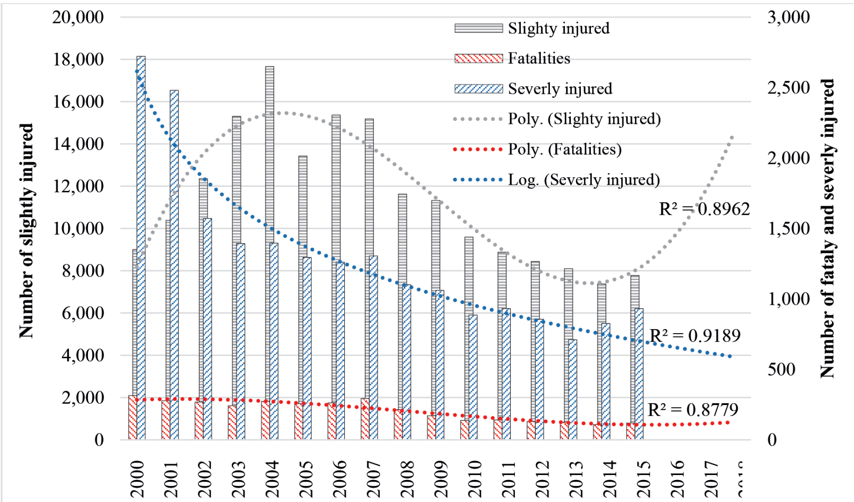
Figure 2: *APW points by road type*



Although the proportion of people killed on motorways is growing, the number of accidents relative to traffic workload is dropping: in 2015, almost three times fewer fatalities per billion vehicle kilometres occurred on Slovenian motorways in comparison to the year 2000 (calculation based on DI.GOV, 2016). A similar trend can be observed with regard to severely injured people on motorways. Regional roads and main roads remain the most dangerous categories in the Slovenian road network also in the view of traffic workload done.

Regardless of recorded improvements in traffic safety records, the best-fitting approximation with a rather high coefficient of determination suggests that we can expect more accidents (the polynomial approximation with the coefficient of determination being 0.919) and more slightly injured road users in the future. However, the number of severely injured road users should further drop and the number of fatally injured people should be fairly steady. This is in line with theory that suggests that an increased volume of traffic over limited transport infrastructure results in lower traffic speeds and thus fewer severe accidents (see e.g. Button, 2010).

Figure 3: *Forecast of traffic safety on Slovenian roads*



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

4.2. Costs of traffic accidents on Slovenian roads

The person who causes a road accident in Slovenia is not reported in almost one-fifth of cases. For that reason, we decided to calculate the costs of accidents as total costs, regardless of the possibility that the driver was actually also the victim through his or her own fault. In any case, the economy loses, due to the lost production, lost tax income, lost spending, medical expenses are covered by government funds, suffering is present etc.

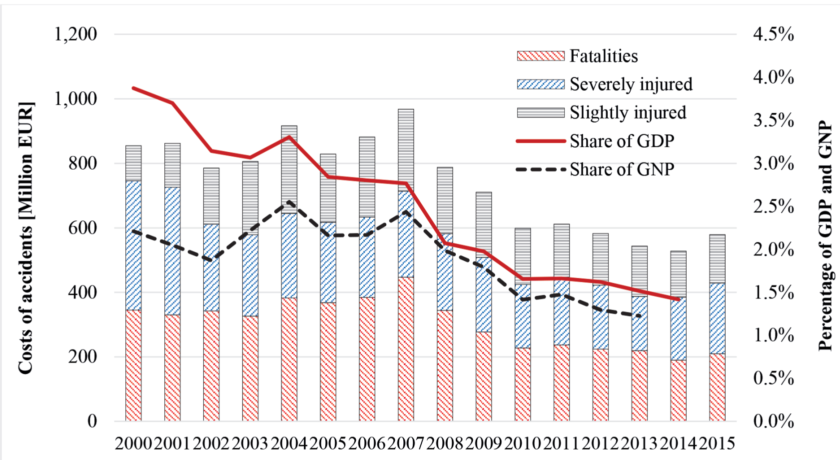
From the only existing study on the external costs of transport in Slovenia, we retrieved basic values for the year 2002 and then adjusted them by using inflation rates. In this study, the external costs of accidents are divided into three main groups – namely economic losses, costs for medical treatment,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

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

Costs for medical treatment:
- Death: €242 / €330
- Severe injury: €5,560 / €7,675
- Slight injury: €1,295 / €1,775

Costs for police work: €58 / €80.

Figure 4: *Costs of traffic accidents on Slovenian roads*



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

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

Meanwhile, the costs of road accidents represent a declining share of GDP and GNP, with the latest now in line with the theory my mid-income countries.

5. Conclusions

In Slovenia, an adequate alternative to road transport is not provided for the movement of freight, and the country's tolling system is also rather friendly to trucking companies. In addition, the use of public transport is decreasing as a result of an improper settlement policy, and the use of personal cars is growing. This results in an unsustainable modal split and growth in road traffic flows, as can be seen in Table 1.

Nevertheless, traffic safety improved in the period analysed and the costs of accidents thus decreased, with the share of GDP and GNP dropping to the level of the average in middle-income countries. This can be attributed mainly to the construction of the motorway network and Slovenian legislation, which requires freight vehicles to use motorways wherever possible, as well as the switch of personal cars to 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. In addition, the sum of traffic flows on main and regional roads (without municipal roads) still accumulates for about 25% above the work done on motorways. As shown in this paper, these roads are still the most dangerous, and with an expected deterioration in traffic safety, the situation on these roads might be seriously jeopardised.

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

These findings suggest that more research should be conducted to find solutions for ensuring high levels of traffic safety and keeping the total cost of accidents below €600 million.

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