An analysis of official road crash cost estimates in European countries

Abstract

This paper gives an overview of official monetary valuations of the prevention of road crashes, road fatalities and injuries in 31 European countries. The values have been made comparable by converting them to Euro in 2015-values, adjusted by purchasing power parities. The monetary valuation of preventing a fatality varies from 0.7 to 3.0 million Euro. The valuation of preventing a serious injury ranges from 2.5% to 34.0% of the value per fatality and the valuation of preventing a slight injury from 0.03% to 4.2% of the value of a fatality. Total costs of road crashes are equivalent to 0.4% to 4.1% of GDP. The method used for obtaining valuations has a major impact on values. Most countries rely on the willingness-to-pay (WTP) approach, which gives higher valuations than other methods. Additional explanations for variations in valuations are differences in the cost components included, different definitions of serious and slight injuries and different levels of underreporting. Harmonization of valuation practices is needed for making sound international comparisons of road crash costs and for cost-benefit analysis at supranational level.

Keywords: costs; road crash; fatality; injury; economic valuation; willingness to pay

1. Introduction

Information about road crash costs is needed for at least two purposes. Firstly, road crash costs are regarded as a high-level outcome indicator for road safety management (Bliss & Breen, 2009). This indicator reflects the magnitude of road crashes as a socio-economic problem, which is influenced by the implementation of road safety policies, among others. Secondly, road crash cost information is used in economic assessments of road safety programs or broader transport projects. In cost-benefit analysis, road crash cost savings reflect the monetary valuation of the benefits of road safety improvements. Consequently, official guidelines for economic appraisal of transport projects usually include monetary valuations of preventing road casualties (for example EC, 2014; USDoT, 2017).

Several international reviews of road crash costs have been made in the past (Wijnen & Stipdonk, 2016; Trawén et al., 2002; Elvik, 2000; Elvik, 1995; Alfaro et al., 1994). However, a comprehensive review covering all current European Union countries has not been conducted yet. Alfaro et al. (1994) concentrated on 14 European countries, while the other studies included countries from several continents (including Europe). This paper aims to fill this gap by presenting a review of road crash costs in 31 European countries, including an assessment of the size of road crash costs (total and costs per casualty and crash), the methods used to estimate these costs, and explanations for differences in cost estimates between countries. The study was conducted within the European Horizon2020 project SafetyCube, which is aimed at developing a road safety Decision Support System (DSS) for road safety policy makers and other stakeholders. This system includes a tool for conducting cost-benefit analyses of road safety measures, using country-specific information on road crash costs. The information on crash costs was collected in collaboration with the European Horizon2020 project InDeV (Kasnatscheew et al, 2016). This paper concentrates on the official values as applied by governmental organizations in economic assessment of road safety or broader transport projects. Note that in some countries other cost estimates are available, for example from academic studies, and that these values may deviate from the values officially used by the government. In Belgium for example, academic studies on road crash costs have been conducted (De Brabander en Vereeck, 2007; De Brabander, 2006), but the results of these studies are not adopted in the governmental guidelines for economic appraisal (RebelGroup, 2013). Policy makers may tend to choose relatively conservative values. For example, the European Conference of Ministers of Transport deliberately choose a value of a fatality that was lower than the scientifically most accurate estimate (ECMT, 1998). Other examples include Belgium, where a higher value of a fatality found by De Brabander (2006) was not used as a standard governmental value, and the Netherlands, where a value of a fatality at the lower bound of a range was chosen as the official value (Wesemann et al., 2005). Given these discrepancies, the present study focuses on the crash costs that are applied by the government and does not include crash costs from other sources.

2. Method for the analysis of official national cost values

To enable a comparative analysis of monetary valuations of road safety in European countries, a framework was defined, consisting of a classification of the main cost components, underlying cost items within each component and methods to estimate each cost item. The framework was based on guidelines for estimating road crash costs, in particular the European COST313 guidelines (Alfaro et al., 1994) and best practices as identified in international reviews of road crash cost studies (Wijnen & Stipdonk 2016).

The main cost components included in the framework are:

1. Medical costs, such as costs of hospitalization, rehabilitation and other medical treatment;
2. Production loss: the loss of production or productive capacity of road casualties;
3. Human costs: immaterial cost of pain, grief, loss of quality of life and lost life years;
4. Property damage, such as damage to vehicles and infrastructure.
5. Administrative costs: costs related to police for attending road crashes, fire service, insurance and legal costs;

6. Other costs, such as funeral costs, congestion costs and vehicle unavailability.

In addition, three valuation methods are identified for estimating these cost components:

1. The restitution costs approach, which comprises estimates of the costs of resources that are needed to restore road casualties and their relatives and friends as much as possible to the situation which would exist if they had not been involved in a road crash. These costs can be interpreted as the direct costs resulting from a crash, such as the costs of hospital treatment and vehicle repair. This approach is typically used to estimate medical costs, property damage and administrative costs, as these costs are associated with restoring the consequences of road crashes. Usually market prices are used to value these costs, if available. For example, costs of vehicle damage are calculated using the price of repairing a vehicle, which represents the value of the resources (e.g. labour and materials) used to repair the vehicle.
2. Human capital (HC) approach: in this approach the value for society of the loss of productive capacities of road casualties is measured. This approach is suitable for estimating production loss. The HC approach can be used to estimate either the actual production loss or the potential production loss. The first concerns the market production of casualties who are employed, while the latter refers to what casualties could potentially produce. Potential production loss takes into account the loss of productive capacities of unemployed people as well as future production of children. Future production is discounted using a social discount rate.
3. Willingness to pay (WTP) approach: in this approach costs are estimated on the basis of the amount individuals are willing to pay for a risk reduction. This approach is generally recommended as the most appropriate method to estimate human costs (Freeman et al., 2014; Boardman et al., 2011; Alfaro, 1994), since there is no market price for these costs. Stated preference or revealed preference methods are used to determine the WTP (see e.g. Bahamonde-Birke et al., 2015; Blaeij, 2003). Revealed preference methods value risk reductions on the basis of actual behaviour, for example purchasing behaviour regarding safety provisions

such as airbags. Stated preference methods use questionnaires in which people, directly or indirectly, are asked how much they are willing to pay for reducing their crash risk. Although both types of methods are valid, reviews show that stated preference methods are much more commonly used in the field of road safety, particularly in Europe (Lindhjem, 2010; Blaeij et al., 2003). Despite several types of potential bias related to using surveys (Bahamonde-Birke et al., 2015 ; Boardman et al., 2011), stated preference methods are often preferred because of their broader applicability and independence of information on actual (purchasing) behaviour. Moreover, consumers are usually not (fully) aware of the risk reduction resulting from safety devices and stated preference methods allow providing this information to respondents to help them understand (small) risk reductions correctly (Lindhjem, 2010).

Note that willingness to pay estimates comprise, in addition to a valuation of immaterial loss of quality of life, a valuation of consumption loss, which overlaps with production loss. Consequently, a correction for consumption loss should be made to avoid double counting (Wijnen et al., 2009). In this respect a distinction is commonly made between gross production loss (including consumption loss) and net production loss (excluding production loss). It is common practice to use the concept of gross production and to deduct consumption loss from WTP estimates (Wijnen & Stipdonk, 2016).

The framework is discussed in more detail in Wijnen et al. (2017).

Based on this framework a questionnaire was developed, including questions on:

- Costs per casualty and per crash, per cost component and by severity level. Seven cost categories were distinguished based on the severity level: fatalities and fatal crashes, serious injuries and serious injury crashes, slight injuries and slight injury crashes, and property damage only (PDO) crashes.
- Cost items included in each cost component.

- Methods and databases used to estimate each cost item.
- Total costs of all casualties and crashes and their percentage of Gross Domestic Product (GDP).
- Year of the cost estimates (primary study and updates).
- Number of crashes and casualties by severity level and definitions of severity levels.

Official cost figures as used by governmental organizations were requested.

Experts from 32 European countries (28 EU-countries, Iceland, Norway, Serbia, and Switzerland) were contacted by sending them a standardized email and asked for literature and other information on road crash costs in their country. The questionnaire was filled in by the researchers as completely as possible on the basis of this literature and then sent to the country experts for checking and completion. Validation checks were performed with a few key indicators to check consistency of values and avoid errors, e.g. a check whether costs per casualty were equal to total costs of casualties divided by number of casualties (for each severity level). The experts were contacted again for validating cases where errors were suspected or for providing additional information. Official cost figures were obtained from 30 countries. The information provided by the Lithuanian expert was not used, because it did not reflect the official figures. A governmental report was used instead (LRA, 2015). Portugal was added using figures from Donário & Dos Santos (2012). The information provided by the Portuguese expert was not used because it was internally inconsistent. No data were obtained for Romania.

An integrated dataset was created by reading in the MS Excel questionnaires using MS Visual Basic. This dataset was exported to a delimited text file and written to a SQLite database (Hipp et al., 2016), using R (R Core team, 2018). The further data cleaning and data analysis took place in this database. Several quality checks were carried out, in particular concerning data completeness and internal consistency. Modifications of the data were done where appropriate, such as adding missing data that could be calculated from data in other parts of the questionnaire or data from other sources. For example, if the total cost as a percentage of GDP was missing, this figure was calculated using total costs from the questionnaire and GDP from Eurostat. In addition, the data were specified according to the severity categories for crashes and injuries in the questionnaire. Finally, all costs figures were converted into Euro and price level 2015 using GDP deflators and Purchasing Power Parities (PPP) from Eurostat. A detailed description of the data processing is given by Wijnen et al. (2017).

3. Results

Costs per fatality

The survey shows that the official estimates of costs per fatality range from €0.7 million to €3.0 million (Figure 1).

There are three potential explanations for the differences in costs per fatality:

- Differences in the definition of a road fatality.
- Differences in costs components that have been included.
- Differences in methods used to estimate each cost component.

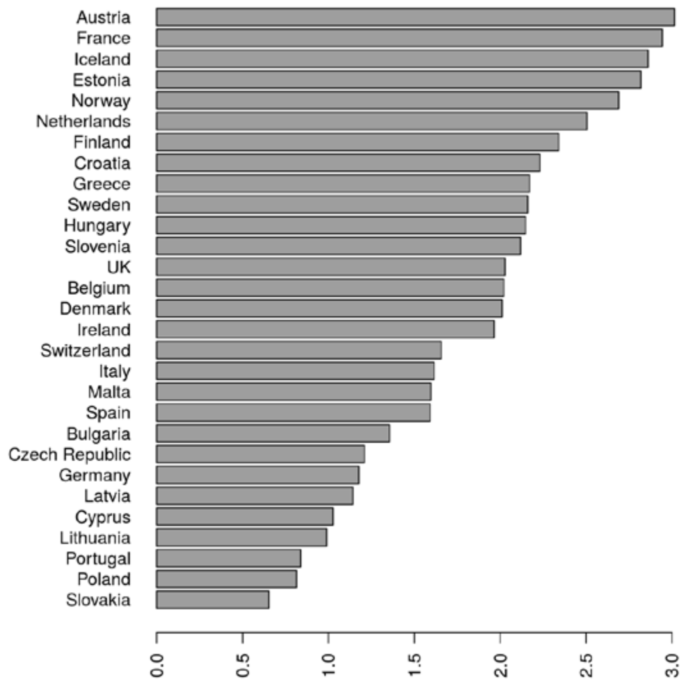

Figure 1 Costs per fatality (Million EUR 2015, adjusted for PPP; N=29; no data available for Luxembourg and Serbia).

Regarding the definition of a road fatality, 95% of the countries (N=21) apply the criterion that a casualty who dies within 30 days after the crash (and as a result of the crash) is regarded as a road fatality.[1] Consequently, differences in definitions are not a main explanation for differences in the costs per fatality.

Concerning cost components, Figure 2 (a 'heatmap') shows how many countries have included each cost component in the costs per casualty and costs per crash by severity level. The black colour indicates that most countries have included a cost component while light grey indicates that few countries have included a cost component. This shows that the majority of countries have included the injury- related costs components (medical costs, production loss and human costs) in costs per fatality (as well as in costs per serious and slight injury). However, crash-related costs (property damage, administrative costs and most of the other costs) are not always included. This is partly explained by the fact that several countries have strictly separated casualty-related and crash-related

[1] For 10 countries the definition of a road fatality was not filled in in the questionnaire. Most probably most of these countries have used the same definition, as the 30 day criterion is the international standard (Eurostat et al., 2009).

costs. They include casualty-related costs only in costs per casualty and crash-related costs only in costs per crash, while other countries have assigned crash-related costs to casualties using information on number of casualties per crash.

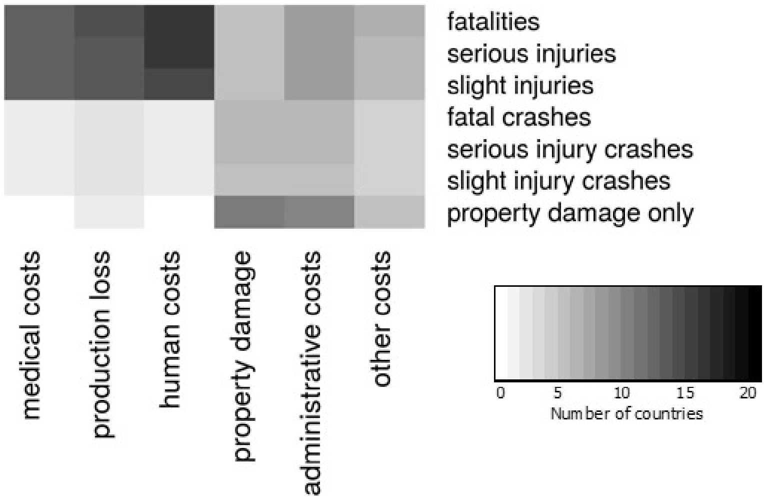

Figure 2 Heatmap of the number of countries which have included each cost component in costs per casualty and crash by severity level.

The results of our survey show that differences in valuation methods across European countries mainly concern human costs. For other cost components, in general there is consensus on the method to be used: human capital approach for production loss and the restitution costs approach for most other cost components. Figure 3 shows the method that is used to estimate human costs of fatalities in each country.[2] Most countries (n=18) apply a WTP method, while three countries use the human capital method (which in fact does not measure human costs but production loss). Two countries apply the restitution costs method. In this case the restitution costs method means that the valuation of a fatality is based on payments made to relatives to compensate their immaterial losses. For the remaining countries the method is not known (other method or no information available).

[2] In the questionnaire information on the method per cost component was asked for, but not separately for fatalities and serious and slight injuries. We assume that the information on the methods applies (at least) to fatalities.

Figure 3: Methods used to estimate human costs of fatalities

Human costs based on a WTP method are found to be much higher than values based on the compensation payments or the human capital approach. Consequently, total costs per fatality are much higher in WTP countries than in other countries since human costs represent a major share in the total costs per fatality in countries that apply the WTP approach (54% to 94%), see Figure 4.

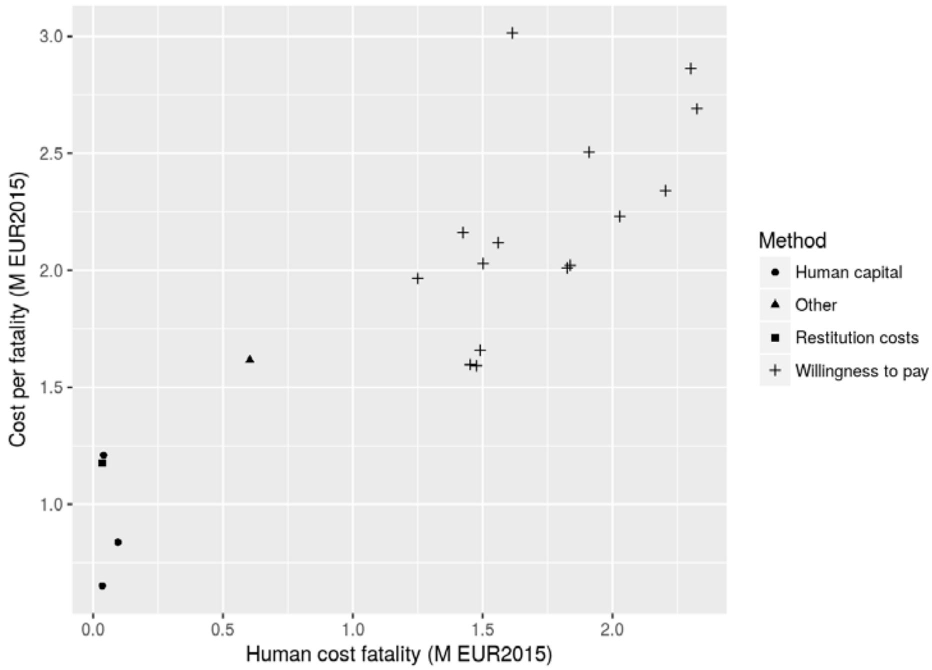

Figure 4: Relation between human costs per fatality, total costs per fatality and method for estimating human costs.

Costs per serious and slight injury

The costs of a serious injury range from 2.5% to 34.0% of the costs of a fatality (Figure 5).[3] Although this is a very wide range, about three quarters of the countries have a value between 10% and 20% of the value of a fatality. This is probably explained by the fact that information on the human costs of serious injuries is very limited, while these costs have large share in total cost per serious injury (51% to 91% in countries using a WTP method). Schoeters et al. (2017) note that only a few European countries conducted WTP study on non-fatal risks: Belgium (De Brabander, 2006), Sweden (Persson et al., 1995; Persson, 2004) and the UK (O'Reilly et al., 1994). Most other countries use the results from the studies in these countries, or they apply a standard percentage of the value per fatality as proposed in European projects (for example the HEATCO project; Bickel et al., 2006). Of course, the variation in the actual values per serious injury is still large (€28,000-€959,000) because there is variation in the human costs per fatality, from which the costs per serious injury are derived. Costs of

[3] Poland is excluded, because the costs per serious injury was stated to be higher than the costs per fatality. This seems to be implausible, because human costs are included in both costs per fatality and cost per serious injury.

a slight injury show even more variation: these costs range from 0.03% to 4.2% of the costs of a fatality (Figure 6). The range of actual values is extremely wide: €296 to €71,742.

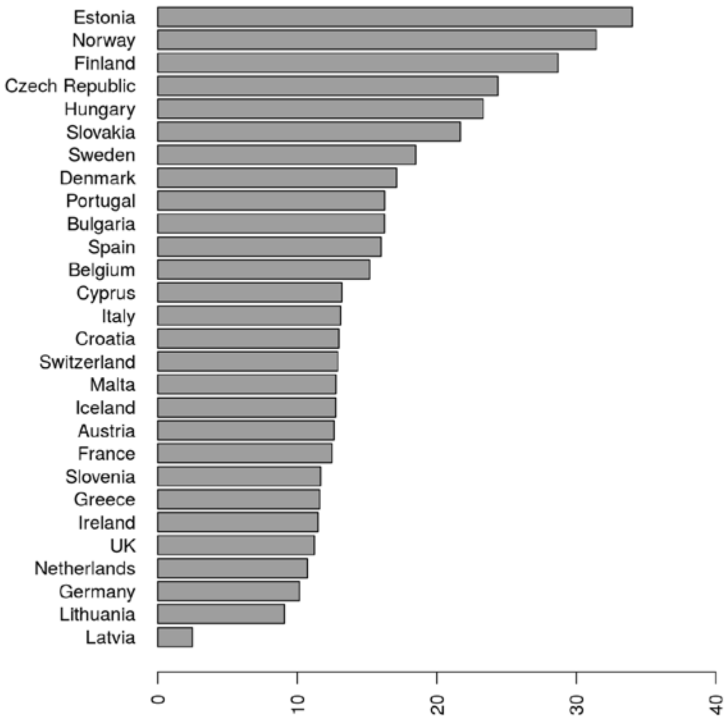

Figure 5: Costs per serious injury as a percentage of the costs per fatality. (N=28; no data available for Luxembourg and Serbia and Poland is excluded)

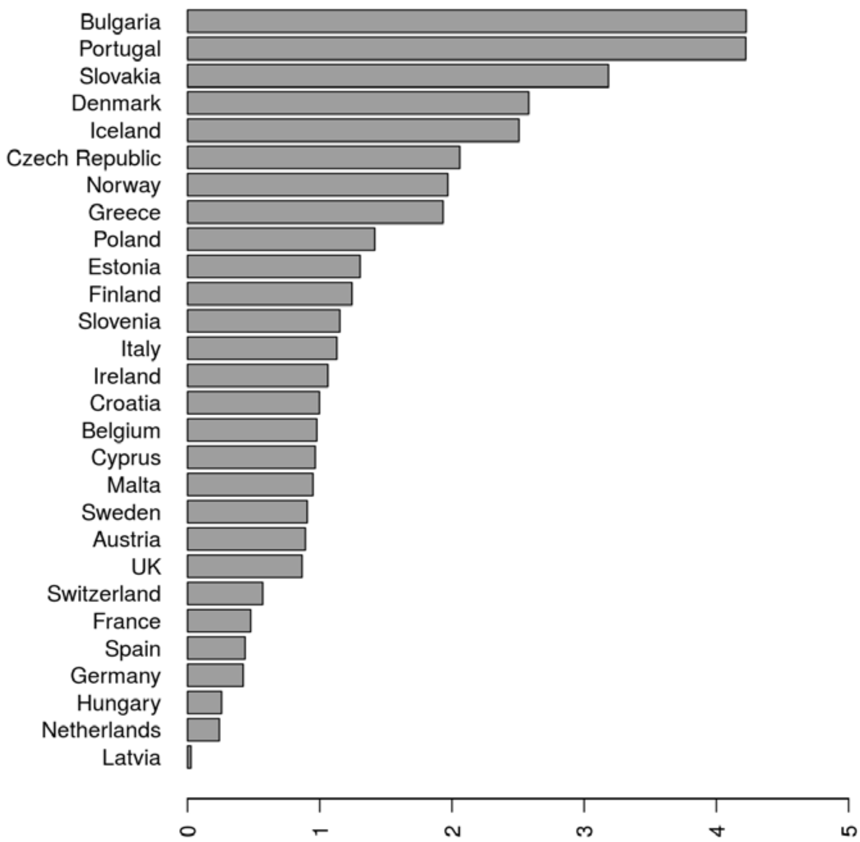

Figure 6: Costs per slight injury as a percentage of the costs per fatality (N=28; no data available for Lithuania, Luxembourg and Serbia).

Three explanations for the variations in costs per serious and slight injury can be put forward. Firstly, the individual countries use different definitions of injuries. Some countries use a criterion based on hospital admission (at least 24 or 48 hours for serious injuries), while other countries use a definition based on the type and severity of the injuries. Also a minimum duration of inability to work and payment of disability benefits are used as criteria in some countries. Secondly, the reporting rate (by the police or hospitals) of injuries may affect the average costs of injuries. A higher reporting rate usually implies that more injuries of lower severity are included in the casualty statistics, resulting in a relatively lower average value per injury. A lower number of serious injuries relative to the number of fatalities is accompanied by relatively higher costs of a serious injury (Figure 7).[4] Thirdly, differences in cost components included and methodological differences may explain the differences in costs per serious and per slight injury. Just as for fatalities, several countries do not include crash-related costs, while casualty-related costs are included by most countries (Figure 2). Regarding methods, the main difference concerns the estimation of human costs (WTP or other methods), similar to fatalities.

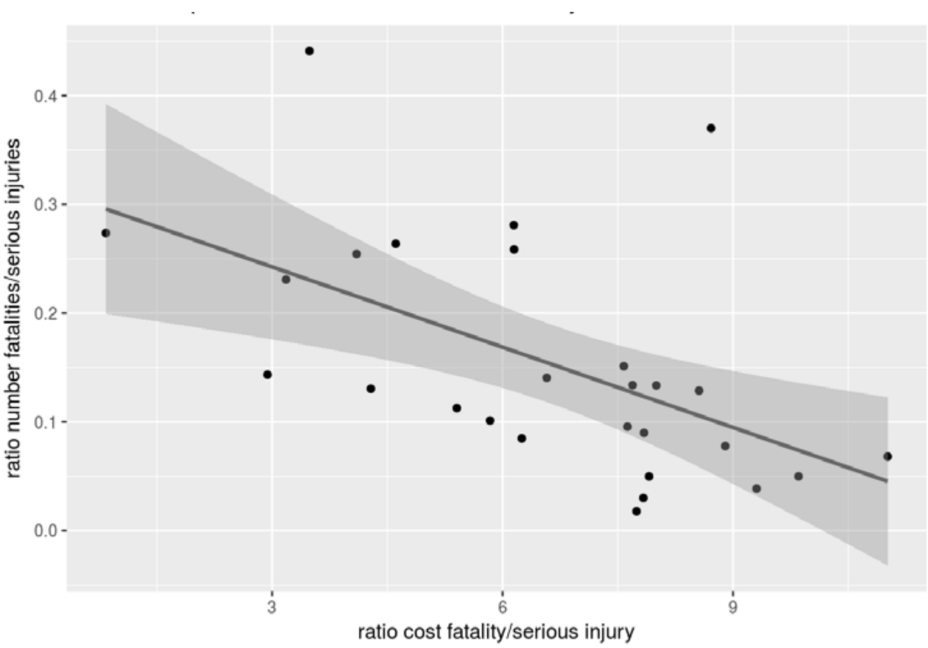

Figure 7: Relation between the ratio of number of fatalities and serious injuries and the ratio of costs per fatality and costs per serious injury (R^2=0.2996; F(1,25)=10.69; p=0.003).

Total costs

The total costs of road crashes as a percentage of GDP show also large variability, with a range from 0.4% to 4.1% (Figure 8). In addition to differences in methods used to estimate costs per casualty (discussed above), two other factors could potentially explain this variation. Firstly, it may reflect

[4] Greece and Latvia are regarded as outliers and therefore are excluded in this graph. In Greece the ratio of number of fatalities/number of serious injuries is extremely high compared to other countries and in Latvia the ratio of costs per fatality/costs per serious injury is extremely high. Without these two countries the relation between the two ratios is significant at the 1% level. If these countries are included the relation is non-significant however.

differences in road safety levels. Evidently, a better road safety performance should ceteris paribus result in lower road crash costs. However, road safety performance cannot explain the full variation as shown by Figure 9. Only a weak positive relation between mortality rate and costs as a percentage of GDP (statistically significant at the 10% confidence level) is found (R^2=0.122, $F(1,28)$=3.89; p=0.59).

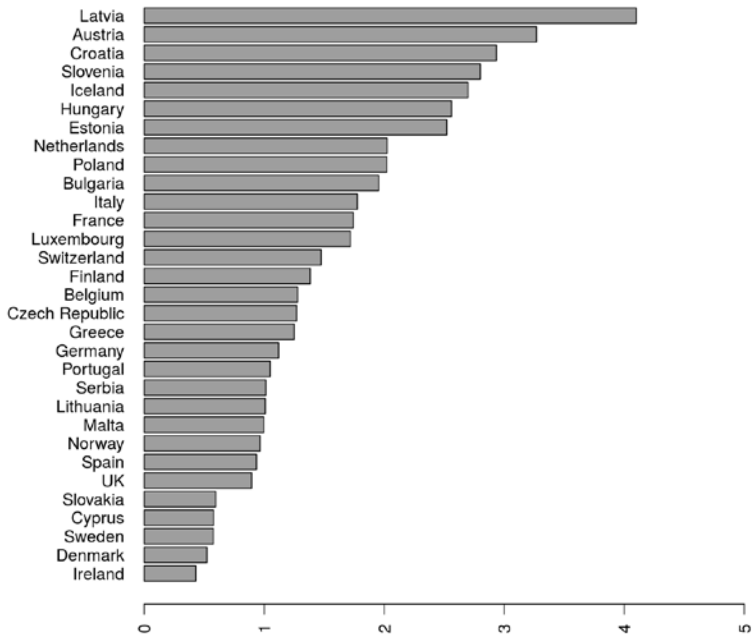

Figure 8: Total costs of road crashes as percentage of GDP

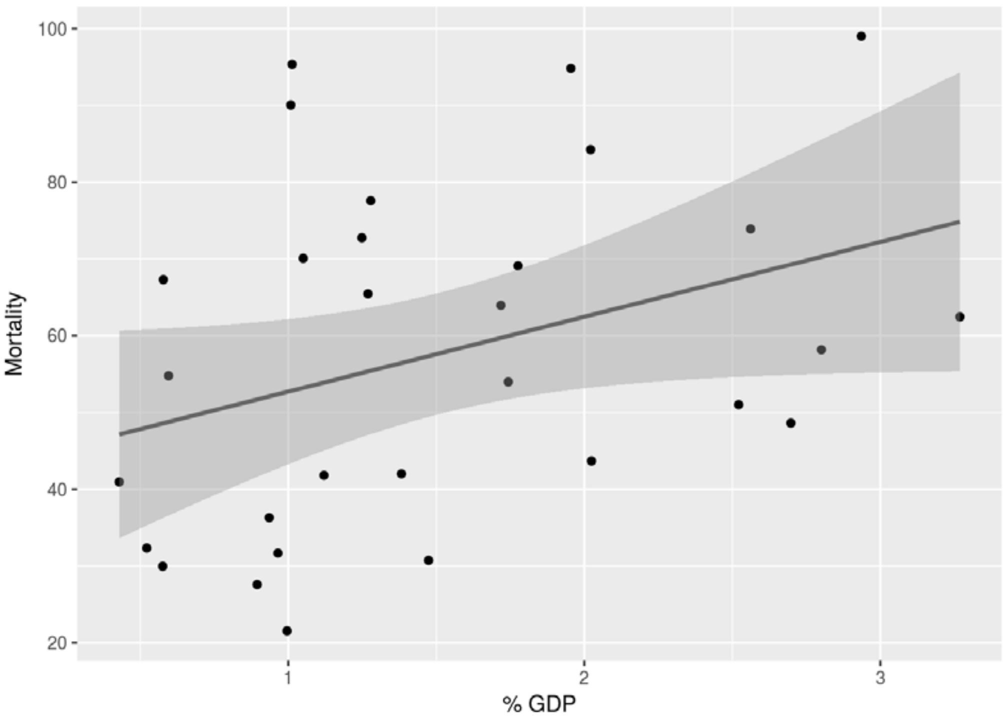

Figure 9: Relation between mortality rate (number of fatalities per million inhabitants) and costs of road crashes as percentage of GDP

Secondly, differences in the methodology that is applied to calculate total costs can explain variation in costs. In addition to the differences in methods to estimate costs per casualty (discussed above), this concerns in particular the extent to which all severity levels have been included in total costs and the extent to which a correction is made for underreporting. Concerning severity levels, all countries include fatalities, serious injuries and slight injuries in the estimate of total costs, but PDO crashes are not included in 44% of the countries (N=29). Exclusion of PDO crashes can result in a considerable underestimation of total costs: PDO crashes have a very significant weight in total costs, up to more than 50% for countries taking into account PDO crashes (figure 10).

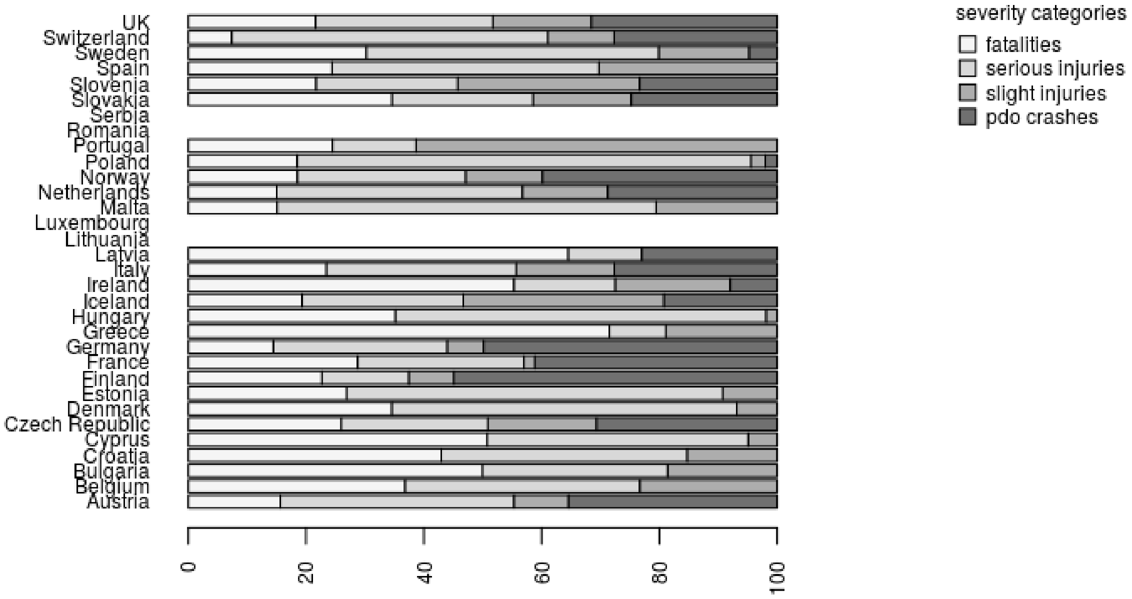

Figure 10: Share of fatalities, serious and slight injuries and PDO crashes in total costs

Figure 10 also shows that injuries have a major share in total costs in most countries. The share of injuries is on average 2.4 times higher than the share of fatalities in total costs. Although the value of a fatality is much higher than the value of a serious or slight injury, the much higher number of injuries results in them having a relatively high share in the total costs in most countries. However, the distribution of costs over severity levels differs considerably between countries, even between countries that include all severity levels. For countries having information on all severity levels, the costs of fatalities account for 7.4% to 55% of the total costs, serious injuries account for 14% to 77%, slight injuries account for 1.9% to 34% and PDO crashes account for 2.0% to 55%. Such variations are explained partly, as discussed above, by variations in reporting rates at each severity level (few countries correct for underreporting of casualties or crashes in their estimates of total costs for instance).

4. Discussion

Our study shows that the official national estimates of road crashes found in European countries vary widely. This in line with the results of previous reviews of road crash costs, which are summarized in Table 2 (including this study). Previous studies found ranges of total costs (as percentage of GDP) which are quite similar to the range we found but including different countries with other valuation methods. Previous studies also found wide ranges of costs per fatality, with the highest value 3.9 to 20.5 times higher than the lowest value. In all of these studies the variation in cost estimates is largely explained by differences in methodologies, particularly concerning methods to estimate human costs, which is in line with the present results. Omission of unreported crashes and casualties further contributes to differences in estimates of total costs and, moreover, results in substantial underestimation of total costs, which is not noticed in previous studies.

Human costs are much higher in countries that use on the willingness to pay approach. Values based on compensation payments appear to be much lower, as these are based on the common practices and judgements of organizations that determine the size of the compensation (e.g. law courts, insurance companies, governments) instead of risk valuations of the individuals involved. Countries that solely rely on the human capital approach have lower values because the production and consumption indicators used in this approach do not capture immaterial costs. These differences particularly affect the costs of a fatality, because human cost have a major share in total costs per fatality (54% to 94%). However, variation in the costs per fatality is not only related to the methodological approach (WTP or other methods), as also WTP estimates vary across countries. This is in line with literature on the VOSL (Value Of a Statistical Life). Several explanations for variation in VOSLs were found in meta-analyses (Lindhjem et al., 2011; De Blaeij, 2003; Miller, 2000), including the type of WTP method (stated versus revealed preferences), the initial risk level, the size of the risk change that is evaluated, the economic welfare level and the characteristics of the mortality risk (e.g. public versus private risk). Hauer (2011) argues that variation in VOSL estimates is inherent to challenges related to the WTP elicitation methods, for example people’s ability to understand small risks and to state their preferences related to those risks. The variation in the human costs of a fatality in our study is not as wide as the variation found in this literature. This is partly explained by the fact that several countries use standard European values. In addition, the people who decide on the official national values, who may be researchers or policy makers, usually can choose from a range of values. They may tend to choose conservative values (as was the case in the Netherlands for example; Wijnen et al., 2009), values that are in the same order of magnitude as the values used in other countries or standardized European values.

If our results are compared with the first European review of road crash costs in 14 European countries (Alfaro et al., 1994), the costs per fatality have converged even though we included more than twice as many countries: the highest value was 11.2 times higher than the lowest in 1994 whereas this ratio is 4.2 in 2015. Apparently, some convergence of methods used to estimate costs per fatality has taken place. However, the range of costs of a serious injury has become much wider: in the COST313 study the highest value was 11 times higher than the lowest (129,0280 versus 11,506 ECU, 1990), whereas in our study this ratio in 34 (€28,000-€959,000, 2015).[5] This is likely to be explained by the fact that we have included more countries that apply different and more heterogeneous definitions of a serious injury and/or different methods to estimate costs of injuries.

Study	Number of countries	Regions/countries	%GDP	Costs per fatality	
				Range	ratio highest/lowest value
Alfaro et al. (1994)	14	Europe	-	0.1-1.5 million ECU (1990)	11.2
Elvik (1995)	20	Europe (15), other (5)	-	0.9-17.8 million NOK (1991)	20.5
Elvik (2000)	11	EU (6), other (5)	1.3-5.7	-	-
Trawen et al.	11	EU (8), US, AU, NZ	-	0.9-3.6 million USD	3.9

[5] The COST313 values only include casualty-related costs (medical costs, production loss and human costs) whereas our estimates also include crash-related costs (property damage and administrative costs). This does not have much influence on the comparison, because crash-related costs have a minor share (4.1%) in total costs per serious injury.

(2002)				(1999)	
Wijnen & Stipdonk (2016)	10	EU (6), AU, NZ, Singapore, US	0.5-6.0	1.4-9.5 million USD (2012)	6.8
Wijnen et al. (2017)	31	EU	0.4-4.1	0.7-3.0 million EUR (2015)	4.2

Table 2: Overview of reviews of road crash costs

We have expressed total road crash costs as a proportion of GDP, which is common practice in international reviews of total road crash costs (Wijnen & Stipdonk, 2016; Elvik, 2000). This enables comparing the costs across countries, as differences in population size and economic performance are accounted for by using GDP as a denominator. However, the proportion of GDP should by no means be interpreted as the impact of road crashes on GDP. Human cost are intangible costs, which are not related to the measurement of income and production at which GDP is aimed. Moreover, road crashes could contribute positively to GDP, because crashes result in production in certain economic sectors such as health care and vehicle repair. GDP is a different concept from the concepts used in welfare economic theory which is the basis for cost-benefit analysis and (thus) for road crash costing. From the welfare economic perspective, costs are related mostly to the immaterial loss of welfare, or loss of quality of life associated with fatalities and injuries. In addition, resources that are used to repair damage are treated as costs in welfare economic theory. This contrasts with the GDP perspective, where using resources for production, also if this is aimed at repairing damage, contributes positively to economic welfare. Moreover, immaterial losses are not included in GDP.

Our analysis shows that the costs of road crashes vary widely across European countries, and that the differences are mainly explained by methodological differences. These differences hinder making sound international comparisons of road crash costs and using costs as a road safety indicator, as different costs represent differences in measurement more than difference in road safety performance. Moreover, it could distort road safety investments at the international level towards countries where costs per casualty are higher (and thus the benefits of these investments are assumed to be higher). For example, cost-benefit analysis of the implementation of European vehicle legislation would require a common value. Using different values could lead to erroneous conclusions about the economic return of such interventions for the different countries, if those differences are related to different valuation methods. For these purposes, harmonization of road crash costs estimates is needed.

5. Conclusions

There are large differences in official estimates of road crash costs in European countries. Total costs range from 0.4% to 4.1% of GDP and cost per fatality from €0.7 million to €3.0 million (2015, adjusted for PPP). Cost per serious injury range from 2.5% to 34.0% of the costs per fatality, and the costs per slight injury from 0.03% to 4.2% of the costs per fatality. The differences are largely explained by differences in methodologies, in particular whether or not a willingness to pay method is applied to estimate human costs, differences in costs components that are included, different definitions of serious and slight injuries and differences in reporting rates of crashes and injuries. The fact that underreporting is not taken into account in cost estimates in most countries, implies a serious underestimation of total costs in these countries. Moreover, several countries do not include property damage only crashes in total costs, implying a further underestimation of total costs.

The methodological differences in cost estimates are a serious obstacle when decisions on countermeasures have to be made at a supranational level or when international comparisons and benchmarking are needed. For these purposes developing harmonized European cost estimates is recommended. In addition, future national road crash costs studies could concentrate on applying international recommended methods (in particular WTP methods), on including all relevant cost components and on taking into account underreporting and PDO crashes, in order to achieve more harmonization.

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