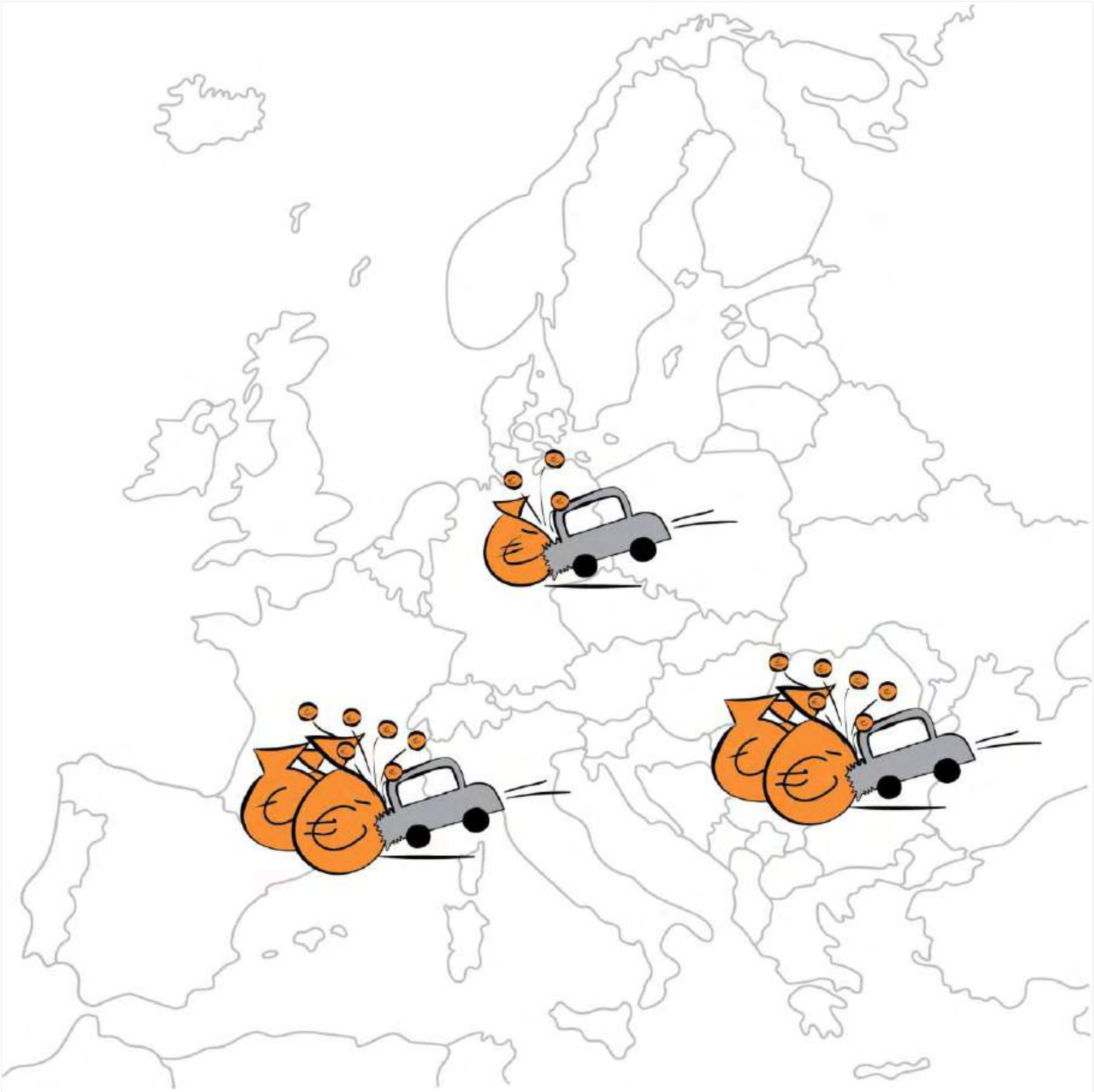

Crash cost estimates for European countries

Deliverable 3.2

SafetyCube

Crash cost estimates for European countries

Work package 3, Deliverable 2

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Table of contents

Executive summary

Safety CaUsation, Benefits and Efficiency (SafetyCube) is a European Commission supported Horizon 2020 project with the objective of developing an innovative road safety Decision Support System (DSS) that will enable policy-makers and stakeholders to select and implement the most appropriate strategies, measures and cost-effective approaches to reduce casualties of all road user types and all severities.

SafetyCube also aims to support stakeholders in doing an Economic Efficiency Assessment (EEA) of road safety measures. To apply an EEA, information on costs of crashes is needed. This Deliverable provides information on costs of crashes in Europe. First of all, it provides an overview of the cost components that should be included in crash cost estimates and how each cost component should be determined according to the international guidelines and best practices. Second, information on costs of crashes is collected by means of a survey among all EU countries. Third, for some countries not all information is available or costs are not calculated according to the international guidelines. In those cases, comparable estimates are provided by means of value transfer. In that way, we also provide an estimate for the total costs of crashes in the EU.

Although they were developed more than 20 years ago, the COST313 guidelines are still the most comprehensive guidelines for estimating the costs of road crashes. Therefore, these guidelines are the main basis for the framework developed for the cost estimates within SafetyCube, although more recent developments have been taken into account as well. Within SafetyCube, costs of crashes are considered from a socio-economic perspective and the following cost components are taken into account:

- Medical costs (e.g. costs of transportation to the hospital, costs related to hospital treatment)
- Costs related to production loss
- Human costs
- Costs related to property damage (mainly vehicles)
- Administrative costs (e.g. police, fire department, insurances)
- Other costs (funeral costs, congestion costs)

According to the international guidelines; medical costs, costs related to property damage, and administrative costs should be calculated by means of the restitution costs method. Costs related to production loss should be calculated by means of the human capital approach, which implies that the loss of productive human capacities is valued. The (individual) willingness to pay (WTP) approach is generally recommended to estimate human costs, although several other approaches have been developed as well. In Germany and Australia for example, human costs are based on financial compensations that are awarded to road casualties or their relatives in courts or by law. Another approach is to deduct human costs from premiums people pay for life insurances or from public expenditures on improving (road) safety. These alternative approaches typically result in much lower values than those from WTP studies. Within SafetyCube we recommend the (individual) WTP approach to estimate human costs, as this is the most theoretically sound method, in particular for use in cost-benefit analysis, and is common practice in many countries.

Information on costs of crashes in European countries was collected by means of an Excel based questionnaire that was developed together with the InDeV project. Information is collected concerning: costs per casualty and crash by severity level, total costs, costs per component, methods and definitions, and number of casualties. Official cost figures used by governmental organizations were requested. Questionnaires were initially prefilled by a responsible SafetyCube or InDeV partner using available information and then sent to experts in each country for a check and final completion. Data from 31 European countries, out of the 32 involved in the study, was obtained and included in the analysis. Within SafetyCube, the questionnaires were integrated into a SQLite database, consistency checks were carried out, and the data was standardized for currency, inflation and relative income differences.

For all EU countries, except Romania, at least some information on costs of crashes was available. Reported costs per fatality vary between €0.7 million per fatality in Slovakia and €3.0 million per fatality in Austria and tend to be higher in North-West Europe than in South and East Europe. Reported costs per serious injury range from €28,000 in Latvia to €959,000 in Estonia, whereas reported costs per slight injury range from €296 in Latvia to €71,742 in Iceland. When we relate the costs per injury to the costs per fatality, it shows that the costs of a serious injury range from 2.5% to 34% of the costs of a fatality, though for about three quarters of the countries this figure is between 10% and 20%. The costs per slight injury are 0.03% to 4.2% of the costs of a fatality.

The total costs of crashes vary between 0.4% and 4.1% of the Gross Domestic Product (GDP). There is no clear geographical pattern. A better road safety performance should in principle result in lower road crash costs, but we found only a weak positive relation between mortality rate and costs as a percentage of GDP. Exclusion of property damage only (PDO) crashes or other severity levels and not-correcting for underreporting can result in an underestimation of the total costs of crashes. Differences between countries are also due to methodological differences, particularly whether the Willingness to Pay (WTP) method is applied for the calculation of human costs. In countries that use the WTP approach, human costs have a major share (34% to 91%) in the total costs of crashes. In countries that apply an alternative method, the share of human costs in the total costs is much smaller (less than 10%). Also, property damage costs and production losses are major cost components in most countries, whereas medical costs and administrative costs are relatively low.

Injuries appear to have a large share in the total costs (on average 2.4 times higher than the share of fatalities in total costs), but this differs substantially between countries. For countries that included all severity levels, fatalities account for 7.4% to 55% of the 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%. Possible explanations for this variation include differences in definitions of severity levels and in reporting rates.

Not all countries have information for all cost components and/or all severity levels. Also, not all countries calculate cost estimates according to the international guidelines. Within SafetyCube, the value transfer method is applied to estimate standard cost values per casualty/crash type and to estimate total costs of crashes according to international guidelines for each EU country. The value transfer method uses crash cost estimates from countries whose estimates are consistent with international guidelines to estimate costs for countries that do not have cost information according to the international guidelines. The general approach is that the median (adjusted for purchasing power parity) value per casualty (fatality, serious injury, slight injury), and per crash (fatal, serious injury, slight injury and PDO), for a specific cost component, is determined for a group of countries that use the recommended methods and included all relevant cost items. This median value is used for countries that have not used the recommended method or do not have information at all for that cost component. The 'standard' costs of a fatality are estimated at €2.3 million. These costs mainly consist of human cost (€1.6 million) and production loss (€0.7 million). Costs per serious and slight injury are estimated at 13% and 1% of the value of a fatality. Also for injuries human costs are by far the largest cost item. Total costs according to the international guidelines in all EU countries individually as well as the EU in total were calculated. For the 28 EU member states costs are estimated at about €270 billion if the results of the value transfer approach are applied. This corresponds to 1.8% of the GDP. This is still an underestimation, because many countries have not corrected the numbers of casualties/crashes for underreporting. If unreported casualties and crashes are taken into account, we expect that total costs are in the order of magnitude of at least 3% of GDP. The European total costs based on the values given in the survey are almost €200 billion, which clearly shows the importance of adding the missing components, and of using a standard methodology, in estimating total costs of crashes.

For future cost studies in individual countries it is recommended to include all relevant cost items and to use the internationally recommended methods, in order to provide a complete picture of the socio-economic costs and to make costs estimates more comparable across Europe. In addition, we recommend monitoring the socio-economic impact of road crashes on a European-scale as well as the methods used to estimate the costs by repeating the survey on a regular basis. Finally, new research into the costs of serious injuries, particularly human costs, is recommended as information on these costs is very limited yet they have a major impact on the total costs.

1 Introduction

This chapter describes the project and purpose of the deliverable. A short description of the work package that produced the deliverable is also provided.

1.1 SAFETYCUBE

Safety CaUsation, Benefits and Efficiency (SafetyCube) is a European Commission supported Horizon 2020 project with the objective of developing an innovative road safety Decision Support System (DSS) that will enable policy-makers and stakeholders to select and implement the most appropriate strategies, measures and cost-effective approaches to reduce casualties of all road user types and all severities.
SafetyCube aims to:

1. develop new analysis methods for (a) Priority setting, (b) Evaluating the effectiveness of measures (c) Monitoring serious injuries and assessing their socio-economic costs (d) Cost-benefit analysis taking account of human and material costs
2. apply these methods to safety data to identify the key road crash causation mechanisms, risk factors and the most cost-effective measures for fatally and seriously injured casualties
3. develop an operational framework to ensure the project facilities can be accessed and updated beyond the completion of SafetyCube
4. enhance the European Road Safety Observatory and work with road safety stakeholders to ensure the results of the project can be implemented as widely as possible

The core of the project is a comprehensive analysis of crash risks and the effectiveness and cost-benefit of safety measures focusing on road users, infrastructure, vehicles and injuries framed within a systems approach with road safety stakeholders at the national level, EU and beyond having involvement at all stages.

1.1.1 Work Package 3

The objective of work package 3 is to define the methodological foundations of the road safety Decision Support System (DSS). The methodological guidelines developed are applied in Work Packages 4, 5, 6 and 7 to identify and analyse road safety risk factors and measures addressing road users, road infrastructure and vehicles. A road safety Decision Support System (DSS) should help policy makers identify important risk factors and the crashes, injuries and fatalities resulting from them; select measures by estimating their safety effects; and set priorities among measures on the basis of their costs and benefits.

To do so, Work Package 3 has produced two sets of guidelines so far:

1. Guidelines for identification of risk factors and evaluation of safety measures (M13) describing how the literature is reviewed, studies are selected in a systematic and documented literature search, and coded into a repository of studies capturing all relevant information for the DSS. The guidelines also describe how studies addressing the same countermeasure or risk factor are summarised into a synopsis, and whenever possible provide an estimate of measure effectiveness (like a CMF – crash modification factor) and a description of how this varies across different conditions.
2. Guidelines for priority setting (D3.4), giving the theoretical background on economic efficiency analysis and comparing different decision criteria and their practical implications. These

guidelines are accompanied by a tool for Economic Efficiency Analysis (EEA) of road safety countermeasures (M12), allowing partners to combine the information about the effectiveness of a measure (i.e. the percentage of crashes or casualties prevented) with the costs of these measures. As input for this tool, costs of crashes are necessary to express all costs and benefits of a measure in monetary values and to compare them in a cost benefit analysis.

The present deliverable provides information on costs of crashes in EU countries. This information serves as input for economic efficiency assessments of road safety countermeasures.

1.2 PURPOSE OF THIS DELIVERABLE

This Deliverable provides crash cost estimates for European countries. Before providing actual cost estimates, we discuss which cost components should be included according to international guidelines on estimating costs of road crashes and how costs for different cost components should be collected. Chapter 2 provides an overview of the main literature on road crash costs, whereas Chapter 3 provides an overview of the relevant cost components and methods to collect costs for the different components.

Information on crash costs is collected by means of a survey among all EU countries. The collection and processing of the data is discussed in Chapter 4. Chapter 5 presents the crash costs that are collected by means of the survey. Not all countries have information on costs of crashes. Moreover, not all countries apply the methods recommended in the international guidelines. Therefore, results from different countries are not fully comparable. In Chapter 6 we provide cost estimates for all EU-countries according to the international guidelines by means of the value transfer method. We also provide an estimate for the total costs of road crashes in the EU. Finally, Chapter 7 presents the conclusions and recommendations.

2 State of the art

This chapter provides an overview of the main literature on road crash costs, in particular guidelines, international reviews of road crash costs, studies from individual countries and European studies that include road crash costs. It is concluded that the European COST313 guidelines from 1994 are most comprehensive as they cover all relevant socio-economic costs.

Costs of road crashes have been studied since several decades. Costs estimates have been made in individual countries and in European studies, international overviews of costs of road crashes have been made and guidelines for estimating these costs have been developed. In this chapter the literature on costs of road crashes is reviewed. The results of this literature review will be used as a basis for the framework for estimating the socio-economic costs of road crashes that is discussed in the next chapter.

2.1 GUIDELINES

Several guidelines have been developed that describe how the socio-economic costs of road crashes should be estimated. The most comprehensive guideline has been developed in the European COST313 project (Alfaro et al., 1994). In this project costs estimates in 14 European countries were assessed, illustrating the different methods in use throughout European countries. On the basis of this review, guidelines were developed, particularly regarding cost components that should be included and methods to be used to estimate these costs.

In addition, the World Bank (2005), the Asian Development Bank (ADB, 2003) and the British Government (TRL, 1995; BRS&TRL, 2003) have developed guidelines. However, they mainly focused on estimating costs of road crashes for low and middle income countries (LMICs). Although they are considered less relevant for the SafetyCube project as it includes mainly high income countries (HICs), they may be useful for guidance on estimating costs components for which data are not readily available (which is more often the case in LMICs). As the COST313 guidelines are of most relevance for the SafetyCube project, they are discussed in more detail below.

2.1.1 COST313

In the European project COST313 (Alfaro et al., 1994), guidelines for estimating road crash costs were developed. The project was initiated by the European Commission and twelve European countries actively participated in this project. To develop the guidelines, information on road crash costs in fourteen countries was collected, including cost estimates, costs components that were included and methods that were used to estimate each cost component. A quantitative analysis of the costs per fatality, serious injury and slight injury was carried out. In this analysis differences between costs were assessed as well as several factors that could explain these differences, including differences in standard of living (gross national product per capita), several factors that affect production loss (discount and growth rate, age structure) and methodological differences. Furthermore, different methods were qualitatively assessed in a multi-criteria analysis. In this analysis the methods were judged on criteria such as theoretical and political acceptability, ability to understand, data availability and ease of making the calculations. On the basis of the information from all countries and the assessments of this information and the available methods, recommendations were given for estimating road crash costs.

COST313 recommends including seven main cost components: medical costs, non-medical rehabilitation, production loss, human costs, property damage, and administration costs. Also inclusion of some other costs that cannot be categorized in any of these components (e.g. funeral costs) is recommended. Furthermore, three methodological approaches are recommended - restitution costs, human capital approach and willingness to pay approach - and COST313 discusses which method is applicable to each cost component.

1- Medical costs: first aid, ambulance, hospital and non-hospital treatment, etc.

2- Non-medical rehabilitation costs, such as house adaptions for disabled people and occupational rehabilitation

3- Production loss: the loss of production or productive capacities

4- Human costs: immaterial cost of lost quality of life and lost life years

5- Administrative costs: police, fire service, insurance, legal costs

6- Property damage: damage to vehicles, infrastructure, freight and personal property

Figure 2-1 Cost components distinguished in the COST313 guidelines (Alfaro et al., 1994)

2.2 INTERNATIONAL OVERVIEWS

Several international overviews of the cost of road crashes in individual countries have been published. Wijnen & Stipdonk (2016) and Elvik (2000) review the total socio-economic costs of road crashes, e.g. as a percentage of GDP, while other studies discuss the costs per casualty (De Blaeij et al., 2004; Trawén et al., 2002; Elvik, 1995).

Wijnen & Stipdonk (2016) provide a detailed review of estimated costs of road crashes and methodologies that have been used in ten high income countries and seven low or middle income countries. Elvik (2000) reviews the costs in 12 countries, including six European countries, but without discussing the methodologies that have been applied. At a European seminar in Neuchatel in 1994, estimates and methods were compared for 12 European countries (INRETS, 1996).

De Blaeij et al. (2004) review the costs per casualty (fatality, serious and slight injury), including a brief discussion of methodological issues. The other two studies (Trawén et al., 2002 and Elvik, 1995) also discuss methodological issues, but they are limited to the costs per fatality.

In addition, several studies provide an overview or meta-analysis of the value of a statistical life (VOSL) in different countries. The concept of VOSL is used to estimate human costs (see Section 3.1.3). Some of these studies specifically focus on road safety (e.g. De Bleaij, 2003), while others also include VOSLs in other areas such as occupational safety or environmental issues (Dionne & Lanoie, 2004; Lindhjem et al., 2011). These studies present averages and ranges of VOSL estimates and they are mainly aimed at identifying factors that explain differences between VOSL estimates (e.g. valuation method, GDP per capita or risk level). In some studies a rule of thumb (MacMahon & Dahdah, 2008) or a 'benefit transfer function' (Miller, 2000; Milligan et al., 2014) is developed on the basis of a (large) number of VOSL studies, to relate the VOSL to GDP per capita. Such a rule of thumb or benefit transfer function can be used to estimate the VOSL in countries that do not have their own VOSL estimate. These studies are not directly relevant for the general methodology for estimating road crash costs, but they are relevant for estimating human costs. Human costs are the immaterial costs of lost quality of life and lost life years and are one of the main cost components. This will be further discussed in Section 3.1.3.

All studies show the divergences between the values used by different countries, reflecting differences in economic development, methodological choices for including or excluding specific cost items, definitions of crash costs, techniques of estimation of crash costs, but also data availability. Also within countries themselves different figures may be available. For example, the official national figures that are used in cost-benefit analysis may deviate from the figures that result from studies into the costs of road crashes. This particularly concerns the value of a statistical life (VOSL): usually an official VOSL is selected out of several VOSLs that are available, for usage in policy evaluation studies. However, from a scientific perspective, it is difficult, if not impossible, to determine one single VOSL.

2.3 EUROPEAN COST STUDIES

Several European reports on the socio-economic costs of road transport have been published. In these studies road crash costs are one of the main cost elements, besides for example costs of congestion, traffic noise and pollution. They provide estimated costs for road crashes. Although these reports are primarily aimed at calculating costs and providing standardized figures per casualty or per kilometer travelled, they also discuss methodological issues and give guidance on how to estimate road crash costs.

Firstly, the European Conference of Ministers of Transport (ECMT, 1998) has estimated the costs per fatality and per serious injury, based on standardized European figures per casualty. Methodological discussions in this report have concentrated on methods to estimate the value of a statistical life (VOSL). The report suggests that the VOSL is a central and crucial value for estimating the crash costs; it appears as the core value of the socio-economic burden of crash costs. The ECMT report has drawn on a previous European study related to the costs of transport concerning the methodology for estimating costs and the costs estimates themselves (INFRAS/IWW, 1995; updated in 2000 and 2004: INFRAS/IWW, 2000; 2004).

Subsequent European projects include UNITE (Nellthorp et al., 2001), HEATCO (Bickel et al., 2006) and Handbook on estimation of external costs in the transport sector (Maibach et al., 2008; updated in 2014: Korzhenevych et al., 2014). These studies adopted the same approach as ECMT (1998), by determining a standard VOSL and estimating other costs as well as for costs of serious and slight injuries as a percentage of the VOSL. These percentages are based on studies on these costs in the UK (human cost of injuries) and Switzerland (other costs). Each of these studies heavily draws on previous reports, in particular ECMT (1998); they all use the same methodology and propose the same values per casualty.

It should be noted that these studies only include external costs of road crashes, defined as costs that are not covered by insurers (and thus not directly paid for by the individual involved in a road crash). This means for example that medical costs and damage to vehicles are not (fully) taken into account in these studies, because they are (partly) paid by insurance companies.

2.3.1 ECMT report 'Efficient transport for Europe'

The aim of this report of the European Conference of Ministers of Transport (ECMT, 1998) was to 'internalize' negative impacts of transport (road, rail, water and air). Internalization means that all costs of transport to society are assumed to be taken into account by road users, so they adapt their travel behaviour in such a way that the negative impacts are reduced.

One of the aspects in this report concerns estimating the external costs of transport, including costs of road crashes, which serves as an input for identifying policy options for internalization. The report focuses on external costs only. These are the costs that are borne by parties other than the person who caused the costs, and (thus) are not accounted for in travel behaviour decisions of individuals. ECMT assumes that all road crash costs that are not covered by insurers are external. The idea is that the other costs are paid for by road users through insurance premiums, so they are internalized. This implies that the EMCT report, in contrast to COST313, does not include the full social costs of road crashes: property damage and insured medical costs are not included.[1]

To estimate the (external) costs of road crashes, ECMT briefly reviews values per life that are being used in a limited number of countries, as well as the methods that have been used to derive these values. To make an estimate of the (external) costs of road crashes, ECMT determines a standard value of a statistical life (VOSL) on the basis of official VOSLs that are used by national road administrations in five countries (1.5 million Euro, price level 1998). Medical costs, costs of replacing employees and administrative costs are added to the VOSL (estimated at 0.2 million Euro, on the basis of INFRAS/IWW (1995)). Costs of serious injuries are estimated as a percentage of the VOSL (13%), based on a study on valuation of human costs of injuries in the UK (O'Reilly et al., 1994). The report presents separate values for each country by differentiating the standard figures by country, depending mainly on the level of GDP and adjusted on the basis of purchasing power parity data.

2.3.2 HEATCO

One of the aims of the European HEATCO project was to develop guidelines for economic appraisal, in particular cost-benefit analysis of infrastructure projects. As an element of these guidelines HEATCO developed standard estimates of external costs of transport, including costs of road crashes, that can be used if national estimates are not available.

Regarding the methodology for deriving standard values, HEATCO draws on the ECMT report: a standard VOSL is determined to which some other cost are added. HEATCO recommends the same VOSL as ECMT as a standard European value (1.5 million Euro), but it is based on different sources. The VOSL in HEATCO is taken from the UNITE report (Nellthorp et al., 2001), that proposes a VOSL of 1.5 million Euro on the basis of a willingness to pay study (stated preference method) in the UK. Other costs are estimated at 10% of the VOSL, which is also taken from the UNITE study. This includes medical costs, administrative costs (police, other emergency services, legal costs and insurance costs), property damage, and production loss. For serious injuries HEATCO proposes a value of 13% of the VOSL (taken from ECMT) and for slight injuries 1% of VOSL (based on ECMT, following UNITE).

[1] Moreover, loss of human productive capacity (gross production loss) is not fully included: this is only partly included in the VOSL(see Section 3.2.2).

2.4 COST STUDIES IN INDIVIDUAL COUNTRIES

In addition to the literature discussed above, experiences in individual countries are relevant for developing guidelines for estimating costs. Some countries have a long tradition in estimating costs and developing methodologies, for example the UK (Jones-Lee and Spackman, 2013), New Zealand (Clough et al., 2015; Wren & Barrell, 2010) and the US. In the US a very comprehensive study into the costs of road crashes has been published recently, including for example a detailed analysis of human costs by injury severity (MAIS 0-5) (Blincoe et al., 2014).

Although these experiences are covered by the international overviews discussed above, studies in individual countries may particularly be relevant for identifying best practices that go beyond the state of the art and for identifying directions for future research and improving the current state of the art. However they are not examined in detail here because the objective of the present guidelines is a framework that can be filled in for the majority of the European countries.

2.5 SUMMARY AND CONCLUSION

Study	Type of study	Scope	Main outcomes on road crash costs
COST313 (1994)	Guidelines for estimating road crash costs, based on a review of road crash costs in 14 EU countries	Comprehensive socio-economic costs of road crashes	Guidelines on which cost components to include in road crash cost studies: – Medical costs – Non-medical rehabilitation – Production loss – Human costs – Property damage – Administrative costs – Other costs Guidelines on which method to use for each cost component
ECMT (1998)	EU cost study aimed at internalization of external costs. Including estimates of external costs of transport.	All external costs of transport (costs not covered by insurances), including external crash costs.	Standardized external cost per casualty (fatality, serious injury, slight injury), consisting of: – Human costs and consumption loss (VOSL) – Medical costs – Costs of replacing employees – Administrative costs
HEATCO (2006)	EU cost study aimed at developing guidelines for economic appraisal of infrastructure projects. Including estimates of external costs of transport.	All external costs of transport (costs not covered by insurances), including external crash costs.	Standardized external cost per casualty (fatality, serious injury, slight injury), consisting of: – Human costs and consumption loss (VOSL) – Medical costs – Production loss – Property damage – Administrative costs

Table 2-1 Summary of main guidelines and studies on costs of road crashes

Table 2-1 summarizes the main reports on costs of road crashes that we discussed in this chapter. It shows that the COST313 guidelines are the most comprehensive guidelines for estimating the costs of road crashes. Although these guidelines have been developed more than 20 years ago, more recent European projects (e.g. HEATCO) as well as other recent publications on costs of road crashes (SWOV, 2014; ERSO, 2006) still refer to these guidelines.

COST313 provides complete guidelines that focus on the full costs of road crashes for society, that means including all costs that are relevant to society. As discussed above, most other studies do not cover all costs, for example because they include only external costs or only fatality and/or injury related costs. Moreover, European studies such as EMCT (1998) and HEATCO mainly focus on the VOSL and hardly pay attention to other costs. Therefore we use COST313 as the main basis for developing a framework (in Chapter 3) for the costs estimates within SafetyCube. In case more recent publications, particularly the recent review by Wijnen & Stipdonk (2016) and experiences in individual countries (in particular the US), indicate that more accurate methods have been developed and applied or that current best practices deviate from COST313, we will follow these new developments.

3 Cost components and methods to estimate them

This chapter presents a framework for estimating costs of road crashes by discussing the components of road crash costs and how the different components can be calculated. Moreover, some methodological issues are discussed regarding the estimation of road crash costs.

3.1 COST COMPONENTS

On the basis of the COST313 guidelines road crash costs can be classified in six main categories related with the functional dimension of these costs: medical costs, production loss, human costs, property damage, administrative costs and other costs (See 2.1.1).[2] In scientific and operational literature (e.g. Wijnen & Stipdonk, 2016; Bickel et al., 2006; Trawén et al., 2002; Alfaro et al., 1994) the defined categories are quite similar. A common classification of costs of road crashes that has been introduced in the COST313 guidelines distinguishes between injury related costs and crash related costs. Following this classification, the six main components can be categorized as illustrated in Figure 3-1.[3] Note that other costs can be either casualty related (e.g. funeral costs) or crash related (e.g. congestion costs). The interest of investigating crash costs this way is to emphasize the costs borne by the victim and also the related material or administrative costs.

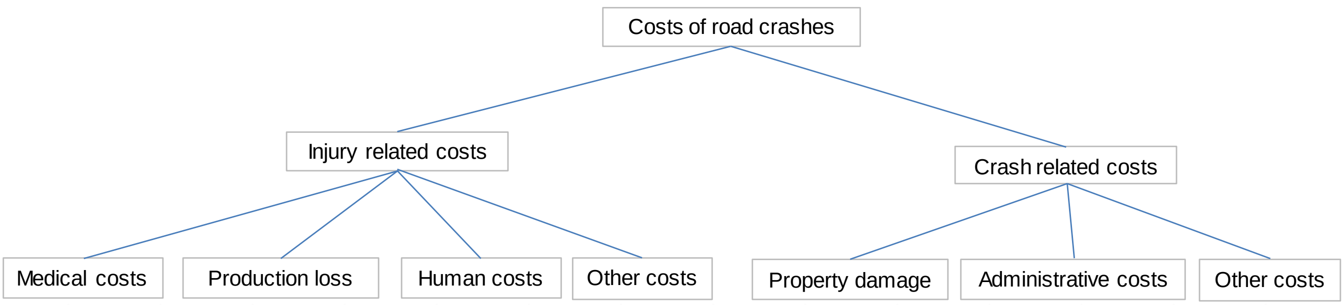

Figure 3-1 Classification of road crash costs: casualty and crash related costs

Classifications that differ from COST313 are also used, for example in European cost studies such as EMCT (1998) and HEATCO (Bickel, 2005) that distinguish between direct and indirect costs. Examples of direct costs are medical costs and property damage, while indirect costs include production loss and human costs. Also some individual countries use their own classification, for example the US and Australia. However, these classifications can be traced back to the six cost components in Figure 1, so eventually the same main cost components are included in these studies (Wijnen & Stipdonk, 2016).

[2] COST313 distinguishes between medical and non-medical rehabilitation. Following common practices, we have merged non-medical with other costs components, particularly production loss.(occupational rehabilitation) and other costs (house adaptions) as discussed below.

[3] Administrative costs related to health insurances are injury related instead of crash related. Since this is not regarded as a main cost component, we have classified administrative costs as crash related.

Below the cost components are discussed in more detail, based on the literature presented in section 2. We distinguish between:

- Main costs items: costs that are included in previous guidelines and that are commonly included in cost studies. Main costs do not only include costs that have a large share in the total costs (e.g. human costs of fatalities and injuries) but also smaller costs that are commonly included (e.g. police costs).
- Minor cost items: costs that are known to be relatively small and are not commonly included in cost studies (for example costs of vehicle unavailability).
- Other cost items: costs that are not always included in previous guidelines and costs studies and whose size is not exactly known but may be substantial (for example loss of household production).

The distinction between these three types of costs items is particularly based on the COST313 guidelines and the review of national costs studies by Wijnen & Stipdonk (2016).

3.1.1 Medical costs

Medical costs relate to the costs of medical treatment of road casualties (including fatalities that were treated in hospital), provided by hospitals and other medical institutions. The main cost items are:

a) First aid at the crash location and transportation of casualties to hospital (ambulance, helicopter).
b) Treatment at the accident and emergency department of hospitals.
c) In-patient hospital treatment (overnight stay in hospital).
d) Out-patient hospital treatment (no overnight stay).
e) Non-hospital treatment, such as treatment provided by rehabilitation centres, general practitioners, physiotherapy and home care.

Minor medical costs are:

f) Aids and appliances, including for example wheelchairs and medicines.

3.1.2 Production loss

Production loss results from road casualties that cannot work anymore, either permanently (fatalities, severe injuries) or temporarily (injuries). The main cost item is:

a) Loss of capacities of casualties to participate in market production due to death (fatalities), disability or sick leave (injuries).

Another cost item is:

b) Loss of future non-market production: household work, taking care of children, and/or voluntary work.

A minor cost item is:

c) Friction costs: costs for employers for recruiting and training new employees to replace road casualties and costs of vocational rehabilitation of casualties, such as the cost of finding a new job and training.[4]

Note that road crashes also result in a loss of consumption: people who are killed in a road crash cannot consume anymore, but also injured people may consume less as a result of their injuries. In this respect the literature makes a distinction between gross and net production loss. Gross production loss includes consumption loss, while net consumption loss is defined as gross production loss minus consumption loss. Gross production loss is measured by the (lost) value added

[4] Note that time spent on vocational rehabilitation should not be included if vocational rehabilitation is regarded as an element of sick leave. In that case the value of this time is included already in production loss of the injured.

that an employed person produces. Part of this value added is used for the payment of wages, which in turn are used for consumption expenditures. Gross production loss is the most common measure for production loss (Wijnen & Stipdonk, 2016).

3.1.3 Human costs

Human costs are the costs of pain, grief, sorrow and loss of quality of life. Although these intangible costs are not reflected by market transactions and market prices, it is common international practice to include human costs in road crash studies as they reflect a loss of social welfare. A distinction can be made between two main cost items:

a) Human costs of fatalities (lost life years).
b) Human costs of injuries (loss of quality of life).

Another cost item is:

c) Human costs for relatives and friends.

3.1.4 Property damage

The main cost item related to property damage is:

a) Damage to vehicles, in particular passenger cars.[5]

Minor cost items are damage to:[6]

b) Infrastructure, fixed roadside objects and buildings.
c) Freight carried by lorries.
d) Personal property.

3.1.5 Administrative costs

The main administrative cost items are:

a) Police costs: costs of time police officers spend on road crashes (excluding prevention of road crashes) as well as material costs such as vehicle costs.
b) Cost of fire services and other emergency services (excluding transportation of casualties to hospital, which is part of medical costs).
c) Insurance costs: the administrative costs of insurers related to insurances, in particular vehicle insurances. There are also administrative costs related to other insurances, particularly health insurances, but it is not common practice to include these costs and they can be categorized as an 'other' cost item.[7] Note that the administrative costs do not include damage payments, as they are included in the calculation of property damage.
d) Legal costs, such as costs to prosecute offenders who caused a road crash, costs of lawsuits resulting from road crashes, and costs of imprisonment. [8]

3.1.6 Other costs

The main other cost items which are usually included in costs studies are:

a) Funeral costs: the difference between the actual costs of a funeral and the future costs of the funeral if the person was not killed in a road crash.

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[5] Wijnen & Stipdonk (2016) show that vehicle damage makes up 90% or more of all property damage

[6] COST313 also includes environmental damage as part of property damage. We have not included these costs here, because they are not included as a separate cost item in road crash cost studies (Wijnen & Stipdonk, 2016). However, costs of pollution may be included in congestion costs (see below).

[7] Two countries in the review by Wijnen & Stipdonk (2016) have included these costs (Germany and Switzerland). This shows that vehicle insurance costs account for 60% to 70% of total insurance costs.

[8] This might include production loss of people who are imprisoned because of causing a road crash. COST313 categorizes this as 'other costs', but we have not included it there since, to our knowledge, these costs have never been included in a road crash cost study so far.

b) Costs of congestion resulting from road crashes, in particular loss of time. In addition, costs of unreliability of travel times, costs of adapting travel behaviour to traffic jams, extra fuel costs and environmental damage (pollution) may be included.

Minor costs that are discussed in the literature and sometimes taken into account in cost studies are:

c) Costs of vehicle unavailability if it is damaged in a crash (e.g. costs of hiring a replacement vehicle, costs of time loss).
d) Visiting people in hospital (time and travel costs of relatives).
e) Costs of house adaptation and costs of moving: the injuries could mean that the casualty's house needs to be adapted (e.g. install an inside elevator), or that the casualty has to move to another house if theirs is not suitable for handicapped people.

3.2 HOW TO ESTIMATE COSTS OF CRASHES?

COST313 distinguishes three types of methods for valuation of road crash costs (see Figure 3-2).

1. Restitution costs (RC) approach: these are the costs of resources that are needed to restore road casualties and their relatives and friends 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 (ERSO, 2006), such as the costs of medical treatment and vehicle repair. The RC approach also applies to administrative costs, as these costs are also aimed at restoring the consequences of a road crash. Market prices or proxy prices are used to value these costs, if they are available.[9] For example, costs of vehicle damage are calculated using the price of repairing a vehicle (including among other things the costs of labour and materials 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. The HC approach is applicable for estimating production loss. As discussed in Section 3.2.2, a distinction is made between gross production loss (including consumption loss) and net production loss (excluding consumption loss).[10]
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 used to estimate the economic value of lost quality of life, since there is no market price for such impacts. The results of WTP studies are used to derive the value of a statistical life (VOSL), which is used to calculate human costs. COST313 distinguishes between individual WTP and social WTP. The social WTP approach considers the amount that society as a whole is willing to pay for a risk reduction. This amount can be derived for example from the (public) expenditures to prevent road casualties ('cost per life saved method'; De Blaeij et al., 2003). Also, a new WTP-approach in which people are asked how the government should trade-off crash risk reductions and travel time savings, from which the VOSL is derived (Mouter et al., forthcoming), can be classified as a social WTP approach. Furthermore, COST313 distinguishes between WTP and 'willingness to accept' (WTA). WTA measures the amount of money people are willing to accept for a risk increase.

[9] The concept of opportunity costs applies here and it is assumed that market prices or proxies reflect opportunity costs, see Section 3.

[10] COST313 also includes the 'value of lost lifetime years' method as a human capital approach. In this method the loss of working as well as non-working time is being valued, including the value of leisure activities for example. We have not included this method, because it overlaps with the WTP approach that also includes the value of such activities. When COST313 was published, a few countries used the WTP approach, so at that time the value of lost lifetime years method could be used as an alternative. Moreover, this approach is related to the DALY approach, which is getting more attention in recent years and has been applied in the US to estimate human costs of injuries (Blincoe et al., 2014). The DALY approach includes a value of lost life years as well as a value of loss of quality of life and is regarded as an alternative for the standard WTP approach that uses the concept of VOSL (Hammitt, 2007).

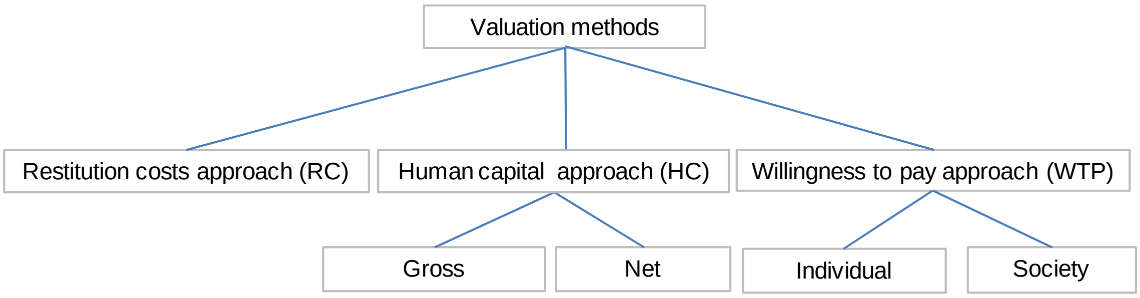

Figure 3-2 Classification of valuation methods (adapted from Alfaro et al., 1994)

3.2.1 Medical costs

The appropriate method for estimating medical costs is the RC method, which implies that the actual costs of medical treatment need to be calculated, such as the costs of ambulance trips, overnight hospital stays and non-hospital treatment. In addition to costs per 'unit' (per ambulance trip, per day, per treatment, etc.), this requires availability of detailed information about the number of 'units', such as number of ambulance trips, average duration of hospital stay (per injury category), frequency of non-hospital treatment, etc.

3.2.2 Production loss

The human capital approach is the appropriate method for estimating production loss. In general, production loss of a casualty is calculated by multiplying the period of time they are not able to work due to the crash by a valuation of the production per person per unit of time. Regarding fatalities, the period of time is the remaining number of productive years until retirement. For injured casualties the relevant period of time ranges from a few days absence from work, to all remaining working years until retirement if someone is permanently disabled.

There are several issues regarding the calculation of production loss (see for example Trawén, 2002):

- **Gross or net production loss?** This issue is related to the measurement of human costs and the concept of VOSL. The VOSL comprises human costs as well as consumption loss (see e.g. Evans, 2001; Wijnen et al., 2009). Since gross production loss also includes consumption loss there are two options to avoid double counting of production loss (Figure 3-3): (1) gross production loss in combination with human costs. This means that consumption loss should be deducted from the VOSL to obtain human costs, or (2) net production loss in combination with VOSL. Wijnen & Stipdonk (2016) show that the first approach is common practice. This approach is recommended because it results in a separate estimate of human costs.

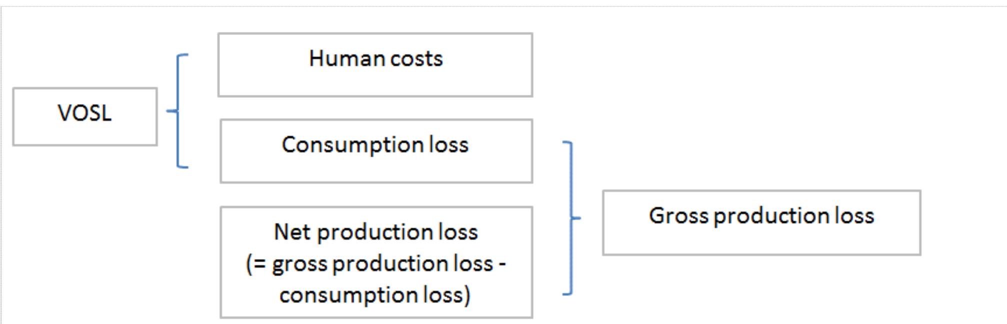

Figure 3-3 Relation between VOSL, human costs, production loss and consumption loss

- **Actual or potential production?** The actual production loss refers to production of casualties who are employed, while the potential production refers to what casualties could potentially produce. Potential production loss accounts for the fact that the loss of productive capacities of unemployed people as well as future production of children also should be valued. Although these people are not (yet) employed, human capital is lost which represents a socio-economic cost. Although both approaches are being used in costs studies[11], we recommend using the potential production loss approach. Baum et al. (2007) explicitly discuss this issue. They stress that the available human capital (supply of labour) determines economic welfare. Loss of human capital implies that the productive capacities of an economy are reduced, which is regarded as a socio-economic cost. Another reason to apply the potential production loss approach is that it (partly) compensates for not including non-market production (see below).
- **Which production indicator?** There are several indicators for production per person. The indicator should reflect the social value of the individual's production. Appropriate indicators that are suggested by COST313 and/or are used in recent cost studies are: gross national/domestic product per capita and income (total income or available income).
- **Discounting:** in economic analyses future costs and benefits are given a lower weight by using a discount rate and this is also recommended (and good practice) in road crash cost studies. Discounting reflects that fact that people show a preference for the present: they assign a higher value to available goods now than in the future ('time preference', see for example Boardman et al., 2006). Discount rates in road crash cost studies in the countries included in Wijnen & Stipdonk (2016) range from 2% to 6%. Usually the discount rate that is recommended in (official) national guidelines for economic analysis (e.g. cost-benefit guidelines) is used.
- **Growth factor**: a growth rate can be applied to account for the fact that (real) production per person grows over time. A difficulty is that production growth is uncertain, especially for a (very) long period. Therefore it is not common practice to apply a growth rate.[12]
- **Non-market production**: ideally, the value of non-market production is included in road crash cost studies. Non-market production can be substantial (e.g. 25% of total production loss in US; Blincoe et al., 2014). However, estimating this production loss is quite complex as it requires data on time spending and values of time. Therefore, it is not common practice to include this production loss, although there are several examples of cost studies taking into account these costs (Wijnen & Stipdonk, 2016). Note that non-market production of unemployed people is taken into account (at least to some extent) if the concept of potential production loss is used.

The RC approach can be used to calculate friction costs, which means that the actual cost of resources (mainly labour) spent on recruiting and training new personnel is estimated.

3.2.3 Human costs

Human costs of fatalities

The willingness to pay (WTP) approach is generally recommended to estimate human costs of fatalities (e.g. Alfaro et al., 1994; Bickel et al, 2005) and it is good practice to apply this approach in road crash cost studies (Wijnen & Stipdonk, 2016). As noted above, COST313 distinguishes between individual WTP and social WTP and between WTP and 'willingness to accept' (WTA). However,

[11] Five out of nine countries in the review by Wijnen & Stipdonk (2016) apply the potential production approach, and the other four, including US, calculate actual production loss.
[12] However, in some studies it is assumed that the growth rate is equal to the discount rate. In that case a 0% discount is used.

reviews (e.g. De Blaeij et al., 2003; Lindhjem, 2010) show that the vast majority of studies into the VOSL (which includes human costs, see Figure 3-3) are based on individual WTP. Moreover, the standard value proposed in HEATCO (Bickel et al., 2005) is based on individual WTP and the WTP values in the countries included in Wijnen & Stipdonk (2016) are all based on the individual WTP approach. Moreover, the individual WTP approach is consistent with economic welfare theory which is the basis for cost benefit analysis (see Section 3.3.1).[13] In this theory socio-economic welfare is determined by individual preferences: welfare is a function of the 'utility' of each individual in society (see for example Boardman et al., 2014). The WTA approach is barely used in VOSL-studies and its results are commonly associated with upward biases. This is explained by 'loss aversion': people are more averted to losing what they have than to refrain from potential gains (with the same size as the loss), and so WTA for a loss is higher than WTP for similar gain. In general the results of WTP approach is regarded as more reliable than results of WTA-studies (Boardman et al., 2011).[14]

Several other approaches have been developed to estimate human costs (see for example World Bank, 2005). One of these approaches uses financial compensations that are awarded to road casualties or their relatives in courts or by law (statutory values). In this approach these compensations are regarded as the value that society attributes to loss of (quality of) life. It is applied in a few countries, for example Germany (Baum et al., 2007) and Australia (BITRE, 2009).

Other approaches derive human costs from premiums people pay for life insurances or from public expenditures on improving (road) safety. These two approaches typically result in (much) lower values than values from WTP studies (Elvik, 1995; Trawén et al., 2002; De Blaeij et al., 2003; Wijnen & Stipdonk, 2016). A fundamental difference between these alternative approaches and the WTP approach is that they are not based on valuations of individuals, which conflicts with economic welfare theory. Finally, sometimes the human capital (HC) approach is considered as an alternative for the WTP approach. However, as discussed above the HC and WTP approach measure different cost items (production loss versus human costs) and so they are complementary instead of alternatives (Alfaro et al., 1994; Wijnen et al., 2009).[15]

It is generally recognized that the WTP approach is the most theoretically sound method to estimate human costs, in particular when costs estimates are used in cost-benefit analysis (Alfaro et al., 1994; BRS & TRL, 2003; World Bank, 2005). This is because the WTP method is consistent with economic welfare theory that underlies cost-benefit analysis. Moreover, the WTP approach is good practice in road crash cost studies (Wijnen & Stipdonk, 2016). Therefore, we recommend the (individual) WTP approach to estimate human costs of road crashes.

Willingness to pay approaches: stated preferences and revealed preferences

There are in general two approaches to determine individual WTP: 'stated preference' (SP) methods and 'revealed preference' (RP) methods (see e.g. De Blaeij, 2003). RP methods value risk reductions on the basis of actual behaviour, for example purchasing behaviour regarding safety provisions (e.g. airbags), while SP methods use questionnaires in which people, directly or indirectly, are asked how much they are willing to pay for more safety. The results of a SP or RP study are used to derive the value of a statistical life (VOSL). Although both SP and RP are both valid methods, reviews show that SP methods are much more commonly used to derive the VOSL for road safety (Blaeij et al.,

[13] Mouter et al. (forthcoming) question the individual approach and present an alternative approach where people's preferences on the government's trade-off of reducing crash risk and travel time savings are asked for, using a stated choice design (discussed below). An academic discussion on to what extent this novel approach is consistent with economic welfare theory has not taken place (yet).
[14] One of the reasons is that results of stated preference studies applying WTP are closer to the results of revealed preference studies, compared to stated preference studies applying WTA (Boardman et al., 2011).
[15] Provided that a correction for double counting of consumption loss is made, see Figure 3-3.

2003; Lindhjem, 2010). A main reason why SP methods are often preferred to revealed preference methods is that SP methods can be applied more easily and are not dependent on information on actual (purchasing) behaviour. Furthermore, consumers usually are not (fully) aware of the risk reduction resulting from safety devices, and stated preference methods allow us to provide this information to help respondents understand (small) risk reductions correctly (SWOV, 2012). However, as noted by Lindhjem et al. (2010), there is a difference between the US and Europe regarding the preferred method: in the US there is more emphasis on RP studies to derive the VOSL than in Europe. The choice of VOSL for transport in the US has recently been critically reviewed (Trottenberg & Rivkin, 2003), and a VOSL based on wage differences between workers who are exposed to different risk levels is recommended ('hedonic pricing' method, an RP approach). This has led to a major upward revision of the VOSL in the US. It should be noted however that this VOSL has not been estimated in the context of road safety.

The SP approach has several advantages above RP, in particular its applicability to road safety risks, and it is good practice in Europe and other parts of the world (e.g. New Zealand) to apply this approach. However, we should also note that SP methods have several limitations. For example, people have difficulties in understanding changes in very small risks and the VOSL resulting from SP studies is known to be dependent on the size of the risk change, the context (road safety, environmental risk, occupational risk) and the specific type of SP method that has been used (Miller, 2000; De Blaeij et al, 2003; Lindhjem et al., 2010). This results in (large) variations in VOSL estimates, also within countries. However, these issues are extensively discussed in the literature and methods have been developed to deal with some of these issues. For example, visual tools have been developed to help people better understand small risk changes, resulting in more reliable estimates (Lindhjem et al., 2010). Moreover, techniques to elicit people's preferences have been improved, for example by using the 'stated choice' approach (Bahamonde-Birke et al., 2015). In this approach people are asked to make choices between several alternatives (e.g. alternative routes) that differ in several respects which include (fatal) risk and costs. This approach in general yields more reliable results than the conventional 'contingent valuation' approach where people are asked more or less directly the amount they want to pay for a risk reduction (Lindhjem et al., 2010).

To conclude, although SP still have several methodological difficulties, with the current state of knowledge the SP approach is considered, at least in Europe, as the most suitable and scientifically sound method to estimate the VOSL in the context of road safety.

Human costs of injuries

Also for human costs of injuries, the WTP approach is generally recommended (Schoeters et al., 2017; Alfaro et al., 1994) and applied in European costs studies (Bickel et al., 2005; ECMT, 1998) as well as in individual countries (Wijnen & Stipdonk, 2016). [16] However, information about human costs of serious and slight injuries is relatively poor compared to human costs of fatalities. WTP studies regarding injuries are very complex, among other reasons because of large variations in the severity of injuries and the impact of these injuries on quality of life. Nevertheless there are examples of thorough WTP studies in a few countries: UK (O'Reilly et al., 1994), Sweden (Persson et al., 1995; Persson, 2004) and Belgium (De Brabander, 2004). In these studies, the WTP for reducing the risk of getting injured is estimated relative to the WTP for reducing fatal risk, resulting in a value per serious and slight injury as a percentage of the VOSL (10-16% for serious injuries and 0.9-1.6% for slight injuries). Despite poor information about human costs of injuries, it is good practice to include these costs (Wijnen & Stipdonk, 2016). The reason is that injuries have a large share in the

[16] This includes methods to estimate the human costs of injuries relative to human costs of fatalities. These methods can be classified as WTP methods because the value per injury is derived from the WTP value of a fatality. See Schoeters et al. (2017) for a further discussion.

total human costs (and thus in the total cost of road crashes): 60% to 80%[17]. In cases where countries do not have country-specific estimates of human costs of injuries, it is common practice to use values from other countries or standard European values (13% of VOSL for serious injuries and 1% for slight injuries; ECMT, 1998; Bickel et al., 2006).

The US adopts a different approach for human costs of injuries, using the concept of QALYs (quality adjusted life years). QALYs comprise years of life lost (YLL) and years lived with disability (YLD), which are expressed in a single measure. For several injury categories (based on the MAIS (Maximum Abbreviated Injury Scale) classification) the number of QALYs is estimated and multiplied by a value per QALY. This value reflects the human costs and is deducted from the VOSL and thus is indirectly based on WTP. This is a promising approach for future application in other countries, because it uses detailed information on the type and severity of injuries and enables valuing different health states of casualties. On the other hand, the QALY approach is quite demanding in terms of data availability on injuries (in particular number of injuries by severity and the consequences of the injuries in terms of quality of life loss). The QALY approach is discussed in Deliverable 7.3 of the SafetyCube project (Schoeters et al., 2017).

Human costs for relatives and friends

Human costs for relatives and friends are not estimated separately in the literature. Generally it is assumed that these costs are included in the values that result from WTP studies, meaning that people take into account human costs for relatives and friends when stating their WTP for reducing crash risk (in SP studies) or in their (risk taking) behaviour (RP studies).

3.2.4 Property damage

The RC approach is the appropriate method for estimating property damage. This means that the actual cost of repairing damage or replacing property is calculated. Regarding the main cost item, vehicle damage, there are two calculation methods. In the first method (bottom-up) the (average) car damage cost is multiplied by the number of cars involved in a crash, while in the second method total damage is directly estimated (e.g. on the basis of insurance data on total payments) and the costs per vehicle or per crash can be derived from the total costs (top-down). Both approaches have limitations due to limited data availability. The bottom-up approach is limited because usually there is no precise information about number of crashes, particularly low severity crashes. This requires an (if necessary rough) estimate of the underreporting of crashes, including property damage only crashes. The top-down approach is limited because data on total damage insurance statistics do not provide a complete picture of the total vehicle damage. Information about the completeness of insurance statistics is required to be able to estimate total vehicle damage. Examples in three countries show that damage that is not included in insurance statistics makes up about 20% to 50% of total vehicle damage (Wijnen & Stipdonk, 2016).

Usually damage to cars, motorcycles and trucks/vans is included in road crash cost studies. Other vehicles may be added, such as buses, mopeds and bicycles. Other property damage mainly concerns damage to infrastructure and fixed roadside objects and buildings. Although this damage is relatively small (at most 10% of the total; Wijnen & Stipdonk, 2016), infrastructure damage is included in several cost studies, mostly based on damage registrations by road authorities.

3.2.5 Administrative costs

Administrative costs consist of police costs, costs of fire service, insurance costs and legal costs. In general, the RC method is appropriate to estimate these costs. The cost of police offers assisting

[17] Based on five countries included in Wijnen & Stipdonk that apply a WTP approach for fatalilties.

when a crash has happened as well equipment they use should be estimated. Two approaches are used in cost studies. Firstly, the costs can be calculated bottom-up, on the basis of the time police officers spend on road crashes (using information on time spent per crash, number police officers per crash and number of crashes) and cost per hour (wage and overhead costs including equipment costs). The second approach is top-down: in this approach the share of police costs related to road crashes in total police costs is estimated, on the basis of time police officers spend on road crashes (excluding prevention, see Section 3.3.3) as a proportion of total time spending.

The two approaches for police costs also apply for costs of fire services: these costs can be estimated either on the basis of costs (time, equipment) per crash and number of crashes, or using total costs of fire services and the proportion of time spent on road crashes in total time spending.

The administrative costs of crashes for insurance companies consist of the cost of personnel handling claims, including overhead costs. It is good practice to include all administrative costs related to vehicle insurances.[18] The underlying idea is that these costs can be attributed to road crashes, because insurance would not be needed if there were no crashes. These costs are usually available from insurance branch statistics. An alternative approach estimates the costs that are specifically related to handling insurance claims resulting from road crashes, based on number of claims and costs per claim.

Just as with police and fire service costs, legal costs can be estimated using a bottom-up or a top-down approach. In a bottom-up approach, the costs per 'unit' (cost for prosecution per offender, per lawsuit, per prisoner) are multiplied by the number of units (prosecuted offenders, lawsuits, prisoners). In a top-down approach the costs due to road crashes as a proportion of total legal costs (costs of prosecution, lawsuits, and imprisonment) is determined on the basis of certain variables (e.g. prosecuted people due to a road crash as a proportion of total number of prosecuted people).

3.2.6 Other costs

The costs of funerals are calculated as the difference between the actual costs of a funeral and the future costs of the funeral if the person was not killed in a road crash. The future costs are calculated as the present value of the costs of a funeral in the future, using a discount rate.

Congestion costs are calculated on the basis of time loss due to traffic jams resulting from crashes and the value of time. Usually standard values of time (by type of road user: business, leisure, etc.) that are used in cost-benefit analysis are applied. Alternatively, congestion costs can be calculated as the proportion of time loss related to road crashes in total time loss due to (all) traffic jams. These total costs may include costs of unreliability of travel times, costs of adapting travel behaviour to traffic jams, extra fuel costs and environmental damage (pollution).

Costs of vehicle unavailability can be estimated using the RC approach: the actual costs of replacing the vehicle (e.g. renting car and time costs) should be calculated.

The cost of visiting casualties can be calculated on the basis of the actual costs of visits, in particular travel costs and time costs (RC approach).

Costs of adapting houses and moving can be estimated through the RC approach. The costs of adapting houses are the actual costs (equipment and labour) of installing a new bath structure, an inside elevator, etc. Moving implies costs directly related with the moving itself, but also some other costs related with a higher rent for instance.

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[18] Five out of eight countries in Wijnen & Stipdonk (2016) adopt this approach.

3.3 SOME METHODOLOGICAL ISSUES

In calculations of costs of road crashes several methodological issues should be addressed. The section discusses these issues, in particular the question from whose perspective the costs are calculated, whether costs per casualty or per crash are calculated, whether prevention costs should be included, how to deal with illegally gained benefits or costs and the usefulness of making cost breakdowns.

3.3.1 Perspective of cost analysis

Costs of road crashes can be considered at different levels – globally, at a European or at a national level – and from different perspectives: stakeholders such as governments, companies, or citizens. Most cost studies are carried out for individual countries and calculate the costs from a socio-economic perspective. This means that costs are generally estimated at the society level as a whole regardless of which stakeholders (road casualties, governments, employers, insurers, etc.) bear these costs. This is consistent with economic welfare theory that provides the basis for cost-benefit analysis (see for example Boardman et al., 2011). This is an important notion because costs of road crashes are an essential input for cost-benefit analyses of road safety measures (See 3.3.2).

In economic theory, welfare is determined by the 'utility' that each individual derives from consumption but also from intangible factors that affect quality of life (e.g. nature, safety), see for example Johansson (1991). Following this theory, socio-economic costs of road crashes consist of loss of utility resulting from crashes. For example, a reduction of a casualty's ability to consume or to enjoy life implies a reduction of utility derived from consuming and quality of life, and this represents a cost. Alternatively, usage of resources needed to restore the utility level after a crash to the initial level can be regarded as a cost. For example, the value of resources (labour, equipment) needed to repair a damaged vehicle represents the cost of this vehicle damage. This value is determined by the 'opportunity costs' of the resources. Opportunity costs of using a resource are defined as 'its value in its best alternative use' (Boardman et al., 2006): the value that society must forgo if the input is used to produce a certain good or service. The idea is that resources that are used for, for example repairing a car, cannot be used for producing something else (that would bring forth utility) and this is regarded as a cost. In practical applications, it is assumed that market prices of resources reflect the value in its best alternative use, and so the prices of resources (in this case the price of labour and equipment that is needed to repair a car) can be used to estimate the costs of vehicle damage.[19] Although economic welfare theory allows taking into account distributional or justice effects among stakeholders, in standard cost benefit analysis (CBA) these impacts are usually not accounted for.

The socio-economic perspective means that some financial transactions that do not necessarily represent any loss of welfare are not included in the cost calculations. Examples are taxes on repaired vehicles for instance: these are revenues for government bodies on the one hand and expenditures for citizens on the other, so there is no social cost and these money transfers do not represent any loss of welfare at the society level. They consist only of transfers between agents. Note that a breakdown of the socio-economic costs into stakeholders who bear these costs can nevertheless be made, as has been done for example in the US and the Netherlands.

[19] Note that from this theoretical notion it follows that money transfers are not regarded as socio-economic costs: the fact that a stakeholder makes a payment as a result of a crash, does not necessarily mean that using resources is at stake. For example, a social security benefit that the government pays to a casualty because he/she is not able to work due to a crash, does not reflect use of resources (apart from resources needed for administrative issues). It is only a money transfer from the government to a casualty to compensate the casualty for income loss. The actual costs of inability to work is the loss of human capacity that could have been used for production.

3.3.2 Total costs versus costs per casualty/crash

Information about the total costs of road crashes gives a picture of the economic burden of road crashes and can serve as an input for setting policy priorities and as a stimulus for improving road safety. Information on costs (as a percentage of gross domestic product) can also be used for making international comparisons and comparisons with the economic burden of issues in other policy fields (e.g. congestion, environmental pollution or other types of accidents and injuries).

For CBA information about the costs *per casualty and/or per crash* is needed. In CBA the reduction of the number of casualties is translated into economic benefits by multiplying the number of casualties/crashes saved (by severity) by the costs per casualty/crash.

Road crash cost studies usually also include estimates of the cost per casualty and/or crash. Since most total costs are in fact calculated on the basis of information on the costs per casualty and the number of casualties, information on costs per casualty is available for most cost items. In cases where only the total costs have been estimated (e.g. total vehicle damage), the cost per severity category should be estimated to be able to then calculate costs per casualty/crash. In CBAs road safety impacts are usually expressed in terms of number of casualties prevented, which means that the cost per casualty should be known (instead of costs per crash). Costs per casualty preferably include both injury related costs and crash related costs, so all costs are included in CBA. This requires that crash related costs are attributed to casualties on the basis of information on the number of casualties per crash.

3.3.3 Costs of road crashes versus prevention costs

A distinction should be made between costs that result from road crashes (e.g. medical costs and property damage) and costs to prevent road crashes. A road crash cost study usually only focuses on costs resulting from crashes, to give a picture of the economic burden of road crashes. Prevention costs are the costs of measures that are implemented to improve road safety, such as infrastructural measures, enforcement and education. Prevention costs enter at the side of the costs in a CBA, whereas prevented costs of road crashes enter at the benefit side.

Following this distinction, this Deliverable only focuses on costs resulting from road crashes. Note that some stakeholders are involved in both types of costs, for example the police. This implies that police costs should be separated into costs that occur after a crash (e.g. time costs of police officers coming to a crash, administration) and police costs of preventing crashes (e.g. time spent on enforcement and equipment).

3.3.4 Production loss related to illegal activities

An issue that is related to welfare theory is the extent to which benefit and costs resulting from illegal activities should be taken into account. This is particularly relevant in economic analysis of crime, for example: should benefits that criminals gain from illegal activities be included in CBA? But it also applies to road safety: for example how to treat benefits gained from violating speed limits (reduced travel time)? This is known as the 'issue of standing' (Wittington & MacRae, 1986): which individuals have 'standing' in CBA and whose costs and benefits should (thus) be included?

This issue is debated in the literature and although there are different opinions, there is evidence for a trend towards not including costs and benefits that are gained in an illegal way.[20] However,

[20] Economic models that included benefits of violators of the law were typically developed in the late 1960s and 1970s, in particular by Becker (e.g. Becker, 1968). In later years, the issues of standing including how to treat became a topic for debate among researchers (see for example Adler & Posner, 2000). Recent publications in the field of road safety show it is

ultimately it is up to the researcher who is carrying out a CBA to decide whether or not to include such benefits.[21]

This issue is also relevant regarding the estimation of production loss: should the loss of production resulting from illegal activities be included? To our knowledge, 'illegal production loss' is usually not included in road crash cost studies.[22] Following the trend of not including costs and benefits resulting from illegal activities as well as common practices in road crash studies, production loss related to illegal activities will not be included in our cost estimates.

3.3.5 Cost breakdowns

In road crash cost studies usually some breakdowns of the costs are made. In general, breakdowns are useful because they provide insight into the nature and causes of the costs which may be used as an input for policy making. For example, if a breakdown into injury severity shows that serious injuries have a major share in total costs; this may direct policy makers to putting more efforts into preventing these injuries.

Usually the costs are itemized by at least:

- Cost component: in each costs study the cost of each component is estimated separately and then total costs are calculated by adding these cost components together. This implies that information on costs per component is always available and can be presented quite easily.
- Injury/crash severity: a breakdown into injury severity is commonly made in cost studies. Common categories are; fatalities, serious injuries, slight injuries and property damage only crashes. Regarding injuries, several countries have more detailed categories. For instance, the US distinguishes between six injury categories based on the MAIS classification. Most studies present the costs per casualty or crash, using several severity categories, and so costs can be fairly easily itemized by injury severity.

Other breakdowns that are sometimes made can concern:

- Stakeholders: a breakdown can be made into stakeholders who bear the costs of road crashes, such as casualties, governmental bodies, insurers, companies/employers and (other) road users. Such a breakdown has been made in the US (Blincoe et al., 2014) and The Netherlands (Wijnen, 2014).
- Vehicle type: a breakdown can be made by vehicle type user, as has been done in Australia (BITRE, 2009) and Switzerland (Sommer et al., 2007).
- Road type: the UK (DfT, 2013) and the US distinguish between road types (three and ten road types respectively).
- Area: costs can be calculated by region or state and/or a distinction between rural and urban areas can be made. This is particularly common practice in (large) countries outside Europe (Australia: BITRE, 2009; New Zealand: Ministry Transport NZ, 2013; US: Blincoe et al., 2014).

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recommended not to include illegally gained benefits (in particular travel time benefits; Elvik, 2006; Wijnen et al., 2016). The latter study shows that such benefits are usually not taken into account in CBAs in the Netherlands.

[21] Note that exclusion of illegally gained benefits and costs only refers to benefits and costs *for a violator* that are *directly* related to his/her illegal activities. Clearly, costs and benefits for other stakeholders related to these activities, for example costs of prevention by the police, should be included in CBA. Another example is production loss resulting from imprisonment of violators. This should be treated as a socio-economic cost, because this production loss is just an *indirect* cost resulting from illegal activities. The production loss is the direct result of imprisonment, not a direct result of the illegal activities.

[22] An exception is Germany (Baum et al., 2007). In Germany loss of production of illegal products (e.g. drugs) is not included, but loss of legal products that are produced in an illegal way are included (e.g. black market activities).

- Age and gender: in Switzerland (Sommer et al., 2007) costs have been calculated by several age categories and by gender.
- Crash type: costs can be calculated for several crash types. In the US costs have been calculated for a number of crash types, such as intersection crashes, single-vehicle crashes and roadway-departure crashes.
- Crash cause: In the US costs have been calculated for various causes such as distraction, alcohol, speeding and non-use of seatbelts.

In general, these other breakdowns require many additional data and for that reason only breakdowns into cost component and injury/crash severity are made in most cost studies. Nevertheless, additional breakdown clearly could provide an added value for road safety policy making.

3.4 SUMMARY

Table 3-1 summarizes the framework for estimating road crash costs according to good practices as discussed in this document. It presents the six main cost categories, costs items that belong to these categories, the appropriate method to estimate these costs items, and some explanation about the cost items and the calculation method. The table makes a distinction between the main cost items that should in all cases be taken into account, and minor and other cost items that can additionally be taken into account. Minor cost items are known to be relatively small compared to the main cost items. Information on other cost items is poor because they are not usually taken into account in cost studies, but the size may be substantial.

Component	Sub component	Method	Explanation
Medical costs			
Main	a) First aid at crash location and transportation	Restitution costs	– Actual costs of medical resources (labour, equipment, etc.), Calculation: costs per 'unit' (per ambulance trip, per day, per treatment, etc.) times the number of 'units' (number of ambulance trips, average duration of hospital stay, frequency of non-hospital treatment, etc.)
	b) Treatment at the accident and emergency department of hospitals	Restitution costs	
	c) In-patient hospital treatment	Restitution costs	
	d) Out-patient hospital treatment	Restitution costs	
	e) Non-hospital treatment (rehabilitation centres, general practitioners, etc.)	Restitution costs	
Minor	f) Aids and appliances	Restitution costs	
Production loss			
Main	a) Lost market production	Human capital	– Production per person per year (e.g. GDP/capita or income) * lost productive years – Gross production loss: including consumption loss

Component	Sub component	Method	Explanation
			– Potential production loss – Discounting future losses
Other	b) Lost non-market production (household work, taking care of children, voluntary work, etc.)	Human capital	– Time spent on non-market production * value of time (e.g. wage as indicator – Discounting future losses
Minor	c) Friction costs	Restitution costs	– Actual costs of recruiting and training new employees and actual costs of vocational rehabilitation
Human costs			
Main	a) Fatalities (lost life years)	Willingness to pay	– VOSL-consumption loss * number of fatalities – Individual WTP from stated or revealed preference studies
	b) Injuries (loss of quality of life)	Willingness to pay	– Serious and slight injuries – %VOSL * number of injuries
Other	c) Human costs for relatives and friends	Willingness to pay	– Not calculated separately: included in WTP fatalities/injuries
Property damage			
Main	a) Vehicles	Restitution costs	– Actual costs to repair damage or replace vehicles – Preferably cars, motorcycles and trucks/vans; optionally buses, mopeds and bicycles – Two calculation approaches: 1.Bottom-up: average damage per vehicle * number of damaged vehicles (including non-reported crashes) 2. Top-down: total vehicle damage (including estimate of non-reported damage)
Minor	b) Infrastructure, fixed roadside objects and buildings	Restitution costs	– Actual costs to repair damage or replace property
	c) Freight carried by lorries	Restitution costs	
	d) Personal property	Restitution costs	

Component	Sub component	Method	Explanation
Administrative costs			
Main	a) Police costs	Restitution costs	– Actual costs of resources of police assistance (labour, equipment) – Excluding costs of prevention – Two calculation approaches: 1.Bottom-up: time spent on road crashes * costs per unit of time 2. Top-down: total police costs * time share road crashes
	b) Fire service costs	Restitution costs	– Actual costs of resources of fire service assistance (labour, equipment) – Bottom-up or top-down calculation (similar to police cost)
	c) Vehicle insurance costs	Restitution costs	– All administrative costs related to vehicle insurances
	d) Legal costs	Restitution costs	– Actual costs of prosecution, lawsuits and imprisonment – Bottom-up or top-down calculation
Other	e) Other insurance costs	Restitution costs	– All administrative costs related to other insurances (e.g. health)
Other costs			
Main	a) Funeral costs		– Difference between the actual funeral costs and (discounted) future costs of the funeral if the person was not killed in a crash
	b) Congestion costs		– Time loss due to traffic jams resulting from road crashes – Calculation: time loss * value of time, or total congestion costs * share road crashes – Cost of travel time, unreliability of travel times, adapting travel behaviour, extra fuel costs and pollution may be included
Minor	c) Vehicle unavailability	Restitution costs	– Actual costs of replacing the vehicle (e.g. renting car and time costs)
	d) Visiting people in hospital	Restitution costs	– Actual costs of visits, in particular travel costs and time costs
	e) Moving and house adaption cost	Restitution costs	– Actual cost for moving and for adaptations (equipment, labour)

Table 3-1 Summary of framework for estimating costs of road crashes: costs components and recommended methods

4 Data collection and processing

Information on costs of crashes in European countries was collected by means of a survey. This survey was developed and distributed together with the InDeV project. Within the SafetyCube project, the data from all questionnaires was combined into a database and quality checks were performed. This process was necessary to make the data available for further analyses and to make the data comparable across countries. All edits made to the data are documented.

4.1 DATA COLLECTION

Data collection was a joint effort between the InDeV and SafetyCube projects (WP3 and WP7) and is described also in chapter 5.1 of the final InDev report (Kasnatscheew et al., 2016).[23] Through this common approach, synergies in the process of information retrieval were gained and the burden to respondents in the member states was minimized.

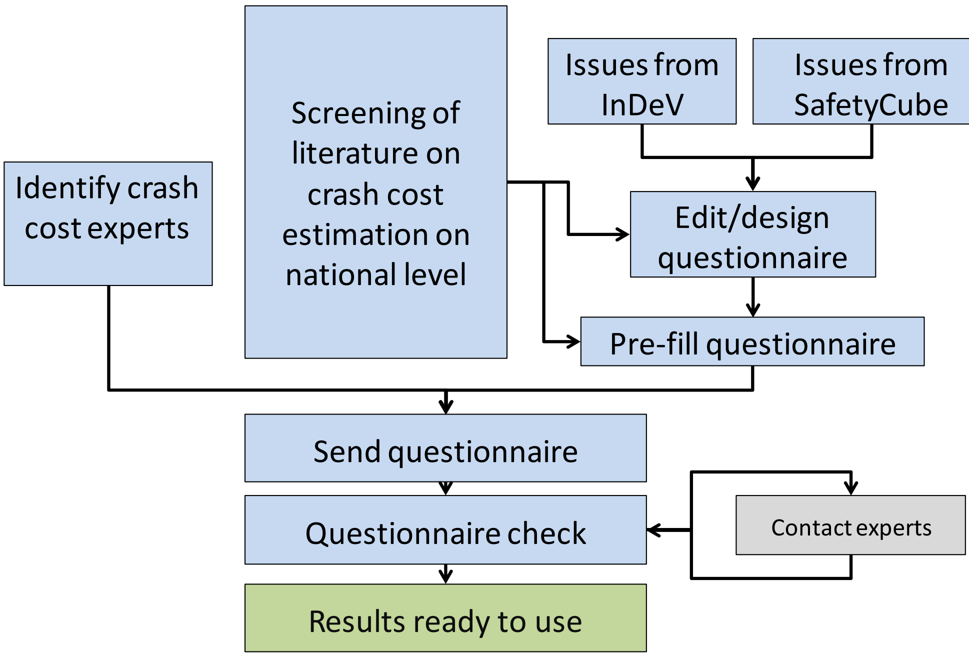

Figure 4-1 Workflow for joint InDeV-SafetyCube Survey (© InDeV)

The objectives of the data collection process were, first, to get a full picture of the availability and the use of data on costs of road crashes in the EU on a country level, and second, to get actual cost information for as many EU countries as possible. At the request of InDeV, a number of non-EU countries were also included, however within SafetyCube we focus only on the European countries. Apart from the 28 EU countires, 4 non-EU countries were included: Iceland, Serbia, Norway and Switzerland.

[23] InDeV: In-Depth understanding of accident causation for vulnerable road users (HORIZON 2020 Project No. 635895).

The following steps were taken in order to achieve these objectives:

- A literature review was performed in order to gather available reports and publications on this topic (see Chapter 2).
- As a result of the literature review and through existing contacts among the InDeV and SafetyCube partners, experts on cost of crashes were identified in the respective EU (28) and non-EU countries (Iceland, Serbia, Norway, Switzerland). See Appendix A for the list of experts.
- Experts were addressed by a standard e-mail letter and asked for cooperation on behalf of both InDeV and SafetyCube; they were requested to either confirm their role or possibly indicate another expert in their country.
- In order to ease the communication with the experts, the contacts were split between the InDeV and the SafetyCube project. Within SafetyCube, three to four contacts (or countries, respectively), were assigned to each partner in Task 3.2. Progress in contacting the experts and obtaining relevant information was monitored and discussed in regular tele-conferences.
- Based of the literature review and the framework of costs components and methods (see Chapter 3), an easy to use, Excel based questionnaire was developed (see Appendix B). This questionnaire covered 6 Chapters: Contact details and estimation figures, Costs per crash/casualty, Methods, Cost per component, Total costs and Number of crashes by severity level. Apart from these a Chapter with Explanations was provided . Specific items covered were:
  - Primary and latest study of cost calculation and the way of updating
  - Definitions of crashes, casualties and severities
  - Cost per crash and per casualty by severity, on unit level
  - Cost per cost component by severity
  - Methods and databases used to estimate cost components
  - Number of crashes/casualties by severity
  - Total costs of crashes and their percentage of GDP
  - Consideration of vulnerable road users (VRU), if available
- The cost questionnaire was pre-filled by the respective InDeV or SafetyCube partner with information available from the literature review or from the experts, and then forwarded to the experts for checking and completion.
- A first round of validation was performed with a few key indicators (e.g. percentage of GDP of total crash costs) and the respective experts were contacted again in case of suspected errors.
- As the InDeV project has a focus on vulnerable road users, selected experts were asked for possible additional cost information for this subgroup of road crashes.

Eventually, 29 experts contributed to the survey at various levels of detail (including experts from the InDeV and SafetyCube projects; see Appendix A - Consulted Experts). With data based only on reports for Portugal and Lithuania, cost information for 31 countries could be analysed. No costs of crash data were obtained for Romania. Please note that not all cost figures are available for all countries and therefore the number of countries in the charts and tables of the result section may differ from the maximum of 31.

4.2 DATA CLEANING AND ANALYSIS

Within SafetyCube, the data was subsequently combined into one cleaned database. This section gives an overview of the steps that were preformed to create this database (Figure 4-2). First the questionnaires were integrated into a SQLite database. Next, the data was prepared for an analysis. This preparation implied particular checks: "Does the data fit the standard severity categories? Is there any data missing? Is the data internally consistent?". Following these checks, several edits were made. Finally small adjustments and a standardization for currency, inflation and Purchasing Power Parities were made to prepare the data for a comparison in the descriptive statistics. This was also necessary to perform additional statistical analyses (Chapter 5) and to proceed the value transfer (Chapter 6). All steps are explained in more detail in the next paragraphs.

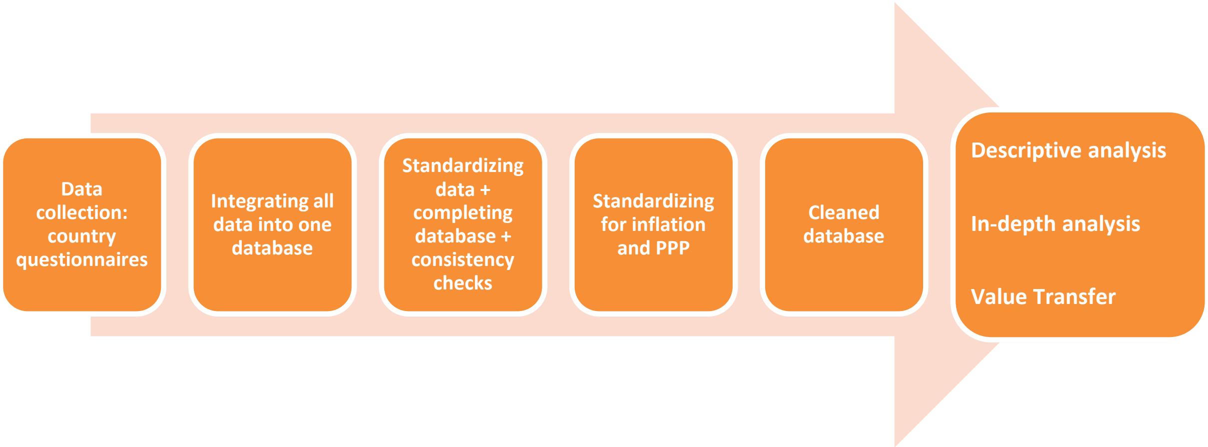

Figure 4-2 Process of data collection, preparation and analysis of crash costs in 32 European countries

4.2.1 Integrating all the questionnaires into one database

All data from the completed questionnaires were integrated into one database. It should mentioned that, while data collection was done together with InDeV, the data cleaning and analysis was performed separately since the projects had different deadlines and a different focus. Therefore the results in this Deliverable can differ from those published by InDeV. On the one hand this is because SafetyCube had more time to consult the experts again when inconsistencies appeared, on the other hand – when there were inconsistencies –different decisions were made in how to deal with them. The most important differences are described in Appendix C.

Since the questionnaire was created in Microsoft Excel and used some Microsoft-only features, the initial integration was done by reading in the different workbooks with responses using Microsoft Visual Basic. To ensure that all the questionnaires could be read in correctly, some checks were performed to verify that the structure of the questionnaire was not changed by the respondent, e.g. adding or moving rows and cells. If a questionnaire failed on a check, the structure was manually restored to the standard structure. These and all other changes were documented on a separate sheet in the workbook used for integration. When all the workbooks were in the original template, they were read in by Microsoft Visual Basic and an integrated dataset was created. This dataset was exported to a delimited text file, read into R, and written to a SQLite database. The further data cleaning and data analysis took place in this database.

Then some basic checks were performed. These checks include: (1) verifying whether the contents of the cells in which the years, the costs and the crash/casualty data had to be filled in were convertible to numeric values, (2) verifying whether the years fell into a logical range of years, (3) verifying whether the official abbreviation of the currency was used, (4) verifying whether percentages were in a reasonable range. Errors were corrected manually and all changes were documented.

4.2.2 Quality checks

The next step was to prepare the data for analysis. In this process particular quality checks were performed. On the basis of these checks edits were made to the original data. All main edits are listed in Appendix D. The quality checks include:

(1) Does the data fit into the seven standard severity categories?

(2) Is the data that is provided in the questionnaire complete?
(3) Is the data that is provided in the questionnaire internally consistent?

Standardization severity categories
The first quality check is to verify whether the data fits the seven standard categories provided by the questionnaire. On the level of casualties these are: (1) fatalities, (2) serious injuries and (3) slight injuries. On the level of crashes these are: (4) fatal crashes, (5) serious injury crashes, (6) slight injury crashes and (7) property damage only (PDO) crashes. The questionnaire allowed the definition of extra categories; for some countries these extra categories were used. In order to allow integration of the responses, information in the extra categories was merged with one of the standard categories.

In some cases, the extra categories didn't fit any standard category, and were mainly a repetition of costs described in other categories. These were not taken into account.
On the other hand there were also countries for which two standard severity categories were combined: this was mostly the case for serious and slight injuries. In that case the combined category was split into the standard categories by back-calculation using other elements in the questionnaire[24]. This resulted in accurate or estimated numbers. When there was not enough information to do a back-calculation (in the case of Lithuania), the combined category was maintained. Hence, when describing the cost per serious injury and the cost per slight injury, the values for Lithuania are set at "missing".

Data completeness
Secondly the completeness of the questionnaires was examined. For many questionnaires not all the values were filled in, and these values were completed when they could be calculated using data from other fields in the questionnaire. The variables for which such a calculation could be made are:
- The cost per unit, in each of the severity categories, could be calculated from the sum of the costs per component The cost per unit, in each of the severity categories, could be calculated by dividing the total costs per severity category by the respective number of casualties or crashes.
- The number of crashes or casualties could be calculated by dividing the total costs per severity category by their respective unit cost.
- The total costs, for each of the severity categories, could be calculated by multiplying the unit costs and the number of casualties or crashes.
- The grand total could be calculated by adding up the total costs in each of the severity categories.

The calculations were always done in original currency and original price level year.
Apart from using data from the questionnaires, we used the CARE database (European Road Accident Database) to add crash/casualty data for the countries where these were missing.

Internal consistency
Next, the internal consistency of the values filled in on the questionnaire was checked. In case of inconsistencies we either went back to the experts or to the original report, or the data was adjusted if that seemed to be the most logical decision. In the exceptional case the data showed very large inconsistencies, a different report with consistent data was used.

[24] For example: when the total costs and the number of crashes/casualties is only known for serious and slight injuries together, but the unit cost is available for serious and slight injuries individually, it is possible to calculate the total costs and number of crashes/casualties for serious and slight injuries separately by writing this problem as a set of two linear equations.

The following consistency checks were performed:

- Is the sum of the costs for all (relevant) cost components equal to the cost per unit? Here differences could be explained by the fact that cost components and unit costs were calculated using different data sources , were based on different years or were defined for different severity categories.
- Is the result of multiplying the unit costs with the number of crashes or casualties from the related severity category equal to the total costs for that severity category? Inconsistencies found could be explained by the fact that different years were used to calculate unit costs and total costs or because the unit costs and total costs were calculated in different studies.
- Is the sum of the total costs for each severity category equal to the grand total as given in the questionnaire? Here experts appeared to have used different elements to calculate the grand total. Different methods to calculate the grand total are (1) the sum of the total costs of casualties, (2) the sum of the total costs of crashes, (3) the sum of the total costs of casualties and the total costs of crashes, or (4) the sum of the total costs of casualties and the total costs of PDO crashes. This consistency check did not result in any changes.
- Is the percentage of GDP taken by the grand total correct? The percentage calculated (by using the same year as in which the costs were expressed) was compared with the percentage that was filled in by the expert. Although many deviations were found, the percentage as filled in by the expert was always close to the percentage calculated.
- Are the crash/casualty data and the costs expressed in the same year? For some countries this was not the case, here the unit costs was adjusted to the year of the crash/casualty data. The costs was adjusted for inflation only, using the GDP deflator. In the descriptive analysis mostly standardized or relative numbers are given, so this adjustment will only have an influence on the percentage of GDP, where the GDP for the adjusted year will be used. Updating the costs for inflation only is not ideal, as GDP will increase more than just for inflation (growth of volume of GDP), resulting in an under- or overestimation of the percentage of GDP (depending on whether the year of the costs is more or less recent than the year of the casualties/crashes). However, for most countries the difference is negligible since the adjustment covers only 1 to 3 years. Cyprus is an exception, as here the unit costs were updated from 2002 to 2015.

4.2.3 Descriptive statistics

In the next chapter the data will be summarized in descriptive tables and figures. To compare the costs across countries, all the cost data was standardized for inflation and Purchasing Power Parity (PPP)[25]. All the data was standardized to EUR 2015 to make economic parameters from different countries and different years comparable. First the costs were updated to the price level of 2015 in their national currency using GDP deflators retrieved from the Eurostat databank. Next, the costs in non-EUR countries were converted to EUR using the exchange rates for 2015 (source: Eurostat). Finally the costs were adjusted for purchasing power differences using price level indices for 2015 (source Eurostat).[26]

While most descriptive tables could easily be retrieved from the database, this was not the case for the distribution of the total costs over cost components. Since the cost components are, in most countries, only filled in per crash or per casualty and not for all crashes together, this figure required extra calculations. The costs per component was multiplied with the number of casualties or crashes for each severity category, and used the sum of these multiplications to give the distribution. For some countries some corrections had to be done. (1) When the crash-related costs are included in the cost components for casualties, the components for crashes are removed to avoid double

[25] Purchasing Power Parities are the rates of currency conversion that equalize the purchasing power of different currencies, they are price relatives that show the ratio of the prices in national currencies of the same good or service in different countries (EU/OECD,2012).

[26] Note that the combination of exchange rates and price level indices is equal to purchasing power parities (PPP), which are commonly used to make economic parameters comparable.

counting or, when the casualty-related costs are included in the components for crashes, the components for casualties are removed. (2) When the cost components of PDO crashes were not given, these were added under "other costs". (3) For some countries, the distribution of costs over cost components can only be given for unit costs and not for total costs because there is no separate crash/casualty data for serious and slight injuries. (4) For some countries the distribution over cost components is only given for total crashes, and not per severity category.

4.3 SUMMARY

In a joint effort with the InDeV project, an Excel based questionnaire was developed and distributed among EU countries to collect information on costs of road traffic crashes. Information was collected regarding costs per crash/casualty of different severity levels (fatal, serious injury, slight injury and property damage only), costs per cost component, total costs of crashes, numbers of crashes/casualties by severity level and the methods on which cost estimates were based. Questionnaires were prefilled by a responsible SafetyCube or InDeV partner on the basis of available cost information and then sent to experts in each country for a check and completion. After a first round of validation, we went back to the experts if necessary. No crash costs information could be obtained from Romania. In total, data from 31 European countries, out of the 32 involved in the study, were included in the descriptive analysis.

Within SafetyCube, the questionnaires were integrated into a SQLite database, the data was fit into standard severity categories and completed and the following consistency checks were carried out:

- The sum of the costs for all (relevant) cost components per casualty/crash should be equal to the total costs per crash/casualty for all severity levels
- The cost per crash/casualty per severity level multiplied with the number of crashes/casualties should be equal to the total costs per severity level
- The sum of the total costs for each severity category should be equal to the grand total as given in the questionnaire.
- The percentage of GDP reported by the expert should be equal to the percentage calculated by SafetyCube
- The crash/casualty data and the costs should be expressed in the same year.

In case of inconsistencies, either the experts or the original report was consulted, or the data were adjusted if that seemed to be the most logical decision. After the consistency checks, the data was standardized for currency, inflation and purchasing power parity (PPP) to create figures comparable between countries.

5 Costs of crashes in European countries: survey results

Reported costs per fatality vary between €0.7 million and €3.0 million. Costs per serious injury vary between €28,000 and €959,000 and costs per slight injury vary between €296 and €71,742. The total costs of crashes vary between 0.4% and 4.1% of the GDP. Variation in costs is mainly explained by methodological differences.

This Chapter discusses the costs of crashes in EU countries that were collected by means of the survey discussed in the previous chapter. Information on costs of crashes was available for all countries except Romania. All values are expressed in EUR price level 2015 and adjusted for relative income differences (see Chapter 4).

5.1 COSTS PER CASUALTY/CRASH

For the different severity categories, costs per casualty/crash are calculated and reported in Appendix E. A detailed discussion for different severity categories follows in the sections below.

5.1.1 Costs per fatality

The survey shows that the official estimates of costs per fatality range from €0.7 million in Slovakia to €3.0 million in Austria (Figure 5-1). In general, values per fatality appear to be higher in North-Western EU countries than in South and East Europe (Figure 5-2).

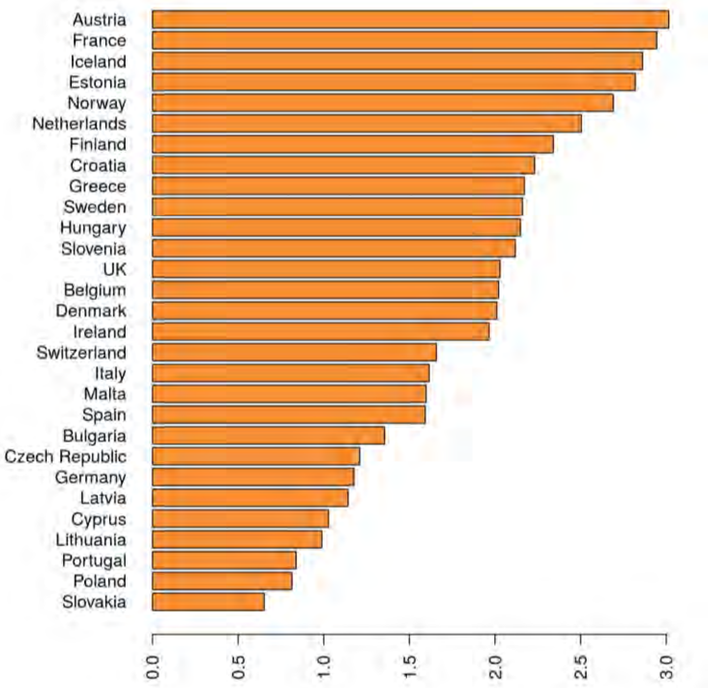

Figure 5-1 Costs per fatality (Million EUR 2015, adjusted for PPP)

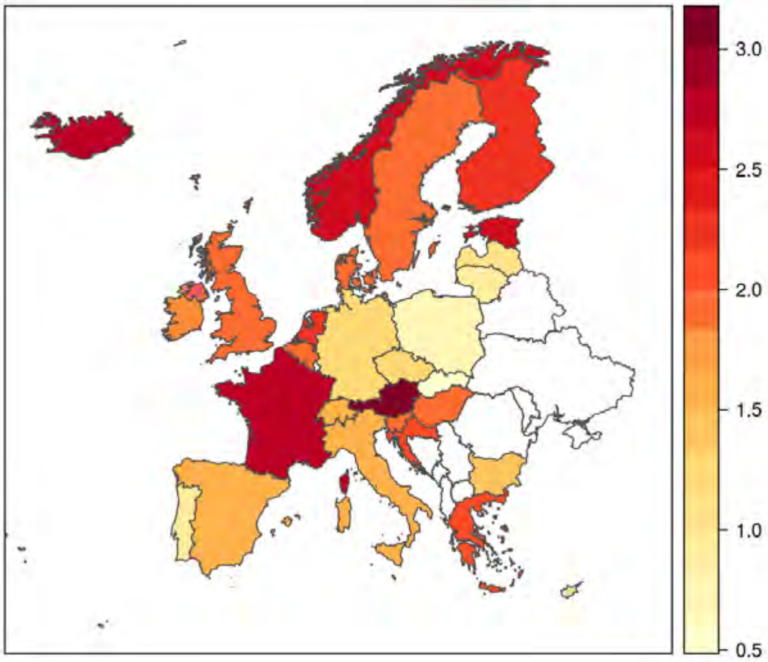

Figure 5-2 Costs per fatality (million EUR 2015)

There are three factors that could explain differences in costs per fatality:

- Differences in the definition of a road fatality.
- Differences in costs components which have been included.
- Methodological differences.

Regarding the definition of a road fatality, most countries apply the same definition based on the criterion that a casualty who dies within 30 days after the crash (and as a result of a crash) is regarded as a road fatality. Only Slovakia uses a criterion of 24 hours instead of 30 days.[27] Consequently, differences in definitions are not a main explanation for differences in costs per fatality.

Concerning cost components, Figure 5-3 (a 'heatmap') shows how many countries have included each cost component in the costs per casualty and crash by severity level. The red colour indicates that most countries have included a costs component while yellow indicates that few countries have included a costs 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 because several countries have strictly separated casualty related and crash related costs, by including 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.

[27] 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.

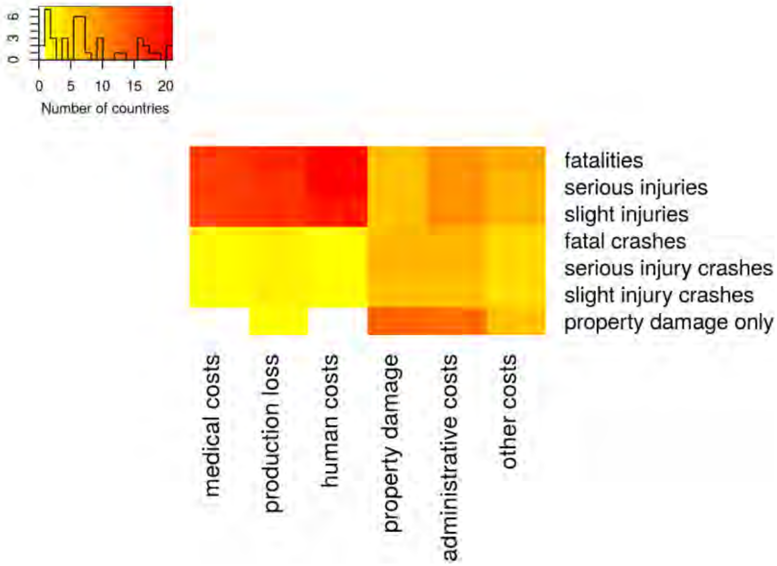

Figure 5-3 Heatmap of the number of countries which have included each cost component in costs per casualty and crash by severity level.

Figure 5-4 shows for each country the number of severity categories for which a separate value of each cost component is available. The maximum number of severity categories is seven: fatalities, serious injuries, slight injuries, fatal crashes, serious injury crashes, slight injuries crashes and property damage only (PDO) crashes. Note that the score for a country is better if a country calculates both costs per casualty and costs per crash. However, this does not necessarily mean that the quality (completeness) of the costs estimates is higher. Costs estimates can be regarded as complete if both casualty and crash related costs are included in either costs per casualty or costs per crash.

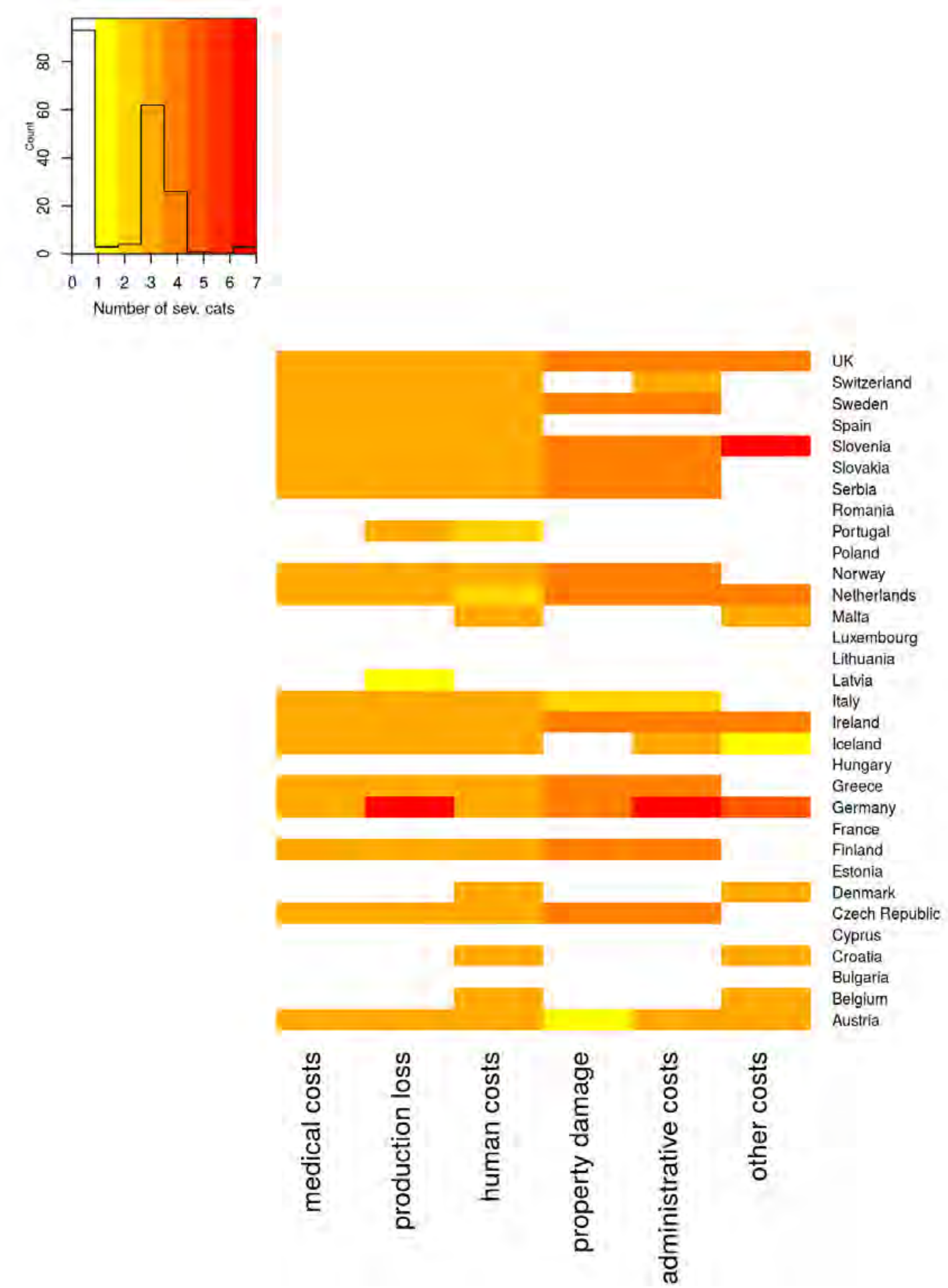

Figure 5-4 Heatmap of the cost components included in severity categories by country

Regarding differences in methods, the method used to estimate human costs of fatalities is most relevant for two reasons. Firstly, human costs have a major share in the costs per fatality in most countries, particularly countries using a WTP method (Figure 5-5).

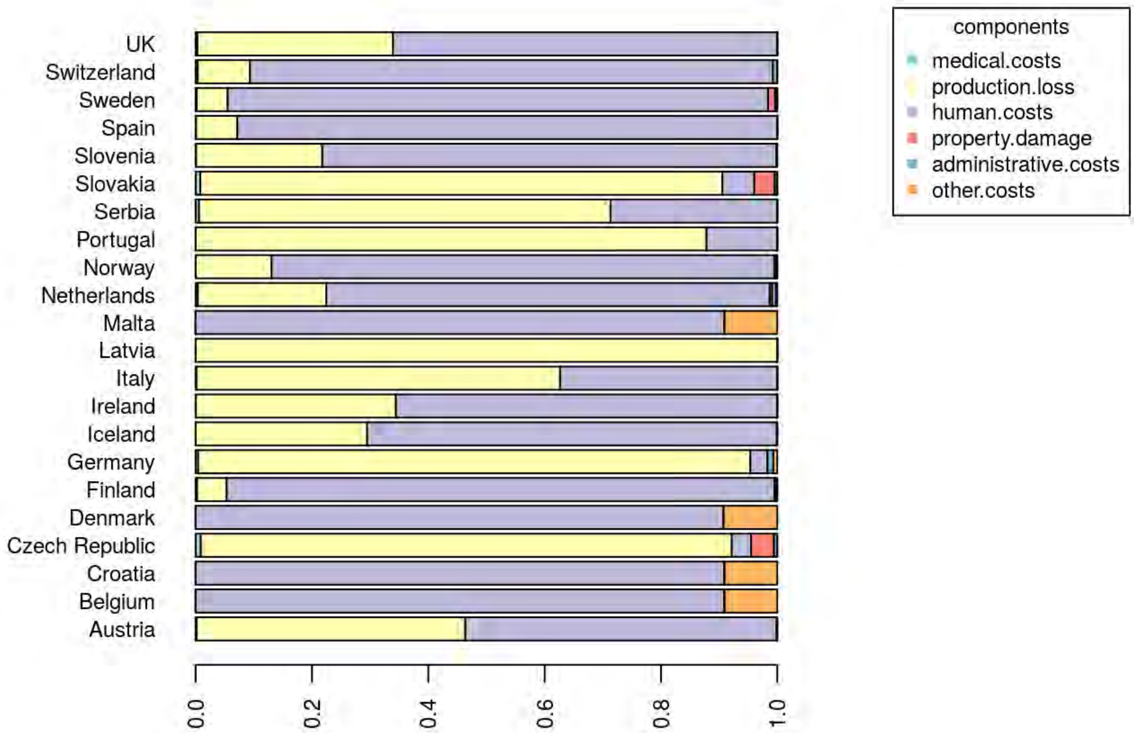

Figure 5-5 Share of cost components in costs per fatality. Only countries where costs per component are known are shown.

Figure 5-5clearly shows that the combination of human costs and within those production loss forms the bulk of the costs for fatalities. Consequently, human costs affect total costs per fatality to a large extent, as indicated by a strong positive relation between total costs per fatality and human costs per fatality (Figure 5-6).

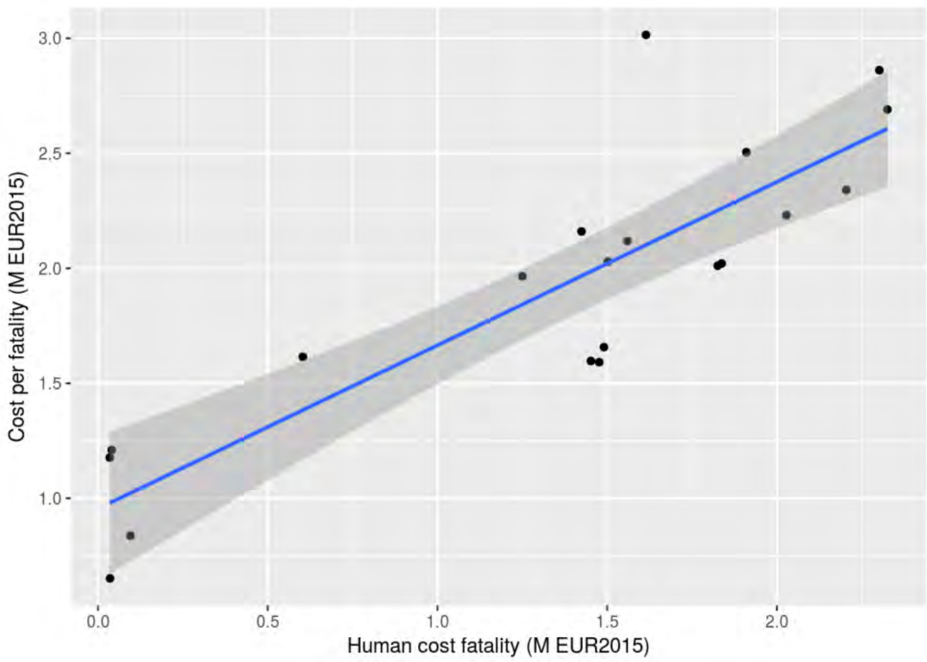

Figure 5-6 Relation between total costs per fatality and human costs per fatality

Secondly, the method for estimating human costs has been discussed intensively over the last decades, particularly regarding whether or not a willingness to pay method (WTP) should be applied (see for example Alfaro et al., 1994; Trawén et al., 2002; Wijnen & Stipdonk, 2016). This is reflected in the results of the survey: for estimating human costs different methods are applied across EU countries, while for all other cost components generally the same methods are used.[28]

Figure 5-7 shows which method is used by each country for human costs:

- Most countries (n=18) apply a WTP method
- Three countries use the human capital method (measuring loss of production and consumption)
- Two countries use 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).

Values based on a WTP method are much higher than values based on the compensation payments or the human capital approach, so total costs per fatality are much higher in WTP countries than in other countries as shown by Figure 5-8.

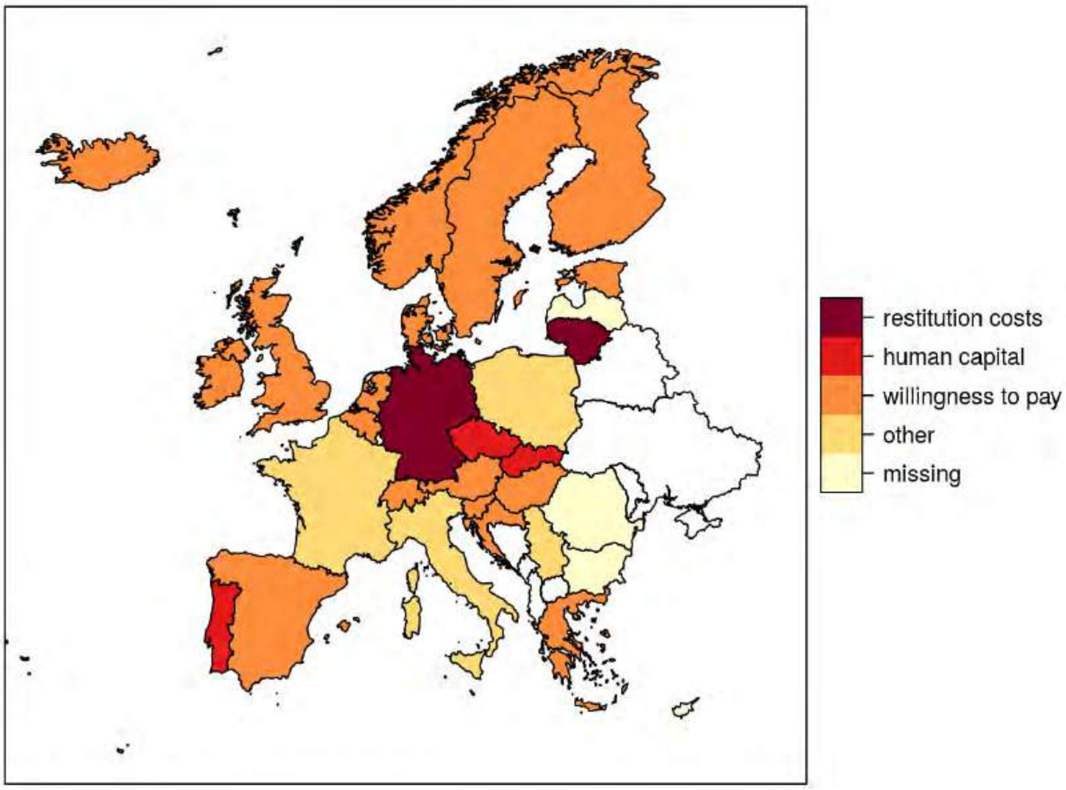

Figure 5-7 Methods used to estimate human costs of fatalities

[28] 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.

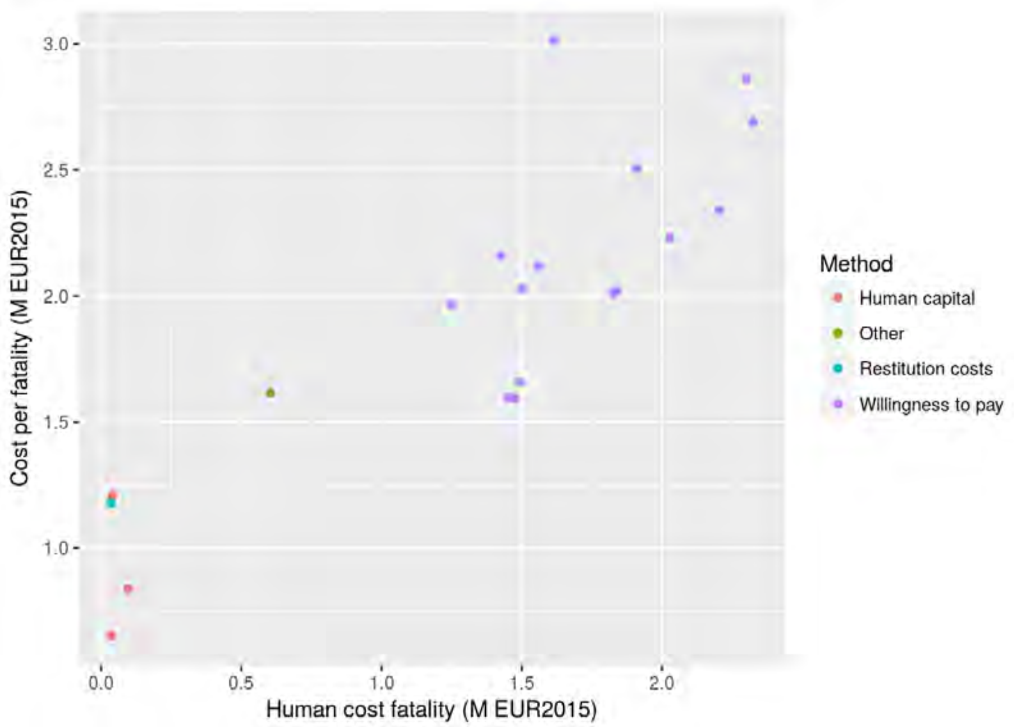

Figure 5-8 Relation between human costs per fatality, total costs per fatality and method for estimating human costs.

Regarding WTP values, four countries have estimates based on a national survey, while other countries (n=5) use standard EU-values (mostly taken from the HEATCO study, see Section 2.3.2) or a value taken from another country (n=2). The EU values (average €1.7 million) are slightly lower than the values based on a national survey (€1.8 million) and also lower than values taken from other countries (€2.3 million). It is surprising that values taken from other countries are higher than values based on a national survey. Presumably, the values taken from other countries are not applied by that country from which they are taken or they are taken from countries which are not represented in the survey. Another explanation could be that higher values from national surveys are more often used by other countries than lower values.

As noted above, for other cost components generally the same methods are used in all countries. Medical costs, property damage and administrative costs are typically estimated using the restitution costs approach, while the human capital approach is applied for calculating production loss. This is in line with the methods recommended in Chapter 3.

Summarizing, the analyses discussed in this section show that differences in costs per fatality between countries are mainly due to different methods being used for the calculation of human costs of fatalities. Countries that apply the WTP approach report higher costs per fatality than countries that apply the human capital approach or the restitution costs approach.

5.1.2 Costs per injured person

The costs of a serious injury range from 2.5% to 34.0% of the costs of a fatality (Figure 5-9).[29] Although this is a very wide range, about three quarters of the countries have a value between 10% and 20% of the value of fatality. This is probably explained by the fact that information on the human costs of serious injuries is very limited (see Section 3.1.3), so many countries relate the

[29] 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.

human costs of a serious injury to the human costs of a fatality, applying a percentage of the human costs of a fatality from the same sources such as the HEATCO project (see Section 2.3.2). Of course, the variation in the actual values per serious injury is still large because there is variation in the costs per fatality: costs per serious injury range from €28,000 in Latvia to €959,000 in Estonia.

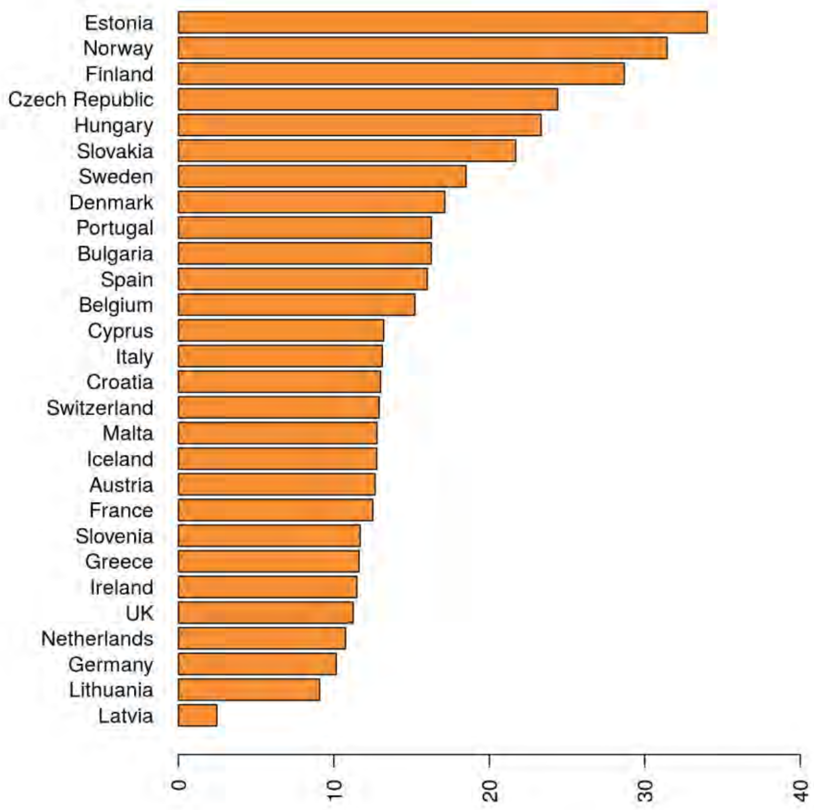

Figure 5-9 Costs per serious injury as a percentage of the costs per fatality (excluding Poland)

Costs of a slight injury show even more variation: these costs range from 0.03% to 4.2% of the costs of a fatality (Figure 5-10). The range of actual values is extremely wide: from €296 per slight injury in Latvia to €71,742 in Iceland.

A main explanation for the large variations in costs per serious and slight injury relates to differences in definitions of these injuries. The definitions of serious and slight injuries used for the costs estimates are very diverse: several countries use a criterion based on hospital admission (at least 24 or 48 hours for serious injuries) while in other countries the definition is based on the type and severity of the injuries. Also the duration of inability to work and whether or not disability payments are paid by insurance companies are used in some countries. Appendix E gives an overview of the costs per serious and slight injury and of the definitions of a serious injury applied (slight injuries are usually defined as all other injuries).

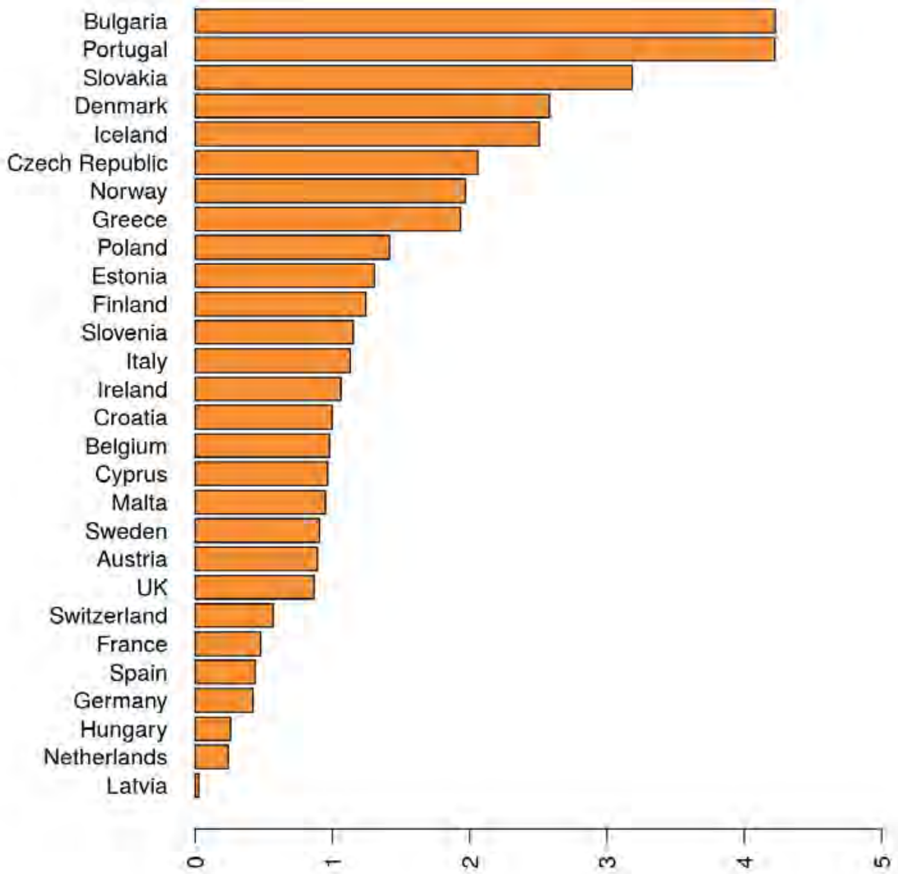

Figure 5-10 Costs per slight injury as a percentage of the costs per fatality

The reporting rate (by the police or hospitals) of injuries may also 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. Figure 5-11 illustrates this for serious injuries: a lower number of serious injuries relative to the number of fatalities is accompanied by relatively higher costs of a serious injury.[30] This might be explained by differences in underreporting: a relatively lower number of serious injuries may reflect more underreporting of less severe injuries, resulting in relatively higher costs per serious injury.

[30] 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.

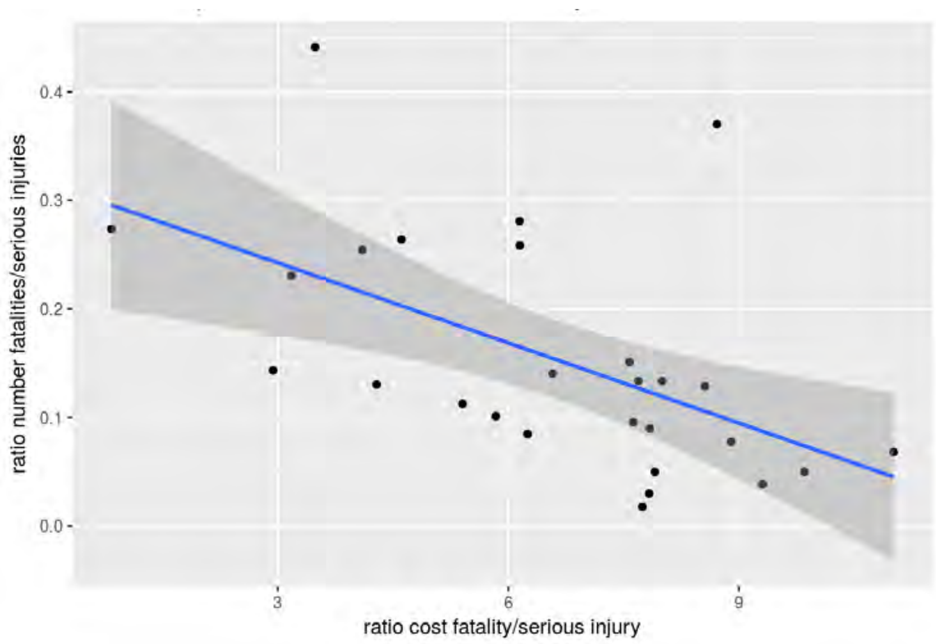

Figure 5-11 Relation between the ratio of number of fatalities and serious injuries and the ratio of costs per fatality and costs per serious injury

In addition to differences in definitions and registration rate, 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 5-3). Regarding methods, the main difference concerns the estimation of human costs (WTP or other methods), as discussed above for fatalities. Several countries have indicated that human costs of serious and slight injuries are determined as a percentage of the human costs of fatalities, but the questionnaire did not reveal detailed information on this issue.

5.1.3 Costs per crash

Most countries have information on costs per casualty but not necessarily on costs per crash: data on costs per fatal, serious injury or slight injury crash were provided by 12 countries, while information on costs per PDO crash was only available in nine countries. Estimating costs per crash requires information on the number of casualties per crash by severity level, for example the number of fatalities, serious injuries and slight injuries per fatal crash, which is apparently not available in most countries.

Costs per fatal crash range from €12,000 to €3.9 million. This very wide range variation is mainly explained by differences in costs components which are included: some countries only include crash related costs (property damage and administrative costs) while other countries also include casualty related costs (medical costs, production loss and human costs). Consequently, in several countries costs per crash are (much) lower than costs per casualty because casualty related costs are not included (Figure 5-12). Differences in countries which include casualty related costs are mainly explained by the differences in the method used to estimate human costs, as discussed in Section 5.1.1.

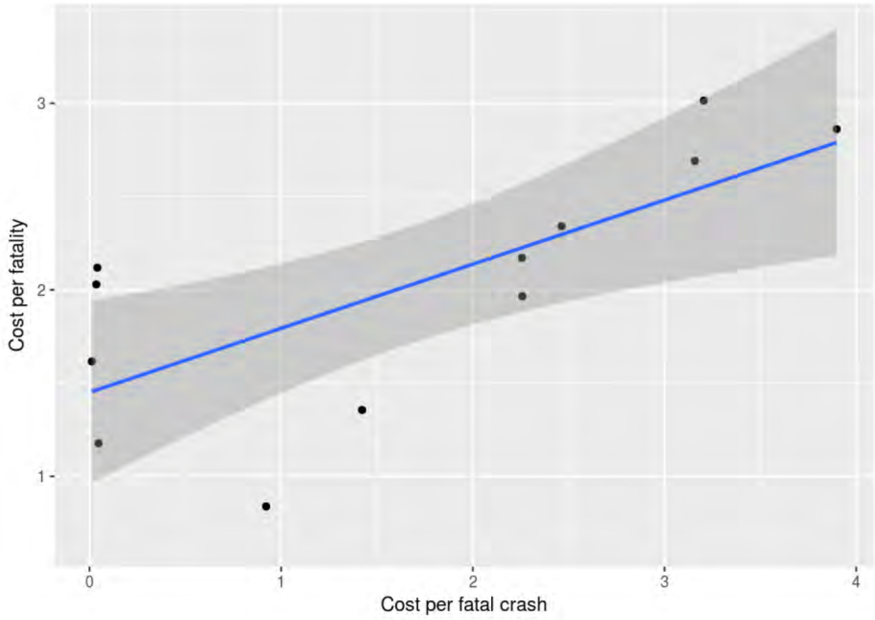

Figure 5-12 Relation between costs of fatality and cost of fatal crash

The costs per serious injury crash range from 11% to 46% of the costs of a fatal crash (Figure 5-13) and costs per slight injury crash from 1% to 34% of a fatal crash (Figure 5-14).[31] The actual values per serious injury crashes range from €12,020 (Italy) to €945,576 (Norway) and for slight injury crashes this range is €7,843 (Serbia) to €179,650 (Iceland).

Similar to fatalities, the wide ranges are explained by differences in cost components included, as discussed above. In addition, the costs per slight or serious injury crash show more variation than costs per seriously respectively slightly injured casualty, because human costs have less influence on costs per crash (if included at all). As discussed in Section 5.1.2, costs per casualty are dominated by human costs for which many countries use the same sources.

[31] A fatal crash is usually defined as a crash with at least one fatality, a serious injury crash as a crash with at least one serious injury but no fatality and a slight injury crash as a crash with at least one slight injury but no fatality or serious injury.

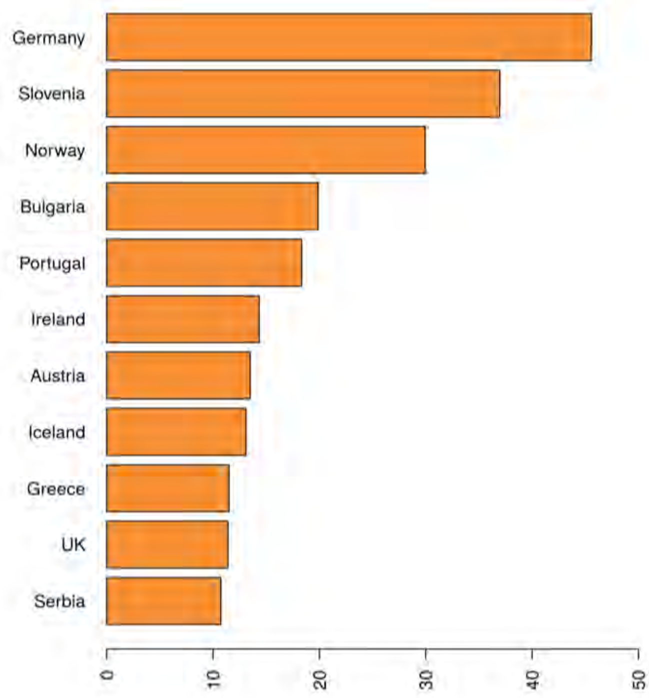

Figure 5-13 Cost of a serious injury crash as a percentage of the costs of a fatal crash

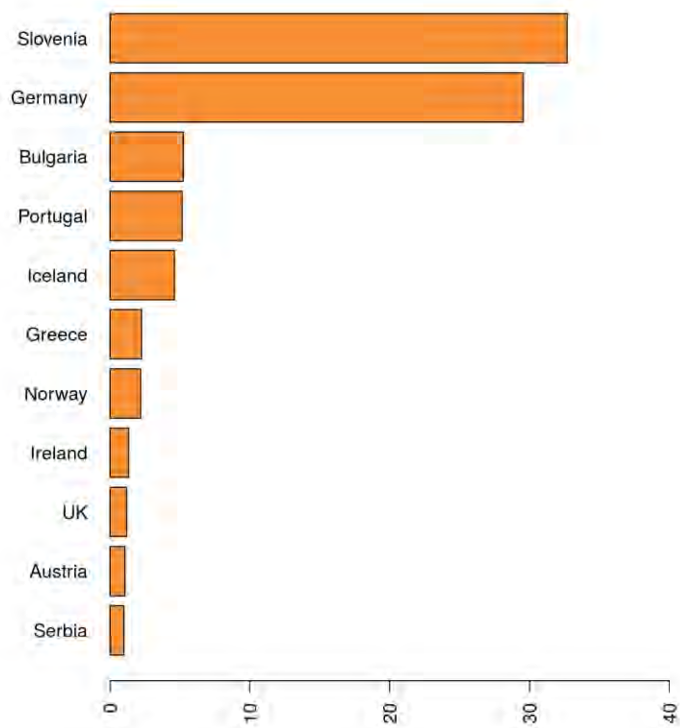

Figure 5-14 Cost of a slight injury crash as a percentage of the costs of a fatal crash

Costs per PDO crash range from €1,276 to €16,905 (Figure 5-15). Variation in these costs probably relates to differences in reporting rates and possibly differences in methods and data sources used, but the survey did not reveal detailed information on this issue.

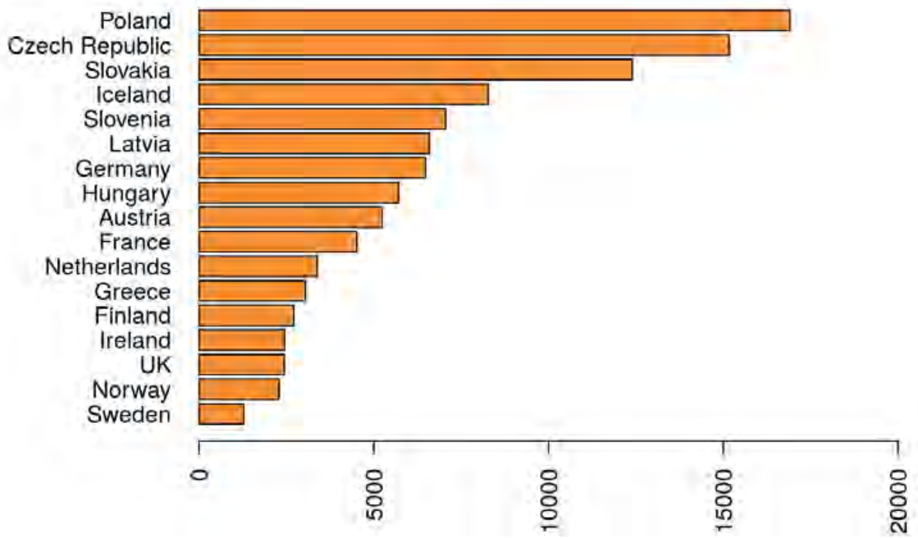

Figure 5-15 Costs per PDO crash (EUR)

5.2 TOTAL COSTS OF CRASHES

The total costs of all road crashes are related to the size of and the number of inhabitants in a country and motorization rate, because these factors affect the total number of kilometres travelled and (thus) the number of road casualties. To correct for these factors, it is common practice to relate the costs of crashes to the Gross Domestic Product (GDP) of a country (Wijnen & Stipdonk, 2016; Elvik, 2000).

Figure 5-16 presents the total costs of road crashes as a percentage of GDP. These percentages are calculated on the basis of the survey results (total costs) and GDP (source: Eurostat), see Chapter 4. This shows that the costs range from 0.4% in Ireland to 4.1% in Latvia. There is no clear geographical pattern, as shown by Figure 5-17.

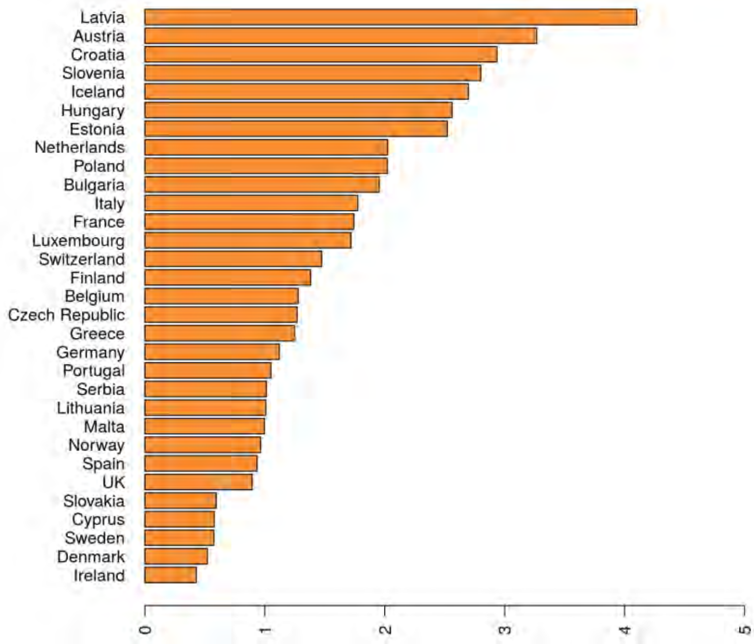

Figure 5-16 Total costs of road crashes as percentage of GDP

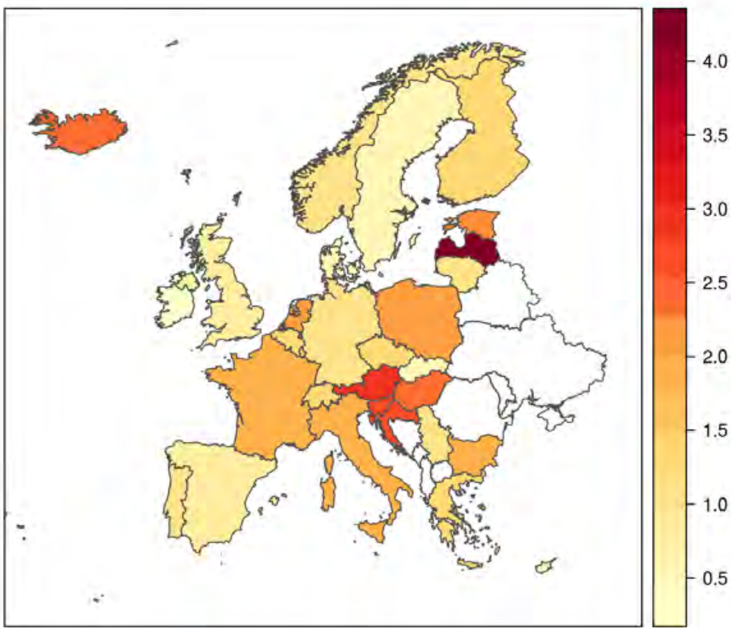

Figure 5-17 Total costs of road crashes as percentage of GDP

There are several explanations for the large variation in total costs as a percentage of GDP, that are explored further in the remainder of this section. Firstly, cost variations may reflect differences in road safety levels, indicated for example by the mortality rate or number of serious injuries per inhabitant. Secondly, differences in the methodology that is applied to calculate total costs can explain variation in costs, in particular:

- The extent to which all severity levels, including property damage only crashes, have been included in total costs.
- The extent to which a correction is made for underreporting.

In addition, differences in the costs per casualty or crash which are explained by methodological differences, as discussed in Section 5.1, also influence total costs. Below we discuss each of these possible explanations.

Road safety level

Evidently, a better road safety performance, in terms of road fatality rate per million inhabitants, should in principle result in lower road crash costs. However, Figure 5-18 shows that there is only a weak positive relation between mortality rate and costs as a percentage of GDP (statistically significant at the 10% confidence level). This indicates that factors other than road safety performance largely explain differences in cost levels.

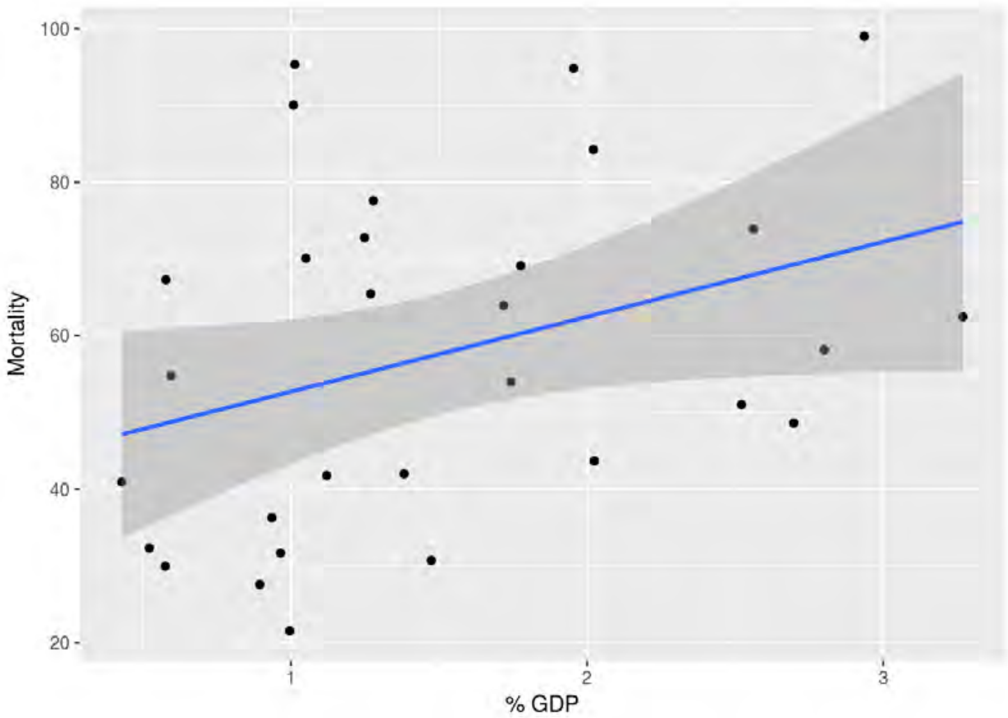

Figure 5-18 Relation between mortality rate (number of fatalities per million inhabitants) and costs of road crashes as percentage of GDP

Severity levels

All countries include fatalities, serious injuries and slight injuries in the estimate of total costs, but PDO crashes are not always included. Figure 5-19 shows that 12 out of 29 countries have not included PDO crashes (for two countries there is no information). This includes both countries with high costs (as a percentage of GDP) and relatively low costs. Exclusion of PDO crashes can result in considerable underestimation of total costs. Figure 5-20 shows that in the majority of countries which have included PDO crashes, these crashes have a share of more than 20 percent in total costs, up to even about 50% in Germany and Finland. Exceptions are Ireland, Poland and Sweden, where PDO crashes have a share smaller than 10% in total costs.

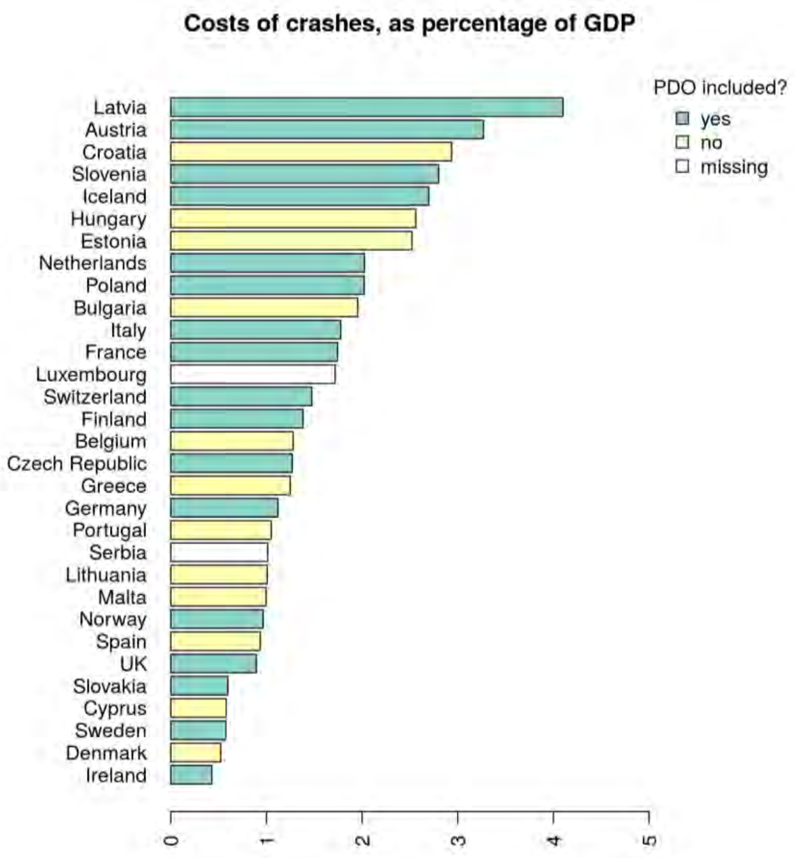

Figure 5-19 Cost of road crashes as a percentage of GDP and inclusion of PDO crashes

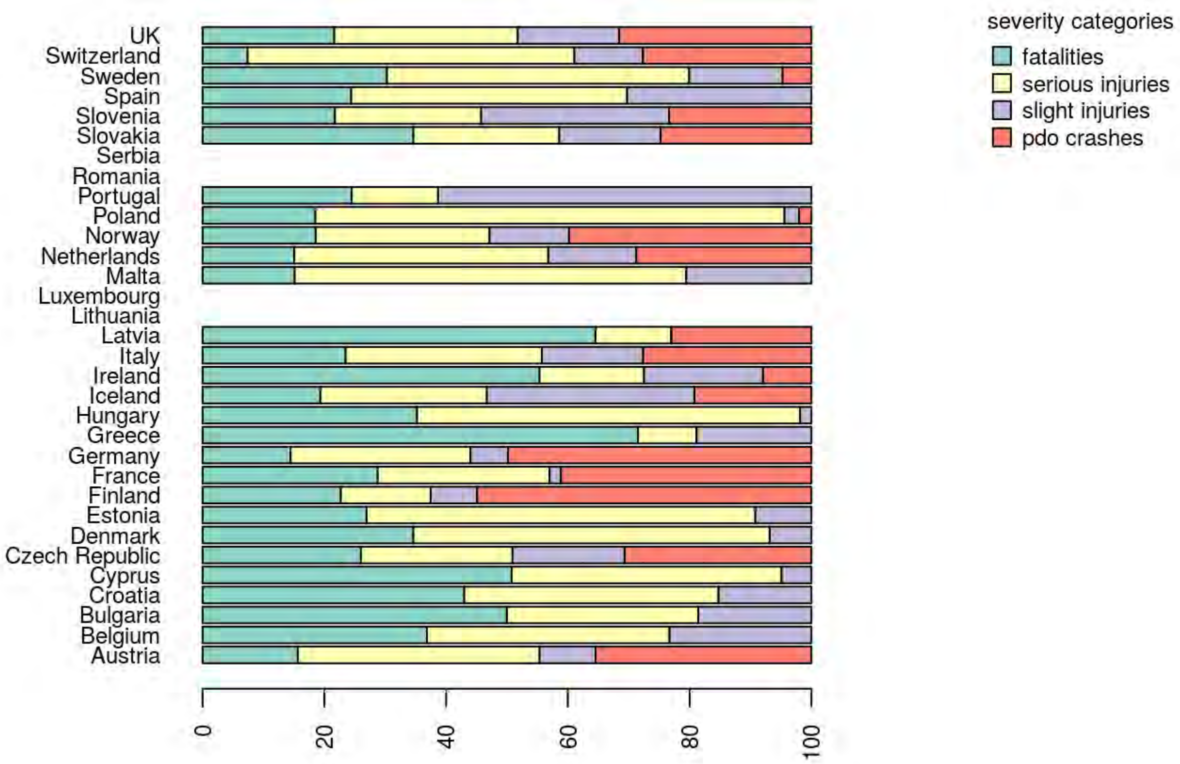

Figure 5-20 Share of fatalities, serious and slight injuries and PDO crashes in total costs

Figure 5-20 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. We should also note that the distribution of costs over severity levels differs considerably between countries, even between countries that included all severity levels. When we select countries that have information on all severity levels, we see that fatalities account for 7.4% to 55% of all 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%.Possible explanations for this variation include differences in definitions of severity levels and in reporting rates.

Underreporting
The survey reveals that only a few countries make a correction for underreporting of casualties or crashes in their cost estimates, see Figure 5-21. Consequently, this implies that costs are underestimated in many countries. Although information on the reporting rates is available in some of these countries, this information is not used in cost estimates. This might be explained by the fact that the available information on costs per casualty or crash cannot easily be applied to non-reported casualties/crashes if these casualties/crashes are less severe (as discussed in Section 5.1.2).

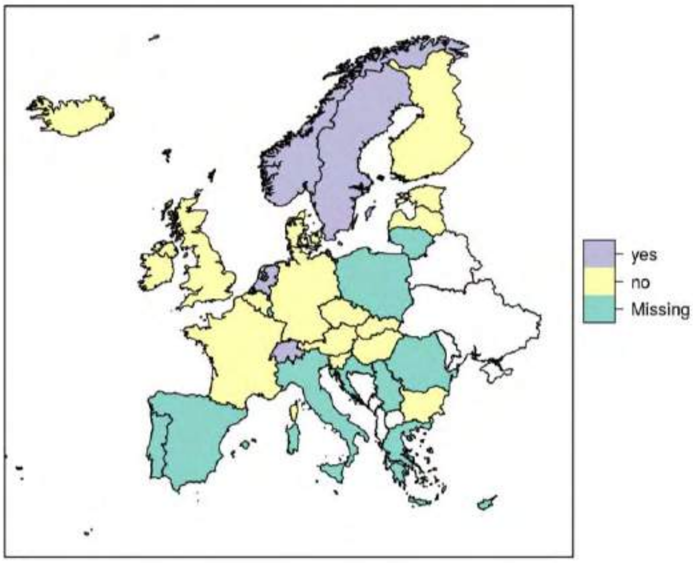

Figure 5-21 Countries which do or do not correct for underreporting in cost calculations

5.2.1 Costs by cost component

Figure 5-22 and Figure 5-23 show the share of the six main cost components in the total costs, for countries using a WTP method and countries which do not use a WTP method respectively. This shows that if costs are based on a WTP approach, human costs have a major share in total costs; these range from 34% in Finland to 91% in Croatia. Note that for some countries this percentage is relatively large because other cost components are not included or only partially included. This applies particularly to countries which have used the HEATCO approach, implying that all costs other than human costs and consumption loss are estimated at 10% of the value of a statistical life (see Section 3.2.3). In other countries human costs still have a large share in total costs, typically around 50% or more. Other methods than WTP, such as the human capital approach or restitution costs (compensation payments) approach, result in much lower values of human costs per casualty, which is reflected in a particularly small share of human costs in total costs (less than 10%).

Consequently, the choice of whether or not to use a WTP method affects the cost figures to a large extent.

Besides human costs, property damage and production losses are major cost components in most countries, while medical costs and administrative costs are relatively low.

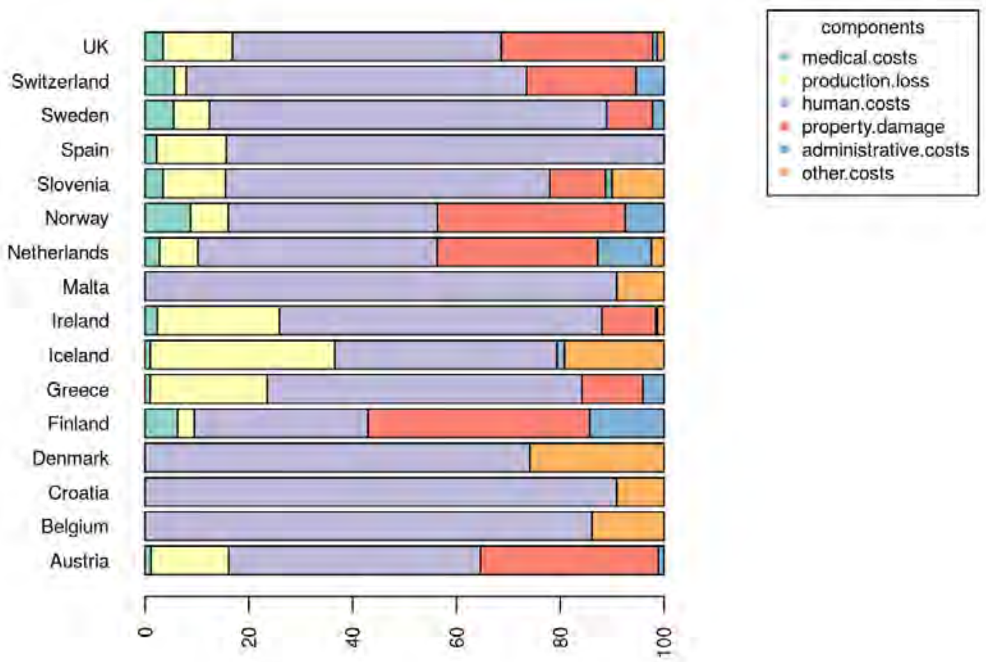

Figure 5-22 Share of costs components in total costs for WTP countries

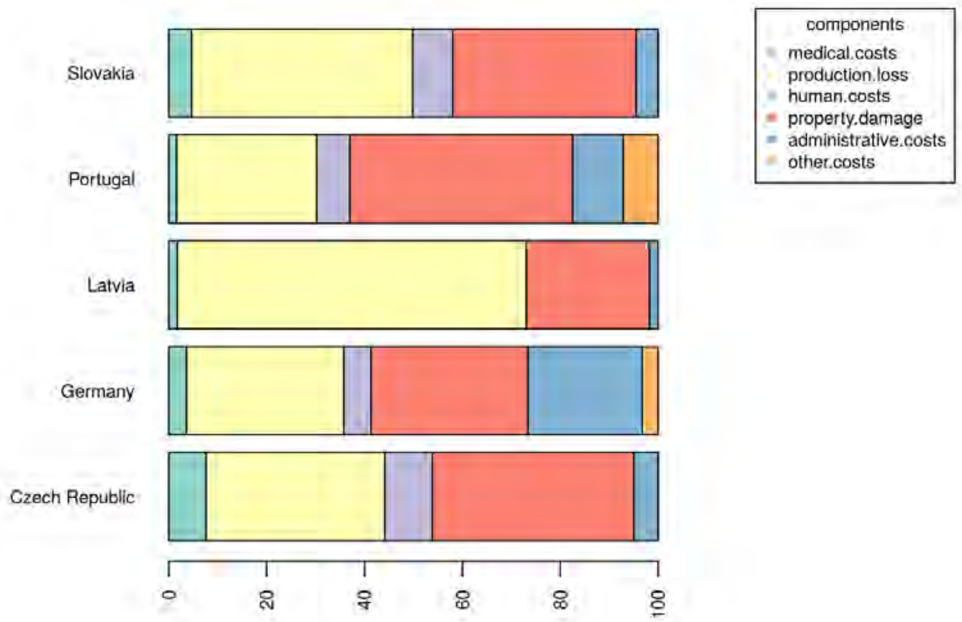

Figure 5-23 Share of costs components in total costs for non-WTP countries

A higher human cost value in WTP-countries does not automatically result in higher total costs as a percentage of GDP, as shown by Figure 5-24.

In several countries using other methods than WTP, total costs as percentage of GDP are higher than in WTP-countries. This implies that other factors, such as road safety level and the extent to which underreporting is taken into account, also affect total costs.

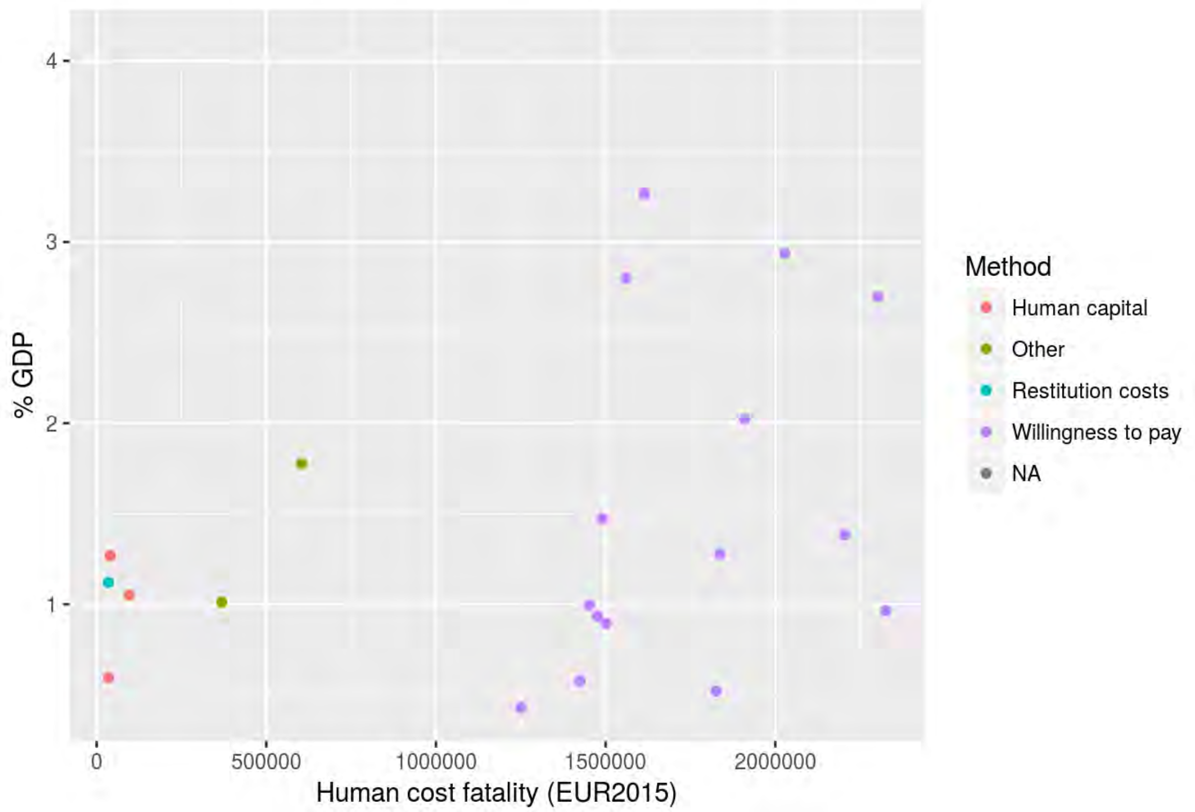

Figure 5-24 Human cost per fatality versus total costs as percentage of GDP, by method for estimating human costs

5.3 ADDITIONAL STATISTICAL ANALYSES

The integrated data presents a unique opportunity for analysis. In this section a preliminary initial attempt is presented. The original idea was to perform two types of analysis: cluster analysis, to define groups of similar countries, and a regression analysis, to allow prediction of one variable from another and a better understanding of the sources of variation in the data. Both of these types of analysis would ultimately serve to inform the value transfer exercise, which is presented in Chapter 6. Unfortunately, none of our first analyses led to conclusions that were immediately applicable to the value transfer.

All statistical calculations were done in R; no special 'packages' were loaded, only base R was used for the analyses presented here.

5.3.1 Clustering

Several clustering algorithms were applied, to different extracts of the dataset. The hope was that this would result in a grouping of countries, and that value transfer might be done between countries of the same group, thus increasing the precision of the estimates for value transfer. Data analysed were:

- Number of components included in the cost calculations. This was seen as a proxy of the completeness of cost categories included in the cost calculations
- Actual components included in the costs calculations.

Clustering based on number of components included

In an initial approach, countries were characterized by the number of components that are included in the calculation of the cost of crashes. This information was extracted from Questionnaire sheet 'Methods' (see Appendix B), and simply calculated as the number of categories that were ticked on. This count was explored as a simple proxy for the amount of detail that countries used in the cost calculations.

Both a kmeans clustering algorithm and a hierarchical method were applied. In a kmeans clustering, the number of groups, usually denoted as 'k', resulting from the analysis must be specified. In order to make a rational choice of k, the analysis was perfomed for a series of values of k, and for each of these the variability explained by the grouping was calculated. The bar graph in Figure 5-25 shows the amount of variability remaining for each value of k. Apart from the big drop going from one to two groups, the remaining variability decreases only very slowly. This led to the conclusion that there are two 'natural' groups of countries in the dataset.

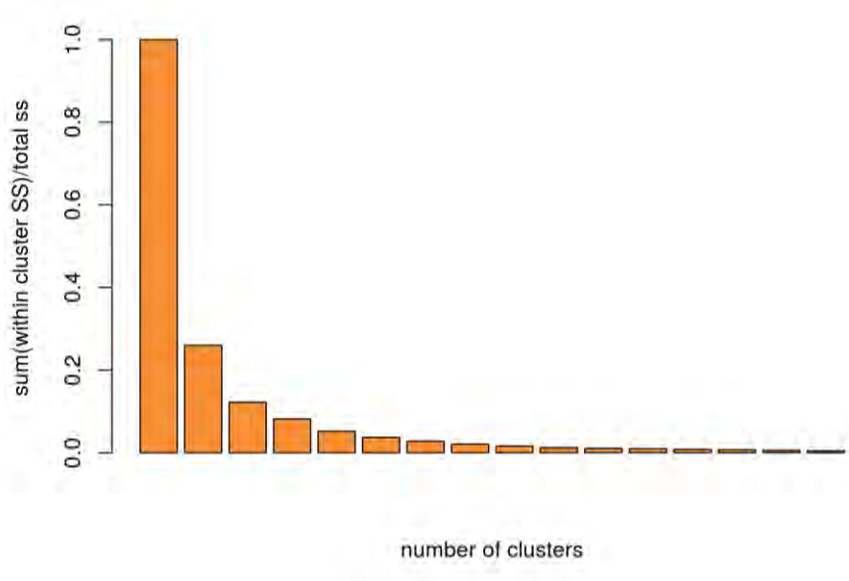

Figure 5-25 Variability remaining after clustering, for different numbers of clusters k

This was confirmed in a hierarchical cluster analysis. Figure 5-26 shows a dendrogram, a tree representation of the relatedness between different countries. In the tree, two clearly separated groups of countries can be seen. Distance measure was "manahattan", linking method "Ward".

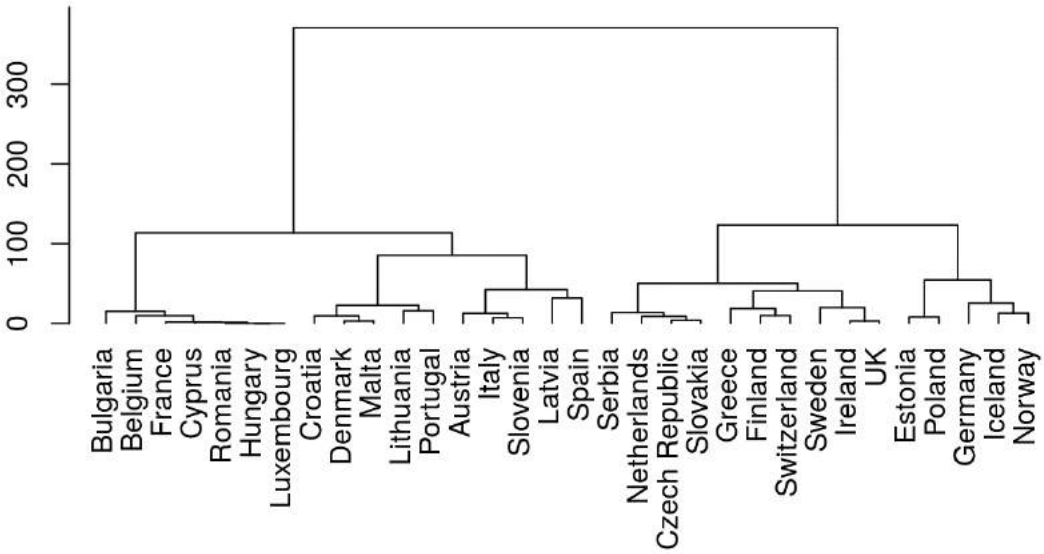

Figure 5-26 Dendrogram of a cluster analysis on the number of components included in cost calculations

Clustering on actual components included

A similar analysis was done on the actual components included, aimed at finding clusters of countries that included the same costs components: each of the flags indicating whether a component was included was taken as a separate binary variable. The results here were inconclusive; no clear-cut groups were identified. No attempt was made to include groups identified here in further analysis.

Deeper analysis, using more and different methods is possible, but it is unlikely that any will result in the same clear separation we found in the analysis based on the number of components.

5.3.2 Regression analysis

Next, a regression analysis was performed to check the predictive value of various variables extracted directly from the questionnaires, and of the cluster membership as calculated in the previous section. In all cases, total cost of crashes as percentage of GDP (further down referred to as %GDP) was used as the sole dependent variable. A series of regression models were built, using different sets of predictor variables, trying to predict either %GDP or its logarithm; in all cases, only simple linear regression was tried (function 'lm()' of base R). Predictor variables used were:

- cluster membership as calculated from Section 5.3.1
- mortality (fatalities as a fraction of population of the country)
- value of the human cost component of a fatality
- whether or not the Willingness to Pay approach was used to estimate this human cost
- number of components included in the cost calculations (same as used for cluster analysis).

Co-linearity of the different predictor variables, and univariate correlation between %GDP, log(%GDP) and individual predictor variables are shown in the correlation matrix (Table 5-1).

	%GDP	log(%GDP)	Cluster membership	Mortality	Human costs fatality	Use WTP
%GDP	1.0000000	0.9553858	0.2244863	0.5943483	0.3427241	-0.0124144
log(%GDP)	0.9553858	1.0000000	0.1579001	0.4851175	0.2897940	-0.0216475
Cluster membership	0.2244863	0.1579001	1.0000000	0.3189727	0.0956112	-0.0168550
Mortality	0.5943483	0.4851175	0.3189727	1.0000000	-0.2797694	-0.4465816
Human costs fatality	0.3427241	0.2897940	0.0956112	-0.2797694	1.0000000	0.9172351
Use WTP	-0.0124144	-0.0216475	-0.0168550	-0.4465816	0.9172351	1.0000000

Table 5-1 Correlation matrix

None of the combinations tried resulted in a very strong correlation; adjusted R square for each of the models is shown in Table 5-2. The strongest correlation was found by predicting %GDP from the predictor variables mortality and human cost of a fatality (HCfat). The p value was 0.00904, showing that the relationship is highly significant. However, the adjusted R^2 of 0.3414 indicates that only just over 34% of the variability of %GDP can be explained by the predictor variables.

Model	**%GDP**	**log(%GDP)**
cluster+mortality+HCfat	0.3176251	0.2589255
cluster+mortality+HCfat+WTP	0.2750333	0.2332314
mortality+HCfat	0.3413103	0.2917941
mortality+HCfat+WTP	0.3033586	0.2614959

Table 5-2: Adjusted R^2 for each of the four combinations of predictor variables tested, with %GDP and log-transformed GDP

Since the inclusion of cluster membership does not have a strong effect on the predictive strength of the model (actually makes the strength of the association decrease slightly), cluster membership was not used to refine the value transfer calculations.

5.4 SUMMARY

This chapter discusses the costs reported in the survey. Reported costs per fatality vary between €0.7 million and €3.0 million and tend to be higher in North-West Europe than in South and East Europe. Reported costs per serious injury range from €28,000 to €959,000 and are between 10% and 20% of the costs per fatality for about three quarters of the countries. Costs per slight injury vary between €296 and €71,742, or between 0.03% and 4.2% of the costs of a fatality. Differences in costs per fatality are mainly due to whether or not the willingness to pay (WTP) method is applied for the calculation of human costs. Differences in costs per injury are also due to this and other methodological differences, as well as differences in cost components that are taken into account, differences in definitions of a serious and slight injury and differences in levels of underreporting.

The total costs of crashes vary between 0.4% and 4.1% of the Gross Domestic Product (GDP). There is no clear geographical pattern. Although a better road safety performance should in principle result in lower road crash costs, there is only a weak positive relation between mortality rate and costs as a percentage of GDP. Differences between countries are also due to methodological differences, for instance, whether the WTP method is applied for the calculation of human costs. Moreover, exclusion of PDO crashes and/or other severity levels and not-correcting for underreporting can result in an underestimation of total costs of crashes.

Regarding the distribution of costs over casualties/crashes of different severity levels, in general injuries appear to have a large share in total costs: the share of injuries is on average 2.4 times higher than the share of fatalities in total costs. However, the results appear to differ substantially between countries. For countries that included all severity levels, fatalities account for 7% to 55% of the costs, serious injuries account for 14% to 77%, slight injuries account for 2% to 34% and PDO crashes account for 2% to 55%. Possible explanations for this variation include differences in definitions of severity levels and in reporting rates.

Looking at the different cost components, the survey shows that for countries that use the WTP approach, human costs have a major share (34% to 91%) in the total costs of crashes. For countries that apply another method for the calculation of human costs, the share of human costs in the total costs is much smaller (less than 10%). Besides human costs, property damage and production losses are major cost components in most countries, while medical costs and administrative costs are relatively low.

6 Crash cost estimates for EU

This Chapter provides comparable cost estimates for all EU countries as well as a cost estimate for the EU in total. The cost estimates are based on the value transfer method. This means that crash cost values from countries whose estimates are consistent with international guidelines are applied to countries that do not have figures consistent with the guidelines or have no figures at all for some costs components.

The previous chapters discussed the results of the survey. Crash cost estimates appeared to differ between countries and these differences are partly due to differences in methodology and differences in crash types and cost components being included. Moreover, for some countries no information was provided or only limited information was available.

In the SafetyCube project, estimates of missing cost components are made, as well as new estimates for costs components which have not been calculated with internationally recommended methods. Hereto we use the 'value transfer' approach, which is explained in Section 6.1. Section 6.2 presents standard values per cost component and casualty/crash type. Section 6.3 subsequently presents an example of the application of these values to Austria. Finally, section 6.4, provides comparable estimates for all EU countries as well as the EU in total. In case the survey also provided information on the costs of crashes in a specific country, we show both the costs that result from the survey and the cost estimates resulting from the value transfer method.

By applying the value transfer method, costs of crashes and results of cost-benefit analyses will be more comparable across countries. For example, if the value per casualty is lower in a certain country because human costs are not calculated on the basis of a WTP method, this would mean that the benefit-cost ratio is lower compared to WTP-countries. In principle this could lead to a lower level of road safety investments in non-WTP countries compared to WTP countries. Using comparable figures based on value transfer avoids this problem to some extent.

6.1 VALUE TRANSFER

The 'value transfer' (or 'benefit transfer') approach in general means that the results of primary valuation studies are used to estimate values in another context (Freeman, 2014). In this case, it means that road crash cost values from countries whose estimates are consistent with international guidelines are applied to countries which do not have figures consistent with the guidelines or do not have these estimates at all.

The value transfer method is applied to:

- Estimate missing cost components.
- Estimate cost components which are not based on the methods recommended in international guidelines.
- Estimate missing numbers of casualties/crashes.
- Estimate cost per crash if only costs per casualty are available and vice versa.
- Estimate costs in countries which have no estimates for costs per casualty or crash (fatal, serious injury and/or slight injury) at all.

The method uses a bottom-up approach. Firstly, cost components within a country are completed. If estimates of a specific cost component are only available per casualty or per crash, the missing values are estimated using the available values per casualty or per crash for the particular country. Secondly, missing cost components are added per country, using cost estimates for this particular component from other countries. The same applies to cost components which are not based on the methods recommended in international guidelines: alternative values are determined using values from countries which have used the recommended methods. Thirdly, total (unit) costs per casualty or per crash are calculated by summing the cost components. Finally, total costs are calculated by multiplying the costs per casualty by the number of casualties or crashes. These different steps are explained in more detail below.

The general approach is that the median (PPP-adjusted, see Section 4.2.3) value per casualty (fatality, serious injury, slight injury) and per crash (fatal crash, serious injury crash, slight injury crash, PDO crash) for a specific cost component is determined for a group of countries that use the recommended methods and have included the cost items which are categorized as 'main' cost items in Chapter 3. This median value is used for countries which have not used the recommended method or have no estimate of this cost component at all. Medians are used instead of means because means can be heavily influenced by extreme values.

To complete the cost components within a country, missing cost components per crash or per casualty are estimated by applying a conversion rate to the available estimates per casualty or per crash of the particular country. This conversion rate is based on information on the number of casualties per crash. Within the countries represented in the SafetyCube project team, this information is only available for Norway and Greece. Table 6-1 shows that the number of casualties per crash is not very different in these two countries, although the road safety situation in these two countries is quite different. Therefore, we assume that the number of casualties per crash in Norway and Greece are representative for other European countries. We use the average number of casualties per crash in these two countries as default values for all countries.

		Fatalities	Serious injuries	Slight injuries
Fatal crash	Greece	1.12	0.19	0.47
	Norway	1.08	0.24	0.40
	average	*1.10*	*0.22*	*0.43*
Serious injury crash	Greece	-	1.11	0.43
	Norway		1.10	0.45
	average	-	*1.11*	*0.44*
Slight injury crash	Greece	-	-	1.33
	Norway	-	-	1.40
	average	-	-	*1.36*

Table 6-1 Number of casualties per crash by severity level in Greece and Norway

The standard value for missing cost components (or for cost components that are not estimated using the recommended method) is determined by the median value of the respective cost components of countries that use the recommended method. Below the value transfer approach for each cost component is described.

Medical costs
If medical costs per fatality, serious injury or slight injury are missing, these costs are estimated on the basis of medical costs in ten countries which have included all main medical cost items (all items except medicines and appliances) in their estimates.[32] All countries have used the recommended restitution costs method, so all available medical costs estimates are used for the value transfer.

Production loss
If production loss is missing, the median value from all other countries is used for the value transfer. Thirteen countries have included market production loss on the basis of the recommended human capital approach. Therefore value transfer is not needed from the perspective of methods. An issue here is the question of whether gross (including consumption loss) or net (excluding consumption loss) production loss is calculated. As explained in Chapter 3, the VOSL also includes consumption loss (besides human costs). If consumption loss is deducted from the VOSL (resulting in human costs), gross production loss should be used. If not, net production loss should be calculated to avoid double counting of consumption loss. We assume that all countries have applied this correctly, as this cannot be checked on the basis of the questionnaire data.

Human costs
According to international guidelines, human costs of fatalities and injuries should be based on a WTP method. The median cost was calculated for each of the severity categories, for the 16 countries for which complete data was available and that used WTP in their estimates. This value was used for countries that used another method, or for which no data were available.

Property damage
If property damage is missing, this cost component is added using the median property damage per casualty or per crash in other countries. Values from eleven countries which apply the recommended restitution costs approach and have at least included vehicle damage are used.

Administrative costs
For administrative costs, costs from eight countries which have included police costs, fire service costs, vehicle insurance costs and legal costs (the main costs items) are used.

Other costs
Regarding other costs, values from the four countries which have included congestion costs are used for the value transfer (not necessarily funeral costs as these costs are known to be relatively very small).

6.2 STANDARD VALUES PER COST COMPONENT AND TYPE OF CASUALTY/CRASH

Table 6-2 gives an overview of all standard values per cost component and per type of casualty or crash. In the last column the sum of the standard values for the cost components is given for each type of casualty or crash. This value serves as the standard value for total (unit) costs per casualty or per crash. All unit costs include both casualty and crash related costs (except PDO crashes for which there are no casualty related costs).

[32] Possibly more countries satisfy the criteria but only for these countries the method and costs items included are known. The same applies to the other cost components discussed..

	Medical costs	Production loss	Human costs	Property damage	Administrative costs	Other costs	Total (unit) costs
Fatalities	€ 5,430	€ 655,376	€ 1,587,001	€ 11,555	€ 6,346	€ 3,638	€ 2,269,346
Serious injuries	€ 16,719	€ 43,627	€ 230,385	€ 7,622	€ 4,364	€ 413	€ 303,130
Slight injuries	€ 1,439	€ 2,669	€ 15,597	€ 5,317	€ 1,876	€ 519	€ 27,418
Fatal crashes	€ 11,757	€ 727,616	€ 1,809,467	€ 17,542	€ 8,891	€ 3,817	€ 2,579,089
Serious injury crashes	€ 19,158	€ 50,285	€ 263,945	€ 11,143	€ 5,557	€ 709	€ 350,796
Slight injury crashes	€ 1,957	€ 3,629	€ 21,212	€ 7,231	€ 2,677	€ 634	€ 37,340
PDO crashes	€ 0	€ 0	€ 0	€ 2,795	€ 764	€ 400	€ 3,960

Table 6-2 Standard values for cost components and unit costs

The 'standard' cost of a fatality is estimated at €2.3 million. These costs mainly consist of human cost (€1.6 million) and production loss (€0.7 million). Costs per serious and slight injury are respectively estimated at 13% and 1% of the value of a fatality. Also for injuries human costs are by far the largest cost item, having a share of 76% in total costs of a serious injury and 57% in the costs of a slight injury. The share of production loss in the costs of a serious injury is relatively small compared to fatalities, because production loss is temporary for most non-fatal injuries. Consequently, human costs have a higher share in costs per serious injury than in costs per fatality. Obviously, medical costs of serious injuries are higher than medical costs for a fatality, but still have a relatively small share in total costs per serious injury.

Logically, costs per crash are higher than costs per casualty for each severity level as there is typically more than one casualty per crash, including casualties of lower severity categories.

6.3 EXAMPLE

To illustrate the process of value transfer, we use Austria as an example. Table 6-3 shows the data that were obtained from the questionnaire. In the original questionnaire the medical costs, production loss, human costs, administrative costs and other costs were given for fatalities, serious injuries and slight injuries, and property damage costs were given for PDO crashes.

	Medical costs	Production loss	Human costs	Property damage	Administrative costs	Other costs	Total (unit) costs
Fatalities	€ 4.728	€ 1,392,700	€ 1,614,285		€ 2,874	€ 69	€ 4.811
Serious injuries	€ 9.822	€ 66,941	€ 301,160		€ 3,293	€ 69	€ 10.270
Slight injuries	€ 177	€ 1,447	€ 23,166		€ 2,031	€ 69	€ 278
Fatal crashes							
Serious injury crashes							
Slight injury crashes							
PDO crashes				€ 5,242			€ 5,242

Table 6-3 Costs per component and cost per unit before value transfer for Austria (EUR2015, PPP)

In this example the value transfer consists of four steps:

1. Medical costs are replaced by the standard values since Austria did not take into account all recommended cost items (emergency department is missing).
2. Property damage for all types of casualties and crashes (except PDO crashes) are filled in with the standard values because they were missing.
3. Medical costs, production loss, human costs, administrative costs and other costs for all types of crashes are calculated from the costs per casualty using the conversion rate from Table 6-1.
4. The total costs per type of casualty or crash are calculated by summing up the components.

Table 6-4 shows the values per cost component and per unit cost after value transfer, with transferred values in italics.

	Medical costs	Production loss	Human costs	Property damage	Administrative costs	Other costs	Total (unit) costs
Fatalities	*€ 5,430*	€ 1,392,700	€ 1,614,285	*€ 11,555*	€ 2,874	€ 69	*€ 3,026,912*
Serious injuries	*€ 16,719*	€ 66,941	€ 301,160	*€ 7,622*	€ 3,293	€ 69	*€ 395,804*
Slight injuries	*€ 1,439*	€ 1,447	€ 23,166	*€ 5,317*	€ 2,031	€ 69	*€ 33,469*
Fatal crashes	*€ 11,757*	*€ 1,547,319*	*€ 1,851,930*	*€ 17,542*	*€ 4,759*	*€ 121*	*€ 3,433,427*
Serious injury crashes	*€ 19,158*	*€ 74,941*	*€ 344,481*	*€ 11,143*	*€ 4,549*	*€ 107*	*€ 454,379*
Slight injury crashes	*€ 1,957*	*€ 1,968*	*€ 31,506*	*€ 7,231*	*€ 2,762*	*€ 94*	*€ 45,518*
PDO crashes	*€ 0*	*€ 0*	*€ 0*	€ 5,242	*€ 764*	*€ 400*	*€ 6,407*

Table 6-4 Costs per component and cost per unit after value transfer for Austria, transferred values in italics (EUR2015, PPP)

6.4 CRASH COST ESTIMATES FOR EU COUNTRIES

6.4.1 Total costs based on survey and value transfer

Based on the unit costs that are calculated by summing up the cost components after value transfer, new total costs are calculated. These totals are estimated by multiplying the (new) unit cost per crash with the numbers of crashes. This approach requires the number of fatal crashes, serious injury crashes, slight injury crashes and PDO crashes for each country. For countries that do not have these numbers of crashes, estimates are calculated in different ways: numbers of fatal, serious injury and slight injury crashes are derived from the numbers of casualties using the average conversion rates in Table 6-1. Missing numbers of PDO crashes are estimated using the median ratio between PDO crashes and slight injuries in all other countries where these numbers are filled in. Appendix F includes the numbers of casualties and crashes and Appendix G the unit costs that were used for the calculations. Appendix G shows that almost all unit costs have been adapted in the value transfer process, because the cost components were missing or the method for estimating cost components were not consistent with international guidelines.[33] Table 6-5 gives an overview for all countries of the original total (before value transfer) and the total calculated on the basis of the total costs of crashes (fatal crashes, serious injury crashes, slight injury crashes, PDO crashes).[34]

The estimate for the grand total for the 28 EU member states comes to €267 billion. For all countries involved in the study (EU28 + Iceland, Norway, Serbia and Switzerland) the total costs sum up to €280 billion. This corresponds to 1.76% of the GDP for EU member states, and to 1.73% of the GDP for all countries involved in the study. It should be noted that this is still an underestimation of the total costs, because many countries have not corrected the numbers of casualties/crashes for underreporting (discussed below).

[33] Only the costs per fatality and per serious injury in the Netherlands were not changed.

[34] Total costs were also calculated by multiplying the (new) unit costs with the numbers of casualties and the number of PDO crashes, resulting in slightly lower costs than totals based on crashes. One reason for this might be that some crash-related cost components were, in spite of all the value transfer calculations, not included in the casualty related costs. Though the two estimates are very close together, and choosing one over the other might not result in any significant differences, we regard totals based on crashes as the best estimate.

To evaluate the effect of value transfer on the totals, the sum of the total costs as filled in on the questionnaire of all EU 28 countries (without Romania where this total was missing) is compared to the sum of the total costs after value transfer of these countries (without Romania).The European total based on the values given in the questionnaire is €197 billion, while the total based on value-transferred costs is €259 billion (without Romania). This clearly shows the importance of adding the missing components, and of using a standard methodology, in estimating total costs of crashes.

	Original total costs	Total costs based on value transfer
Austria	€ 10,083	€ 11,049
Belgium	€ 4,613	€ 6,947
Bulgaria	€ 1,920	€ 2,855
Croatia	€ 2,211	€ 3,147
Cyprus	€ 115	€ 282
Czech Republic	€ 3,197	€ 5,278
Denmark	€ 1,058	€ 1,113
Estonia	€ 701	€ 475
Finland	€ 2,361	€ 2,605
France	€ 34,725	€ 30,431
Germany	€ 32,374	€ 51,806
Greece	€ 2,748	€ 2,746
Hungary	€ 4,516	€ 4,295
Iceland	€ 320	€ 249
Ireland	€ 722	€ 694
Italy	€ 30,609	€ 39,534
Latvia	€ 989	€ 2,862
Lithuania	€ 611	€ 1,043
Luxembourg	€ 880	€ 236
Malta	€ 95	€ 162

	Original total costs	Total costs based on value transfer
Netherlands	€ 11,990	€ 17,667
Norway	€ 2,259	€ 2,447
Poland	€ 14,792	€ 12,842
Portugal	€ 2,535	€ 4,763
Romania		€ 8,091
Serbia	€ 792	€ 3,939
Slovakia	€ 663	€ 1,414
Slovenia	€ 1,373	€ 828
Spain	€ 11,019	€ 29,347
Sweden	€ 1,928	€ 1,673
Switzerland	€ 5,528	€ 6,279
UK	€ 18,019	€ 23,253
EU28 – Total (rounded)	**€197,000**	**€ 267,000**
EU28 + 4 Total (rounded)	**€206,000**	**€ 280,000**

Table 6-5 Total costs (in Million Euro), as originally filled in on the questionnaire and as calculated with transferred values for crashes (EUR2015, corrected for PPP).

6.4.2 Impact of underreporting

As discussed in Section 5.2, just four countries (Netherlands, Norway, Sweden, Switzerland) have based cost calculations on reported and unreported casualties or crashes, while 17 countries have not included unreported casualties or crashes (for 11 countries there is no information from the survey).[35] This means that the total costs as calculated above still underestimate the 'real' costs. To give an indication of this underestimation, we discuss the costs in the Netherlands, the UK and the US, as for these countries information on the impact of underreporting on costs is available.

Table 6-6 shows that in the Netherlands the costs are three times higher if unreported casualties and crashes are included. This difference is mainly attributed to underreporting of serious injuries and PDO crashes. Particularly the underreporting rate of PDO crashes is very high. In other countries this rate of underreporting of PDO crashes might be lower if the number of PDO crashes is based on insurance statistics instead of police reports. This is because not all PDO crashes may need to be reported to the police, but a claim may be submitted to an insurance company. If PDO crashes are

[35] The level of underreporting can be determined by linking different databases, in particular police, hospital and insurance databases, see for example Derriks & Mak (2007).

excluded, costs based on the true numbers of casualties are still 2.3 times higher than costs based on reported casualties only. Note that we have assumed that the costs per reported casualty are equal to costs per unreported casualty, although costs per unreported casualty are likely to be lower due to lower severity. Still, we can conclude that the unreported casualties contribute substantially to the total costs.

	Cost per casualty / PDO crash	Police reported numbers	Unreported numbers	Costs reported numbers	Costs unreported numbers	Total costs
Fatality	2,611,500	644	76	1,682	198	1,880
Serious injuries	280,642	7,028	11,548	1,972	3,241	5,213
Slight injuries	8,633	10,071	97,915	87	845	932
Other injuries	4,870	5,146	174,868	25	852	877
PDO crashes	3,520	56,866	964,052	200	3,394	3,594
Total				3,966	8,530	12,496

Table 6-6 Costs of road crashes in the Netherlands in 2009 on the basis of police reported and unreported numbers of casualties and PDO crashes (million Euro, Dutch price level 2009). Source: own calculations based on De Wit & Methorst (2012).

Recent costs calculations in the UK (DfT, 2016) come to the same conclusion: costs including unreported casualties and crashes are 2.3 times higher than the costs of reported numbers only (£35.6 billion versus £15.3 billion).

In the US, on the other hand, total costs based on all casualties/crashes are only a factor of 1.1 higher than the costs of reported numbers only (Blincoe et al., 2014). This is mainly explained by zero or very low underreporting rates of fatalities (no underreporting) and serious injuries (4.3% underreporting of MAIS 3 injuries, no underreporting of more severe injuries). These underreporting rates are much lower than in the Netherlands and the UK (and probably most EU countries).

The data from the Netherlands and the UK indicate that the total costs of road crashes in the EU (1.7% of GDP) is likely a huge underestimation of the 'real' costs including costs of unreported casualties and crashes. A percentage in the order of magnitude of at least 3% of the GDP would probably be a more realistic estimate of the total costs of all casualties and crashes. Further research into reporting rates of casualties and crashes and costs per unreported casualty/crash, which is beyond the scope of this project, would be needed to make a more precise estimate of the total costs.

6.5 SUMMARY

The previous chapter showed that not all countries have (complete) information on the costs of crashes and that not all countries apply the recommended methods. This chapter applies the value transfer method to estimate missing cost items and to estimate comparable cost values for all EU countries.

The value transfer method uses crash cost estimates from countries whose estimates are consistent with international guidelines to estimate costs for countries that do not have cost information according to the international guidelines. The median (PPP-adjusted) value per casualty (fatality, serious injury, slight injury) and per crash (fatal, serious injury, slight injury and PDO) for a specific cost component is determined for a group of countries that use the recommended methods and included all relevant cost items. This median value is used for countries that have not used the recommended method or do not have information at all for that cost component.

Section 6.2 provides standard costs per fatality/fatal crash, serious injury/serious injury crash, slight injury/slight injury crash and PDO crash. The 'standard' costs of a fatality are estimated at €2.3 million. These costs mainly consist of human cost (€1.6 million) and production loss (€0.7 million). Costs per serious and slight injury are estimated at 13% and 1% of the value of a fatality; this is the same as the values found in the HEATCO study. Also for injuries the human costs are by far the largest cost item. Table 6-5 provides estimates for total costs according to the international guidelines in all EU countries as well as the EU in total. Total costs for the 28 EU member states are estimated at about €270 billion, and for all countries involved in the study (EU28 + Iceland, Norway, Serbia and Switzerland) the total costs are estimated at €280 billion. This corresponds to 1.7% to 1.8% of the GDP. This is still an underestimation of the total costs, because many countries do not correct the numbers of casualties/crashes for underreporting. If unreported casualties and crashes are taken into account, we expect that total costs are in the order of magnitude of at least 3% of the GDP.

7 Conclusions and recommendations

Cost estimates appear to differ considerably between countries and are highly influenced by the method that is applied for the calculation of human costs; countries that apply the willingness to pay (WTP) approach report much higher cost estimates than countries that apply alternative approaches. We recommend including all relevant costs items in costs studies, to use the internationally recommended methods, particularly the WTP approach, and to include unreported casualties and crashes as much as possible. Results from the value transfer method that are applied to develop a consistent set of EU values can be used if values are missing or have not been based on recommended methods.

7.1 CONCLUSIONS

Following the literature review on costs of road crashes, we conclude that, although being developed more than 20 years ago, the COST313 guidelines are still the most comprehensive guidelines for estimating the costs of road crashes. The COST313 guidelines provide complete guidelines as they focus on the full costs of road crashes for society. Most other studies do not cover all costs, for example because they include only external costs or only fatality and/or injury related costs, or mainly focus on the value of a statistical life (VOSL) and hardly pay attention to other costs such as medical costs, production loss and property damage. Therefore, we developed a framework for analyzing the costs of road crashes mainly on the basis of COST313. Adjustments were made following more recent literature on costs of road crashes, including a categorization of costs items according to their relevance and potential size.

The cost information that was collected by means of the survey reveals that costs per casualty vary considerably between countries. Reported costs per fatality vary between €0.7 million and €3.0 million, reported costs per serious injury vary between €28,000 and €959,000 and reported costs per slight injury vary between €296 and €71,742. Differences in costs per casualty are due to: 1) methodological differences, especially concerning the method applied for the calculation of human costs, 2) differences regarding the cost components that are taken into account, 3) differences in the definitions of a serious and a slight injury, and 4) differences in levels of underreporting. Differences in costs per fatality are mainly due to the method that is applied for the calculation of human costs; the willingness to pay (WTP) approach results in much higher estimates of human costs than alternative approaches, particularly cost estimates on the basis of financial compensation awarded to road casualties or their relatives in courts or by law.

Also the total costs of crashes as a percentage of the Gross Domestic Product (GDP) differ considerably between countries: crashes cost a country between 0.4% and 4.1% of the GDP. Although a better road safety performance should in principle result in lower road crash costs, we found only a weak relation between mortality rate and costs as a percentage of GDP. Also in this case, differences are to a large extent due to methodological differences, such as different methods for the calculation of human costs. Countries that use the WTP approach to calculate human costs in general report higher total costs of crashes (as a percentage of GDP) than countries that apply an alternative approach. Moreover, exclusion of PDO crashes or other severity levels and not-correcting for underreporting results in an underestimation of total costs of crashes.

Human costs appear to be a very important cost component and the method used to determine human costs appears to be very determinative for the crash cost estimates. In countries that use the WTP approach, human costs have a major share (34% to 91%) in the total costs of crashes. In countries that apply an alternative method, the share of human costs in the total costs is much smaller (less than 10%). Also, property damage costs and production losses are major cost components in most countries, whereas medical costs and administrative costs are relatively low.

Regarding the distribution of costs over casualties/crashes of different severity levels, in general injuries appear to have a large share in total costs: the share of injuries is on average 2.4 times higher than the share of fatalities in total costs. However, the results appear to differ substantially between countries. For countries that included all severity levels, fatalities account for 7.4% to 55% of the 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%. Possible explanations for this variation include differences in definitions of severity levels and in reporting rates. Nevertheless, the fact that injuries in general have a large share in the total costs provides a strong economic argument to concentrate road safety policy and cost-benefit analysis also on (serious) road injuries, in addition to fatalities.

Finally, it appeared to be possible to develop a set of consistent cost estimates for EU countries, applying the value transfer method. The value transfer method uses crash cost estimates from countries whose estimates are consistent with international guidelines to estimate costs for countries that do not have cost information according to the international guidelines. The 'standard' costs of a fatality are estimated at €2.3 million. These costs mainly consist of human cost (€1.6 million) and production loss (€0.7 million). Costs per serious and slight injury are estimated at 13% and 1% of the value of a fatality and also for injuries, human costs are by far the largest cost item.

Applying the results of the value transfer gives a total cost estimate of about €270 billion for the 28 EU member states and of €280 billion for all countries involved in the study (EU28 + Iceland, Norway, Serbia and Switzerland). This corresponds to 1.7% (all countries) to 1.8% (EU28) of the GDP. However, this is still an underestimation of the total costs, because many countries do not correct the numbers of casualties/crashes for underreporting. If unreported casualties and crashes are taken into account, we expect that total costs are in the order of magnitude of at least 3% of the GDP. The European total cost based on the values given in the survey is almost €200 billion, which clearly shows the importance of adding the missing components, and of using a standard methodology, in estimating total costs of crashes.

7.2 RECOMMENDATIONS

7.2.1 Recommendations for costs studies and cost-benefit analysis

In order to provide a complete picture of the socio-economic costs we recommend including all relevant cost items in costs studies and to use the internationally recommended methods. This also enhances the international comparability of the cost estimates, which is encouraged by several international road safety organizations (Wijnen et al., 2016). We recommend including at least the following cost components:

- Medical costs: treatment at the scene and transportation to the hospital, hospital treatment (emergency department, in-patient and out-patient) and non-hospital treatment (general practitioner, rehabilitation, etc.).
- Costs related to production loss, including at least loss of market production.
- Human costs of fatalities and serious and slight injuries.
- Costs related to property damage, including at least vehicles damage.
- Administrative costs related to police, fire department, vehicle insurance and legal costs.
- Other costs: funeral costs and congestion costs.

Medical costs, costs related to property damage and administrative costs should be calculated by means of the restitution costs method. Costs related to production loss should be calculated by means of the human capital approach and human costs should be calculated by means of the (individual) willingness to pay (WTP) approach.

To estimate total costs, it is important to use numbers of casualties or crashes which are corrected for underreporting as much as possible. Calculations based on reported numbers only, as is current practice in most countries, results in a (large) underestimation of total costs. In addition, it is recommended to include the costs of property damage only crashes, as the survey shows that these costs have a substantial share in the total costs in most countries.

We recommend including all severity levels when costs figures (costs per casualty or per crash) are applied in cost-benefit analysis. Excluding lower severity levels is likely to result in considerable underestimation of the benefits, because of the sizable costs of lower severity casualties/crashes. If a country does not have information for all severity levels (including PDO crashes) for all cost components, or does not apply the recommended methods for the determination of the costs of crashes, we recommend using the cost values provided in Table 6.4 of this Deliverable.

7.2.2 Recommendations for further research

Since costs of road crashes are commonly regarded as a general road safety indicator, we recommend repeating the survey on costs on a regular basis to monitor the socio-economic impact of road crashes on a European-scale. This enables policy makers and researchers to monitor developments in the costs and in the (harmonization of) methods used to estimate the costs, and to use up-to-data cost figures in policy documents and cost-benefit analysis.

The analysis of cost data in the study was mainly descriptive. Further statistical analysis is recommended to better understand which factors explain variation in cost estimates across countries and what the contribution of each factor is. Potential factors of interest include geographical situation, economic performance, motorization rate and mobility by transport mode. These analysis will also help to further improve the value transfer method developed in this study, for example by selecting values from a specific group of countries which show similar characteristics as the country the values are transferred to.

Information on costs of injuries, particularly human costs of injuries, is poor. Contrary to studies into the value of a statistical life, just a few studies have been carried out regarding injuries. Based on the information from these studies, the (human) costs of injuries appear to have a major share in the total costs of road crashes. Therefore, new research into the human costs of serious injuries is recommended in order to improve the quality of the cost estimates of injuries and thus total costs. New approaches, particularly the QALY-approach, may be further investigated or applied to estimate human costs of injuries (see SafetyCube Deliverable 7.3; Schoeters et al., 2017).

References

ADB (2003). *Road Safety Guidelines for the Asian and Pacific Region*. Asian Development Bank, Manila.

Adler M.D. and E.A. Posner (2000). Implementing Cost-Benefit Analysis when preferences are distorted, in M.D. Adler and E.A. Posner, eds., Cost-benefit Analysis; Legal, Economic and Philosophical Perspectives, University of Chicago Press.

Alfaro, J. L., Chapuis, M., Fabre, F. (Eds.) (1994). S*ocio-economic cost of road accidents: final report of action COST 313*. Commission of the European Community, Brussels.

Bahamonde-Birke, F.J., Kunert, U. & Link, H. (2015). The Value of a Statistical Life in a Road Safety Context — A Review of the Current Literature, Transport Reviews, 35 (4), pp. 488-511.

Baum, H., Kranz, T. & Westerkamp, U. (2007). Volkswirtschaftliche Kosten durch Straßenverkehrsunfälle in Deutschland. Heft M208. Bundesanstalt für Straßenwesen, Bergisch Gladbach.

Becker, G.S. (1968). Crime and punishment, an economic approach. Journal of Political Economy, 76 (2), pp. 169-217.

Bickel, P. et al. (2006). *Proposal for harmonised guidelines*. EU project HEATCO Deliverable 5. University of Stuttgart, Stuttgart.

BITRE (2009). Costs of road crashes in Australia 2006. Research report 118. Bureau of Infrastructure, Transport and Regional Economics, Canberra.

Blaeij, A.T. de (2003b). The value of a statistical life in road safety; Stated preference methodologies and empirical estimates for the Netherlands. Tinbergen Institute Research Series, Vrije Universiteit, Amsterdam.

Blaeij, A.T. de, Florax, R.J.G.M., Rietveld, P. & Verhoef, E. (2003). The value of statistical life in road safety; A meta-analysis. In: Accident Analysis and Prevention, vol. 35, nr. 6, p. 973-986.

Blaeij, A. de., Koetse, M., Tseng, Y.Y., Rietveld, P.,Verhoef, E. (2004). *Valuation of safety, time, air pollution, climate change and noise; methods and estimates for various countries*. Report prepared for ROSEBUD. Department of Spatial Economics, Vrije Universiteit, Amsterdam.

Blincoe, L.J., Miller, T.R., Zaloshnja, E. & Lawrence, B.A. (2014). The economic and societal impact of motor vehicle crashes 2010. National Highway Traffic Safety Administration, Washington.

Boardman, A.E., Greenberg, D.H., Vining, A.R. & Weimer, D.L. (2011). *Cost-benefit analysis. Concepts and practice*. Fourth edition. Prentice Hall, Upper Saddle River, New Jersey.

Brabander, B. de (2006). Valuing the reduced risk of road accidents. Empirical estimates for Flanders based on stated preference methods. PhD Thesis. Hasselt University, Diepenbeek.

BRS&TRL (2003). *Guidelines for estimating the costs of road crashes in developing countries*. Babtie Ross Silcock & Transport Research Laboratory.

Cough, P., Guria, J., and Bealing, M. (2015). Approaches to valuing injury and mortality risk in transport assessments, Report 571 New Zealand Institute of Economic Research (NZIER), Wellington.

Derriks, H. M. & Mak, P.M. (2007). Underreporting of road traffic casualties. IRTAD special report. OECD, Paris.

DfT (2013). A valuation of road accidents and casualties in Great Britain in 2012. In: DfT (2013), Reported Road Casualties in Great Britain: 2012 Annual Report. Department for Transport, London.

DfT (2016). Reported Road Casualties Great Britain: 2015 Annual Report. Department for Transport, London.

Dionne, G. & Lanoie, P. (2004). Public choice and the value of a statistical life for cost-benefit analysis: the case of road safety. In: Journal of Transport Economics and Policy, vol. 38, nr. 2, p. 247-274.

ECMT (1998). *Efficient transport for Europe; Policies for internalisation of external costs*. Organisation for Economic Co-operation and Development OECD, Paris.

Elvik, R. (1995). *An analysis of official economic valuations of traffic accident fatalities in 20 motorized countries*. Accident Analysis and Prevention, vol. 27, nr. 2, pp. 237-347.

Elvik, R. (2000). *How much do road accidents cost the national economy?* Accident Analysis and Prevention, vol. 32, nr. 6, pp. 849-851.

Elvik, R. (2006). Are individual preferences always a legitimate basis for evaluating the costs and benefits of public policy? The case of road traffic law enforcement. Transport Policy 13, pp. 379-385.

ERSO (2006). *Cost-benefit analysis.* European Road Safety Observatory. Retrieved January 18, 2008 from www.erso.eu.

Evans, A. (2001). The economic appraisal of road traffic safety measures in Great Britain. Paper for ECMT Round Table 117 "Economic evaluation of road traffic safety measures". ECMT, Paris.

EU/OECD (2012). Eurostat-OECD Methodological Manual on Purchasing Power Parities. European Union/OECD, Luxembourg.

Freeman, A.M., Herriges, J.A., & Kling, C.L. (2014). The measurement of environmental and resource values. Theory and methods. Third edition. Resources for the future, New York.

Hammitt, J.K. (2007). Valuing Changes in Mortality Risk: Lives Saved Versus Life Years Saved. Review of Environmental Economics and Policy, vol. 1 (2), pp. 228–240.

INFRAS/IWW (1995). *External Effects of Transport*. International Union of Railways UIC, Paris.

INFRAS/IWW (2000). *External costs of transport; accident, environmental and congestion costs in Western Europe*. INFRAS/IWW, Zürich/Karlsruhe.

INFRAS/IWW (2004). *External costs of transport; Update study.* INFRAS/IWW, Zürich/Karlsruhe.

INRETS (dir.), (1996). *Monétarisation des conséquences des accidents de la route*, Editions Paradigme, Orléans.

Johansson, P.-O. (1991). *An introduction into modern welfare economics*. Cambridge University Press, Cambridge.

Jones-Lee, M. and Spackman, M. (2013). The Development of Road and Rail Transport Safety Valuation in the United Kingdom. Research in Transportation Economics, Vol. 43, p. 23-40.

Kasnatscheew, A., Heinl, F., Schoenebeck, S., Lerner, M., & Hosta, P. (2016). Review of European Accident Cost Calculation Methods – With Regard to Vulnerable Road Users. Deliverable 5.1 of the Horizon 2020 InDeV project.

Korzhenevych, A., et al. (2014). *Update of the Handbook on External Costs of Transport.* European Commission, Brussels.

Lindhjem, H., Navrud, S., & Braathen, N.A. (2010). *Valuing lives saved from environmental, transport and health policies; a meta-analysis of stated preference studies.* OECD, Paris.

Lindhjem, H., Navrud, S., Braathen, N.A. & Biausque, V. (2011). Valuing mortality risk reductions from environmental, transport and health policies; a global meta-analysis of stated preference studies. In:*Risk Analysis*, vol. 31, nr. 9, p. 1381-1407.

McMahon, K. & Dahdah, S. (2008). *The true costs of road crashes*. International Road Assessment Programme iRAP.

Maibach, M., Schreyer, C., Sutter, D., Van Essen, H.P., Boon, B.H., Smokers, R., Schroten, A., Doll, C., Pawlowska, B., Bak, M. (2008). *Handbook on estimation of external costs in the transport sector*. Internalisation Measures and Policiesfor All external Cost of Transport (IMPACT). CE Delft, Delft.

Miller, T.R. (2000). Variations between countries in values of statistical life. In: Journal of Transport Economics and Policy, vol. 34, nr. 2, p. 169-188.

Milligan, C., Kopp, A., Dahdah, S. & Montufar, J. (2014). Value of a statistical life in road safety: A benefit-transfer function with risk analysis guidance based on developing country data. Accident Analysis and Prevention, 71, pp. 236-247.

Ministry of Transport NZ (2013). *The social costs of road crashes and injuries; June 2013 update*. Wellington: Ministry of Transport New Zealand.

Mouter, N., van Cranenburgh, S., & van Wee, B. *Do individuals have different preferences as consumer and citizen? the trade-off between travel time and safety.* Forthcoming.

Nellthorp, J., Sansom, T., Bickel, P., Doll, C., & Lindberg, G. (2001). *Valuation Conventions for UNITE (UNIfication of accounts and marginal costs for Transport Efficiency).* Funded by 5th Framework RTD Programme. University of Leeds, Leeds: Institute for Transport Studies ITS.

O'Reilly, D. et al. (1994). The value of road safety. UK research on the valuation of preventing non-fatal injuries. Journal of Transport Economics and Policy, 28(1), pp. 45-59.

Persson, U. et al. 1995. Valuing the Benefits of Reducing the Risk of non-fatal Road Injuries: the Swedish Experience. In C. Schwab and N. Soguel (eds.). Contingent Valuation, Transport Safety and the Value of Life. Kluwer Academic Publishers, Boston.

Persson, U. (2004). Valuing reductions in the risk of traffic accidents based on empirical studies in Sweden.Lund Institute of Technology, Lund.

Schoeters, A., Wijnen ,W., Carnis, L., Weijermars, W., Elvik, R., Johanssen, H., Vanden Berghe, W., Filtness, A. and Daniels, S. (2017). Costs related to serious injuries, Deliverable 7.3 of the H2020 project SafetyCube.

Sommer, H., Brügger, O., Lieb, C. & Niemann, S. (2007). *Volkswirtschaftliche Kosten der Nichtberufsunfälle in der Schweiz; Strassenverkehr, Sport, Haus und Freizeit [Costs to the national economy of non-occupational accidents in Switzerland: Road traffic, sport, home and leisure]*. Beratungsstelle für Unfallverhütung, Bern.

SWOV (2014). The valuation of human losses of road deaths. Factsheet, January 2012. SWOV, The Hague.

SWOV (2014). *Cost of road crashes*. Factsheet, March 2014. SWOV, The Hague.

Trawén, A., Maraste, P. & Persson, U. (2002). *International comparison of costs of a fatal casualty of road accidents in 1990 and 1999*. Accident Analysis and Prevention, vol. 34, nr. 3, p. 323-332.

TRL (1995). *Costing Road Accidents in Developing Countries*. Overseas Road Note 10. Transport Research Laboratory, Crowthorne.

Trottenberg, P. & Rivkin, R.S. (2013). *Guidance on treatment of the economic value of a statistical life in U.S. Department of Transportation analyses*. U.S. Department of Transportation, Washington.

Wijnen, W., Wesemann, P. & de Blaeij (2009). Valuation of road safety effects in cost-benefit analysis. Evaluation and Program Planning, 32, pp. 326-331.

Wijnen, W. (2014). Financieringsmogelijkheden voor 'Opschakelen naar meer verkeersveiligheid': een verkenning. Kostendragers en baathebbers in verkeeersveiligheid [*Funding opportunities for 'Changing into a higher gear towards road safety improvement': an exploration. Cost bearers and beneficiaries in road safety*.] SWOV report R-2014-40. SWOV, The Hague.

Wijnen, W., Verster, N. & Wesemann, P. (2016). *Economische waardering van invoering, aanscherping en handhaving van wettelijke snelheidslimieten in het verkeer [Economic valuation of implementing, strengthening and enforcing legal traffic speed limits].* TPEdigitaal, 10(1), pp. 72-87.

Wijnen, W. & Stipdonk, H. (2016). Social costs of road crashes: an international analysis. *Accident Analysis and Prevention*, 94, 97–106.

Wijnen, W., Schroten, A. & 't Hoen, M. (2016). *Costs of road crashes in the Netherlands; an assessment of scenarios for making new cost estimates.* CE Delft / W2Economics, Delft.

Wit, M. de & Methorst, R. (2012). *Kosten verkeersongevallen in Nederland; Ontwikkelingen 2003-2009.* Rijkswaterstaat, Dienst Verkeer en Scheepvaart, Rotterdam.

World Bank (2005). *Valuation of accident reduction*. Transport Note No. TRN-16. World Bank, Washington.

Wren, J., and Barrell, K., 2010. *The Costs of Injury in New Zealand and Methods for Prioritising Resource Allocation: A background briefing paper to inform the evaluation of the New Zealand Injury Prevention Strategy.* New Zealand Injury Prevention Secretariat, ACC, Wellington, New Zealand.

Abbreviations

CBA	Cost-Benefit Analysis
CMF	Crash Modification Factor
DSS	Decision Support System
EEA	Economic Efficiency Assessment
ECMT	European Conference of Ministers of Transport
EU	European Union
GDP	Gross Domestic Product
HC	Human capital
HIC	High Income Countries
LMIC	Low and Middle Income Countries
MAIS	Maximum Abbreviated Injury Scale
PDO	Property Damage Only
PPP	Purchasing Power Parity
QALY	Quality Adjusted Life Year
RC	Restitution costs
RP	Revealed Preferences
SP	Stated Preferences
UK	United Kingdom
US	United States
VOSL	Value Of a Statistical Life
VRU	Vulnerable Road User
WTA	Willingness To Accept
WTP	Willingness To Pay
YLD	Years Lived with Disability
YLL	Years of Life Lost

Glossary

COST313	European study (1994) in which guidelines for estimating road crash costs were developed
Administrative cost	Costs of police costs, fire services and other emergency services (excluding transportation of casualties to hospital), insurance costs and legal costs, as a result of road crashes
Consumption loss	Loss of consumption of road casualties as a result of a road crashes
Cost-Benefit Analysis (CBA)	Analysis of all impacts of a (road safety) intervention on socio-economic welfare, in which all impacts are expressed in monetary terms as much as possible
Gross production loss	Production loss including consumption loss
HEATCO	European study aimed at developing guidelines for economic appraisal of transport projects (HEATCO: developing Harmonised European Approaches for Transport Costing and project assessment)
Human capital (HC) approach	Valuation method measuring the value for society of the loss of productive capacities of road casualties
Human costs	Intangible costs of pain, grief, sorrow and loss of quality of life
Medical costs	Costs of medical treatment of road casualties (including fatalities that were treated in hospital), provided by hospitals and other medical institutions
Net production loss	Production loss excluding consumption loss
Non-market production	Production resulting from unpaid activities, such as household work and voluntary work
Opportunity cost	The value of a resource in its best alternative use
Prevention costs	Costs of road safety interventions aimed at preventing road crashes
Production loss	Costs resulting from lost productivity if road casualties cannot work anymore due to a crash, either permanently (fatalities, severe injuries) or temporarily (injuries)
Property damage	Damage to vehicles, infrastructure, fixed roadside objects, buildings, freight carried by lorries and personal property, as a result of road crashes
Purchasing Power Parity	The rates of currency conversion that equalize the purchasing

(PPP)	power of different currencies: price relatives that show the ratio of the prices in national currencies of the same good or service in different countries
Quality Adjusted Life Year (QALY)	A measurement unit expressing quality of life gains, combining impact on mortality and morbidity
Restitution costs (RC) approach	Valuation method measuring the costs of resources that are needed to restore road casualties and their relatives and friends to the situation which would exist if they had not been involved in a road crash
Revealed preference (RP) method	Valuation method in which willingness to pay is derived from actual behaviour
Stated preference (SP) method	Valuation method in which willingness to pay is derived by asking people, directly or indirectly, how much they are willing to pay for more safety
Value transfer	Economic valuation method in which results of primary valuation studies are used to estimate values in another context
Willingness to accept (WTA) approach	Valuation method measuring the amount of money individuals are willing to accept for a risk increase
Willingness to pay (WTP) approach	Valuation method measuring the amount of money individuals are willing to pay for a risk reduction
Years Lived with Disability (YLD	Years lived with quality of life loss due to an injury, weighted for the severity of this impact on quality of life (expressed by a disability weight)
Years of Life Lost (YLL)	Number of life years lost due to a road crash

Appendix A Consulted experts

Country	Expert	Organization
Austria	Robert Bauer	Austrian Road Safety Board (KfV)
Bulgaria	Nikolay Ivanov	Bulgarian Branch Association for Road Safety
Croatia	Davor Brcic	University of Zagreb, Faculty of Transport and Traffic Sciences
Cyprus	Theodore Zachariadis	University of Cyprus
Czech Republic	Jan Tecl	Transport Research Centre (CDV)
Denmark	Mette Moller	Technical University of Denmark (DTU)
Estonia	Erik Ernits	Estonian Road Administration
Finland	Riikka Rajamaki	Finnish Transport Safety Agency Trafi
France	Dominique Mignot and Laurent Carnis Luc Baumstark	IFSTTAR Lyon University
Germany	Kasnatscheew Anatolij	Federal Highway Research Institute
Greece	Eleonora Papadimitriou / Akis Theofilatos	National Technical University of Athens
Hungary	Peter Hollo	Institute for Transport Science (KTI)
Iceland	Gunnar Geir Gunnarsson and Haraldur Sigþórsson	Icelandic Transport Authority
Ireland	Sharon Heffernan	Road Safety Authority
Italy	Davide Shingo Usami	CTL - Sapienza University of Rome
Latvia	Aldis Lama	Road Traffic Safety Directorate
Lithuania[1]	-	-
Luxembourg	Paul Hammelman	Barreau de Luxembourg
Malta	Philip von Brockdorff	University of Malta
Netherlands	Wim Wijnen	W2Economics

Norway	Rune Elvik	Institute of Transport Economics (TØI)
Poland	Agata Jazdzik-Osmolska	Roads and Bridges Research Institute
Portugal[2]	-	-
Romania	Madalina Stoenescu	Romanian Road Transport Authority (ARR)
Serbia	Dragoslav Kukic, Alan Ross	The Automobile and Motorcycle Association of Serbia (AMSS)
Slovakia	Štefan Machciník	Transport Research Institute, Inc.
Slovenia	Andraž Murkovič	Slovenian Traffic Safety Agency
Spain	Jorge Eduardo Martínez Pérez	University of Murcia, Department of Applied Economics
Sweden	Gunnel Bangman	Swedish Transport Administration
Switzerland	Steffen Niemann	Swiss Council for Accident Prevention (Bfu)
UK	Henry Kelly	Department for Transport

[1] For Lithuania only information was used from the report *Statistics of fatal and injury road accidents in Lithuania, 2011-2014* published by the Lithuanian Road Administration under the Ministry of Transport and Communications, Traffic Safety Division.

[2] For Portugal only information was used from the report *The economic and social cost of road accidents, the Portuguese case* by A. Donário and R. Borges dos Santos.

Appendix B Questionnaire

Questions to crash costs experts

Contact details	
Name	
Organisation	
E-mail	
Phone	

Estimation figure(s)			
Is there an official figure (acknowledged by the national government) for estimating costs of road crashes?	☐ Yes	☐ No	
Are there any other figures in use? Please explain.			
Is one of these figures also used in CBA? Please specify which one.			
What are the official discount rate values in your country? How high are they?	☐ Risk free value:	☐ Medium value for risk:	☐ other:
For all figures, please fill in the following information:			
	Official figure	[Figure 2, if applicable]	[Figure 3, if applicable]
What is the base year the relevant study was carried out?			
What is the most recent year for which the costs have been updated?			
Which method was used for the update? (For explanation see blue tab below)			
new prices (inflation correction)	☐	☐	☐
new number of casualties	☐	☐	☐
new other basic data	☐	☐	☐
other	☐	☐	☐
If "other", please explain (or any other comments):			

VRU consideration		
Does the crash cost calculation consider vulnerable road users (VRU)?	☐ Yes	☐ No
If yes: **How?** (e.g. separate estimates for VRU, adjusting factors for cost rates of VRU, ...)		

The information which is asked on the next tabs (**in green,** see below) relates only to the official figure (not Figure 2 or 3).

Excel-File Sheet 1: Questionnaire for experts on crash costs – Contact and estimation figure

Costs per unit

Information on costs per casualty and per crash
Please specify the costs per unit (casualty or crash) and add further information, if available.

Currency, in which the official information is provided (EUR/Pound/etc.):	
Price level of the year on which the costs are based on (e.g. costs for 2014, expressed in *price level 2015*)	

What is the definition of a **crash/accident in road traffic**?	

Costs per casualty		
Costs per fatality		Definition of 'fatality'
Costs per serious injury		Definition of 'serious injury'
Costs per slight injury		Definition of 'slight injury'
possible other group (name of group)		(Definition of group)
possible other group (name of group)		(Definition of group)

Costs per crash		
Costs per fatal crash		Definition of 'fatal crash'
Costs per serious injury crash		Definition of 'serious injury crash'
Costs per slight injury crash		Definition of 'slight injury crash'
Costs per property damage only (PDO) crash		Definition of 'property damage only crash'
possible other group (name of group)		(Definition of group)
possible other group (name of group)		(Definition of group)

Excel-File Sheet 2: Questionnaire for experts on crash costs – Cost per unit

Methods (official figure)

Cost component	incl. in crash costs	Cost item	Method if 'other' or several options: specify in 'further comments' For explanation see blue tab below.	Database if 'other' or several options: specify in 'further comments' For explanation see blue tab below.	incl. in cost item	Cost element	Cost item is included in...									
							fatalities	seriously injured	slightly injured	property damage only	crashes with fatalities	crashes with seriously injured	crashes with slightly injured	crashes with property damage only	other group, see Cost per unit	other group, see Cost per unit
Medical costs	☐	First aid and transportation			☐	ambulance	☐	☐	☐		☐	☐	☐		☐	☐
					☐	helicopter										
					☐	other:										
	☐	Emergency department					☐	☐	☐		☐	☐	☐		☐	☐
	☐	In-patient hospital treatment (overnight stay)					☐	☐	☐		☐	☐	☐		☐	☐
	☐	Out-patient treatment (no overnight stay)					☐	☐	☐		☐	☐	☐		☐	☐
	☐	Non-hospital treatment			☐	rehabilitation centres	☐	☐	☐		☐	☐	☐		☐	☐
					☐	general practitioners										
					☐	physiotherapy										
					☐	home care										
					☐	other:										
	☐	Aids and appliances					☐	☐	☐		☐	☐	☐		☐	☐
	☐	*other items:*					☐	☐	☐		☐	☐	☐		☐	☐
	further comments (other method, database, other value from which country etc.):															
Production loss	☐	Loss of future market production			☐	gross production loss (incl. consumption loss)	☐	☐	☐		☐	☐	☐		☐	☐
					☐	net production loss										
					☐	other:										
	☐	Friction costs			☐	recruiting and training new employees	☐	☐	☐		☐	☐	☐		☐	☐
					☐	vocational rehabilitation of employee (victim)										
	☐	Loss of non-market production			☐	household work	☐	☐	☐		☐	☐	☐		☐	☐
					☐	taking care of children										
					☐	voluntary work										
					☐	other:										
	☐	*other items:*					☐	☐	☐		☐	☐	☐		☐	☐
	further comments (other method, database, other value from which country etc.):															
Human costs	☐	Victims					☐	☐	☐		☐	☐	☐		☐	☐
	☐	Relatives and friends					☐	☐	☐		☐	☐	☐		☐	☐
	☐	*other items:*					☐	☐	☐		☐	☐	☐		☐	☐
	further comments (other method, database, other value from which country etc.):															
Property damages	☐	Vehicle damage					☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	☐	Infrastructure					☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	☐	Freight carried by lorries					☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	☐	Personal property					☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	☐	*other items:*					☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	further comments (other method, database, other value from which country etc.):															
Administrative costs	☐	Police operations					☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	☐	Fire department					☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	☐	Administration of health insurances					☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	☐	Administration of vehicle insurances					☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	☐	Legal costs					☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	☐	*other items:*					☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	further comments (other method, database, other value from which country etc.):															
Other costs	☐	Funeral costs					☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	☐	Vehicle unavailability					☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	☐	Congestion costs					☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	☐	Visiting people in hospital					☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	☐	Costs of house adaptation or moving					☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	☐	*other items:*					☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	further comments (other method, database, other value from which country etc.):															

Excel-File Sheet 3: Questionnaire for experts on crash costs – Methods

Explanations

tab "Contact and estimation figure"

Updating methods:

Several approaches for regular (e.g. yearly) cost updates may be applied:

- New price level: in this case the costs for the base year are (only) corrected for inflation

- New number of casualties: in this case the costs in the base are corrected for the new number of casualties in a more recent year. This means that the costs per casualty in the base year (that may have been corrected for inflation: 'new prices level') are applied to the new number of casualties.

- New other basic data: other basic data, such as new information on the production per person or vehicle repair costs (apart from inflation), may be used to update costs.

tab "Methods"

Cost estimation methods:

Restitution costs approach

These are the costs of resources that are needed to restore road casualties and their relatives and friends to the situation which would exist if they would not have involved in a road crash. These costs can be interpreted as the direct costs resulting from a crash, such as the costs of medical treatment and vehicle repair. The restitution costs approach also applies to administrative costs, as these costs are also aimed at restoring the consequences of a road crash. Market prices or proxy prices are used to value these costs, if they are available. For example, costs of vehicle damage are usually calculated using the price of repairing a vehicle (including among other things the costs of labour and materials to repair the vehicle).

Human capital approach

In this approach the value for society of the loss of productive capacities of road casualties is measured. The human capital approach is applicable for estimating production loss. Distinction can be made between gross production loss and net production loss. Gross production loss includes consumption loss, while net production loss does not include consumption loss.
Gross production loss is measured by the (lost) value added that an employed person produces. Part of this value added is used for the payment of wages, which in turn are used for consumption expenditures. Net production loss is calculated by subtracting consumption loss from gross production loss. Several indicators for production loss may be used, such as gross national/domestic product per capita and income (total or available income).

Willingness to pay approach

In the willingness to pay (WTP) approach costs are estimated on the basis of the amount individuals are willing to pay for a risk reduction. This approach is used to estimate the economic value of lost life years and lost quality of life, since there is no market price for such impacts. The WTP can be based on questionnaires in which people, directly or indirectly, are asked how much they are willing to pay for more safety ('stated preferences'), or on actual behavior, for example purchasing behavior regarding safety provisions such as airbags ('revealed preferences'). The results of WTP studies are used to derive the value of a statistical life (VOSL), which is used to calculate human costs of fatalities. The WTP approach also applies to injuries. In WTP studies for injuries, the amount people are willing to pay for reducing the risk of getting injured is estimated, e.g. relative to the WTP for reducing fatal risk.

other methods

possible options: proxy prices, rule of thumb, experts' estimates, ...

Database

Several databases may be used to estimate costs, including data from the police, hospitals, insurance companies and specific national surveys. Also values from other countries or European values may be used, for example the value of a statistical life (VOSL) from another country or a European standard VOSL. In that case the method that has been used in that country should be filled in in the 'method' column.
Note that more than one database may have been used to estimate a cost item, for example different databases for the number (e.g. number of ambulance trips) and the unit costs (e.g. costs per ambulance trip). This can be explained in the 'further comments' box.

Excel-File Sheet 4: Questionnaire for experts on crash costs – Explanations

Costs per component

More detailed information Do you have more detailed information on the crash costs **per cost component** and **per casualty**? If so, please fill those in here. If you only have data on total costs, please choose the right tick box.		
Is the information below given in costs per casualty or in total costs?	☑ Costs per casualty (preferred)	☐ Total costs
Currency in which the official information is provided (EUR/Pound/etc.):		

Official figure	Medical costs	Production loss	Human costs	Property damage	Administrative costs	Other costs
fatalities						
serious injuries						
slight injuries						
fatal crashes						
serious injury crashes						
slight injury crashes						
property damage only (PDO) crashes						
[other groups] (your definition from tab 'Costs per unit')						
[other groups] (your definition from tab 'Costs per unit')						
Total crashes						

Further notes:	

Excel-File Sheet 5: Questionnaire for experts on crash costs – Cost per component

Total costs (EURO)

Currency in which information is provided (EUR/Pound/etc)	
Total costs of crashes	
% of GDP	

	Crashes	Casualties
Total costs of fatal crashes/fatalities		
Total costs of serious injury crashes/serious injuries		
Total costs of slight injury crashes/slight injuries		
Total costs of property damage only (PDO) crashes		
[other groups, your definition from tab **'Costs per unit'**]		
[other groups, your definition from tab **'Costs per unit'**]		

Excel-File Sheet 6: Questionnaire for experts on crash costs – Cost per component

Number of crashes

These figure are taken from CARE. Please check whether they are correct and up-to-date.

Same definitions as above. Estimation is possible in case no exact figures are available, please provide the number which is used in cost estimates.

	Number of casualties/crashes	
	Casualties	Crashes
Year, for which the information was collected		
Are these numbers corrected for underreporting? (please explain)		
Number of fatalities/fatal crashes		
Number of serious injuries/serious injury crashes		
Number of slight injury crashes		
Number of property damage only crashes		
[other groups, your definition from tab **'Costs per unit'**]		
[other groups, your definition from tab **'Costs per unit'**]		
in total		

Prefilled by BASt/KfV

Excel-File Sheet 7: Questionnaire for experts on crash costs – Cost per component

Appendix C Main differences with the results of InDeV

The data collection was done together with InDeV, while the data cleaning and analysis were done separately. The differences between the results in this deliverable and the deliverable of InDeV () can be explained by the fact that SafetyCube published its deliverable later and received extra information from the experts, and by the fact that – when inconsistencies appeared – we made different decisions in how to deal with them. In this paragraph we will describe the main differences in our results.

Firstly our data is different because InDeV standardized the data to EUR 2014, while SafetyCube standardized to EUR 2015. Also different inflation indicators were used. Corrections for Purchasing Power Parity were done in both projects. New information was available for SafetyCube after the publication of the deliverable of InDeV, this was the case for Greece (completely new questionnaire) and Spain (slightly adjusted questionnaire). When inconsistencies appeared, or different reports were available, SafetyCube and InDeV made different decisions for Cyprus, Hungary, Latvia, Portugal, Serbia and Slovenia. Cyprus was not taken into account by InDeV because the costs and the crash/casualty data given were for different years; SafetyCube choose to update the costs to the year of the crash/casualty data. For Hungary, SafetyCube used the original values given in the report, while InDeV used the updated values as filled in on the questionnaire. For Latvia there were two questionnaires, based on two different reports available; while InDeV choose to use the questionnaire with the most recent data, SafetyCube decided to choose the questionnaire with the most consistent data. Because of high inconsistencies SafetyCube decided to use an alternative source for Portugal where the data was more consistent. For Serbia, SafetyCube decided not to use the cost per fatality, since it was higher than the cost per fatal crash. For Slovenia, InDeV decided to use the value from IRTAD while SafetyCube used the values from the original questionnaire.

Appendix D Data edits per country

Country	Step in the data cleaning process	Data edit or inconsistency
Belgium	**Data completeness**	The total costs, for each of the severity categories, is calculated by multiplying the unit costs and the number of casualties or crashes.
Bulgaria	**Standardization severity categories**	Only the total number of injured was given. The number of serious and slight injuries is back-calculated using the ratio of serious and slight injuries, which was found in the CARE database.
	Data completeness	The total costs, for each of the severity categories, is calculated by multiplying the unit costs and the number of casualties or crashes.
Croatia	**Data completeness**	The total costs, for each of the severity categories, is calculated by multiplying the unit costs and the number of casualties or crashes. The number of crashes/casualties is added from the CARE database.
Cyprus	**Data completeness**	The total costs, for each of the severity categories, is calculated by multiplying the unit costs and the number of casualties or crashes.
	Edits for internal consistency	The unit costs are adjusted to the same year as the crash/casualty data (from 2002 to 2015).
Czech Republic	**Data completeness**	The cost per unit, in each of the severity categories, is calculated by dividing the total costs per severity category by the respective number of casualties or crashes.
	Edits for internal consistency	The unit costs are adjusted to the same year as the crash/casualty data (from 2015 to 2014).

Denmark	**Data completeness**	The total costs, for each of the severity categories, is calculated by multiplying the unit costs and the number of casualties or crashes.
	Edits for internal consistency	The unit costs are adjusted to the same year as the crash/casualty data (from 2015 to 2014).
Estonia	**Data completeness**	The total costs, for each of the severity categories, is calculated by multiplying the unit costs and the number of casualties or crashes.
Finland	**Standardization severity categories**	Cost per "injury accident" is not taken into account (repetition of costs described in other categories).
	Edits for internal consistency	The unit costs were defined for other severity categories than the cost components. To match the standard severity categories, the unit costs were replaced by the sum of the cost components. The unit costs are adjusted to the same year as the crash/casualty data (from 2013 to 2014).
France	**Data completeness**	The number of PDO crashes is calculated by dividing the total costs for PDO crashes by the unit cost per PDO crash.
Germany	**Standardization severity categories**	"Severe PDO crashes" and "other PDO crashes" were collapsed to "PDO crashes".
Greece	**To give the distribution of of the total costs over cost components**	Because the casualty-related costs are included in the components for crashes, the components for casualties are removed to avoid double counting .
Hungary	**Data completeness**	The total costs, for each of the severity categories, is calculated by multiplying the unit costs and the number of casualties or crashes. The number of crashes/casualties is added from the CARE database.
	Edits for internal consistency	Due to large inconsistencies we went back to the original report and used non-updated data instead of the updated data that the expert sent us.

Iceland	**Standardization severity categories**	Cost per "injury or fatal crash" is not taken into account (repetition of costs described in other categories).
	Edits for internal consistency	The unit costs are adjusted to the same year as the crash/casualty data (from 2013 to 2015).
	To give the distribution of of the total costs over cost components	Because the cost components of PDO crashes were not given, these were added these under "other costs".
Ireland	**Inconsistencies that dit not lead to an edit**	The sum of the cost components is not equal to the cost per unit because different data sources are used.
Italy	**Standardization severity categories**	Cost per "injury severity not specified" is not taken into account (repetition of costs described in other categories). Only the total number of injured was given. The number of serious and slight injuries is back-calculated using other information in the questionnaire.
	To give the distribution of of the total costs over cost components	The distribution of costs over cost components can only be given for unit costs and not for total costs because there is no separate crash/casualty data for serious and slight injuries.
Latvia	**Standardization severity categories**	"Property damage" was changed to "cost per PDO crash". This is not correct, as this item also includes property damage costs for fatal and injury crashes. But doing so allowed to estimate total costs correctly. For the Value Transfer exercise as described in Chapter 6, this value was omitted, and property damage estimated from values of other countries.
	Data completeness	The total costs, for each of the severity categories, is calculated by multiplying the unit costs and the number of casualties or crashes.
	To give the distribution of of the total costs over cost components	The distribution over cost components is only given for total crashes, and not per severity category.

Lithuania	**Data completeness**	The total costs, for each of the severity categories, is calculated by multiplying the unit costs and the number of casualties or crashes. The number of crashes/casualties is added from the CARE database.
	Edits for internal consistency	Due to large inconsistencies we decided to use a different report with more consitent data.
Netherlands	**Standardization severity categories**	"Other injuries" was collapsed with the existing category "slight injuries".
Norway	**Standardization severity categories**	"Very serious injuries" was collapsed with the existing category "serious injuries".
	Data completeness	The cost per unit, in each of the severity categories, is calculated from the sum of the costs per component.
	To give the distribution of of the total costs over cost components	Because the crash-related costs are included in the cost components for casualties, the components for crashes are removed to avoid double counting .
Poland	**Standardization severity categories**	Cost per "collision" was changed to cost per "PDO crash". Cost per "crash" is not taken into account (repetition of costs described in other categories). Only total costs for the total number of injured was given. Separate total costs for serious and slight injuries was back-calculated using other information in the questionnaire.
	Data completeness	The number of PDO crashes is calculated by dividing the total costs for PDO crashes by the unit cost per PDO crash.
Portugal	**Data completeness**	Due to large inconsistencies we decided to use a different report with consistent data.
	To give the distribution of of the total costs over cost components	The distribution over cost components is only given for total crashes, and not per severity category.
Serbia	**Edits for internal consistency**	The cost per fatality is removed because it was higher than the cost per fatal crash.

	To give the distribution of of the total costs over cost components	The distribution of costs over cost components can only be given for unit costs and not for total costs s because the cost components refer to a different region, and it does not make sense to multiply these costs with Serbian crash/casualty data.
	Inconsistencies that dit not lead to an edit	The sum of the cost components is not equal to the cost per unit because the cost components are based on a study performed in Republika Srpska (a part of Bosnia Herzegovina). The cost components were only available for the original study, while the unit costs were adjusted for Serbia.
Slovakia	**Data completeness**	The number of PDO crashes is calculated by dividing the total costs for PDO crashes by the unit cost per PDO crash.
	Inconsistencies that dit not lead to an edit	The result of multiplying the unit costs with the number of crashes or casualties from the related severity category is not equal to the total costs for that severity category. The differences found have no clear explanation.
Slovenia	**Standardization severity categories**	Cost per "victim without an injury" is not taken into account (does not fit any standard category).
	Inconsistencies that dit not lead to an edit	The result of multiplying the unit costs with the number of crashes or casualties from the related severity category is not equal to the total costs for that severity category. The differences found have no clear explanation.
Spain	**Edits for internal consistency**	The total costs for fatalities was not filled in correctly, it was replaced by the multiplication of the number of fatalities and the cost per fatality.
Sweden	**Inconsistencies that dit not lead to an edit**	The sum of the cost components is not equal to the cost per unit because the data refered to different years. The unit costs and the crash/casualty data are expressed for 2014, except for the number of PDO crashes, which is only given for 2005.
Switzerland	**Standardization severity categories**	"Disabled" and "moderately injured" were collapsed with the existing category "serious injuries".
	Inconsistencies that dit not lead to an edit	The result of multiplying the unit costs with the number of crashes or casualties from the related severity category is not equal to the total costs for that severity category because the data refer to different years.

UK	**Inconsistencies that dit not lead to an edit**	The sum of the cost components is not equal to the cost per unit because different data sources are used.

Appendix E Costs per casualty/crash and definitions of serious injuries

	Costs per casualty (EUR 2015, PPP adjusted)			Definition serious injury	Costs per crash (EUR 2015, PPP adjusted)			
country	fatality	serious injury	slight injury		fatal	serious injury	slight injury	PDO
Austria	3,014,655	381,285	26,880	> 24 days sick-leave or equivalent impairment (judged by the police)	3,204,602	432,355	34,475	5,242
Belgium	2,021,091	307,364	19,766	> 24 hours in hospital after crash				
Bulgaria	1,355,315	220,390	57,267	Severe physical injury (specifications available, e.g. loss of a limb or arm, blindness, life threatening health problems)	1,422,308	282,696	74,705	
Croatia	2,230,967	290,042	22,259	-				
Cyprus	1,027,088	135,535	9,921	-				
Czech Republic	1,210,198	295,199	24,922	severe (non-fatal) injury, as determined by a doctor				15,168
Denmark	2,011,006	344,536	51,898	-				

	Costs per casualty (EUR 2015, PPP adjusted)			Definition serious injury	Costs per crash (EUR 2015, PPP adjusted)			
country	fatality	serious injury	slight injury		fatal	serious injury	slight injury	PDO
Estonia	2,819,426	959,011	36,802	receiving permanent disability compensation				
Finland	2,340,452	671,383	29,111	-	2,462,633			2,707
France	2,944,662	368,029	14,070	> 24 hours in hospital after crash				4,514
Germany	1,177,194	119,480	4,954	> 24 hours in hospital after crash	47,430	21,622	14,021	6,479
Greece	2,171,344	252,277	41,971	-	2,256,488	259,628	50,959	3,044
Hungary	2,147,976	501,194	553	> 48 hours in hospital or fracture, or suffering specific injuries (e.g. facture, internal injuries, burn)				
Iceland	2,861,281	364,914	71,742	specific injuries, e.g. fracture, concussion, shock requiring medical treatment	3,897,933	510,584	179,650	8,273
Ireland	1,965,163	225,511	20,860	hospital admission or specific injury (e.g. fracture, concussion, internal injuries, crushings)	2,257,825	323,845	30,391	2,443

	Costs per casualty (EUR 2015, PPP adjusted)			Definition serious injury	Costs per crash (EUR 2015, PPP adjusted)			
country	fatality	serious injury	slight injury		fatal	serious injury	slight injury	PDO
Italy	1,615,566	211,860	18,245	> 24 hours in hospital after crash	11,801	12,020	12,020	
Latvia	1,141,935	28,205	296	> 24 hours in hospital after crash				6,586
Lithuania	988,981	89,804		-				
Luxembourg				> 24 hours in hospital after crash				
Malta	1,597,160	203,913	15,159	-				
Netherlands	2,504,928	269,149	6,031	hospital admission and injury severity MAIS2+				3,376
Norway	2,690,394	845,812	52,970	life-threatening or leading to permanent impairment (very serious) and specific injuries, mostly requiring in-patient hospital treatment	3,158,354	945,576	69,356	2,286

	Costs per casualty (EUR 2015, PPP adjusted)			Definition serious injury	Costs per crash (EUR 2015, PPP adjusted)			
country	fatality	serious injury	slight injury		fatal	serious injury	slight injury	PDO
Poland	814,504	975,074	11,536	-				16,905
Portugal	838,109	136,365	35,391	-	921,422	168,983	47,649	
Romania				-				
Serbia				overnight hospital stay or specific injuries (e.g. fractures, concussion, internal injuries, crushing)	782,342	84,058	7,843	
Poland	814,504	975,074	11,536	-				16,905
Slovakia	652,238	141,504	20,767	severe health impact (not specified)				12,398
Slovenia	2,118,429	247,550	24,412	life threatening injury or permanently/temporary inability to work	41,093	15,192	13,433	7,052
Spain	1,592,359	254,777	6,938	-				
Sweden	2,160,235	399,728	19,561	-				1,276
Switzerland	1,657,430	214,023	9,428	inability to work or carry out daily activities > 3 months				

	Costs per casualty (EUR 2015, PPP adjusted)			Definition serious injury	Costs per crash (EUR 2015, PPP adjusted)			
country	fatality	serious injury	slight injury		fatal	serious injury	slight injury	PDO
UK	2,028,793	227,979	17,575	hospital admission or specific injury (e.g. fracture, concussion, internal injuries, crushings)	2,283,687	260,543	27,500	2,435

Appendix F Number of casualties and crashes used in value transfer calculations

Country	Fatalities	Serious injuries	Slight injuries	Fatal crashes	Serious injury crashes	Slight injury crashes	PDO crashes
	Values based on value transfer in italics, other values are original values						
Austria	523	10,502	34,522	429	9,262	26,917	646,553
Belgium	841	5,982	54,381	702	5,346	41,489	*331,370*
Bulgaria	708	2,738	6,233	*658*	*2,379*	*4,637*	*37,981*
Croatia	426	3,184	15,155	*396*	*2,767*	*11,275*	*92,347*
Cyprus	57	377	570	56	324	280	*3,473*
Czech Republic	688	2,703	23,655	*640*	*2,349*	*17,599*	64,805
Denmark	182	1,797	1,396	*169*	*1,562*	*1,039*	7,964
Estonia	67	467	1,756	61	433	1,345	29,218
Finland	229	519	6,186	208	475	4,641	478,863
France	3,557	26,635	46,413	*3,306*	*23,147*	*34,531*	3,155,290

Country	Fatalities	Serious injuries	Slight injuries	Fatal crashes	Serious injury crashes	Slight injury crashes	PDO crashes
	Values based on value transfer in italics, other values are original values						
Germany	3,377	67,732	321,803	3,187	58,744	240,504	2,104,250
Greece	795	1,016	13,548	739	854	10,097	*82,555*
Hungary	740	5,671	15,246	*688*	*4,928*	*11,343*	*92,901*
Iceland	16	178	1,130	16	155	741	5,500
Ireland	188	508	6,252	179	398	4,399	21,734
Italy	4,090	42,768	255,877	3,847	29,724	177,833	*1,559,185*
Latvia	559	4,369	1,890	*520*	*3,797*	*1,406*	34,510
Lithuania	265	817	3,072	*246*	*710*	*2,286*	*18,719*
Luxembourg	36	319	1,029	33	*277*	*766*	*6,270*
Malta	9	300	1,290	*8*	*261*	*960*	*7,861*
Netherlands	720	18,600	288,000	*669*	*16,164*	*214,273*	1,021,000
Norway	160	693	5,670	148	597	4,380	403,719
Poland	3,202	11,696	30,849	*2,976*	*10,164*	*22,952*	*187,978*
Portugal	741	2,637	43,924	674	2,128	32,624	*267,651*

Country	Fatalities	Serious injuries	Slight injuries	Fatal crashes	Serious injury crashes	Slight injury crashes	PDO crashes
	Values based on value transfer in italics, other values are original values						
Romania	1,818	8,122	24,212	*1,690*	*7,058*	*18,014*	*147,536*
Serbia	688	3,544	14,891	*640*	*3,080*	*11,079*	*90,738*
Slovakia	296	1,122	5,316	*275*	*975*	*3,955*	13,240
Slovenia	120	932	7,778	112	868	5,605	11,358
Spain	1,688	19,891	477,022	*1,569*	*17,286*	*354,907*	*2,906,732*
Sweden	270	2,395	15,130	*251*	*2,081*	*11,257*	71,340
Switzerland	247	13,860	65,950	*230*	*12,045*	*49,067*	*401,866*
UK	1,775	22,807	169,895	1,658	20,676	123,988	2,232,305

Appendix G Unit costs used in value transfer calculations

country	Fatalities	Serious injuries	Slight injuries	Fatal crashes	Serious injury crashes	Slight injury crashes	PDO crashes
	Values based on value transfer in italics, other values are original values (EUR 2015, PPP corrected)						
Austria	*3.026.912*	*395.804*	*33.469*	*3.433.427*	*454.379*	*45.518*	*6.407*
Belgium	*2.519.610*	*311.916*	*30.203*	*2.851.136*	*360.419*	*41.129*	*3.960*
Bulgaria	*2.269.346*	*303.130*	*27.418*	*2.579.089*	*350.796*	*37.340*	*3.960*
Croatia	*2.710.496*	*336.421*	*32.056*	*3.067.298*	*388.434*	*43.649*	*3.960*
Cyprus	*2.269.346*	*303.130*	*27.418*	*2.579.089*	*350.796*	*37.340*	*3.960*
Czech Republic	*2.769.658*	*475.705*	*39.454*	*3.174.119*	*546.769*	*53.586*	*15.725*
Denmark	*2.507.875*	*310.064*	*30.076*	*2.837.765*	*358.308*	*40.955*	*3.960*
Estonia	*2.269.346*	*303.130*	*27.418*	*2.579.089*	*350.796*	*37.340*	*3.960*
Finland	*2.344.090*	*671.796*	*29.630*	*2.738.535*	*758.752*	*40.225*	*3.107*
France	*2.269.346*	*303.130*	*27.418*	*2.579.089*	*350.796*	*37.340*	*3.960*
Germany	*2.290.290*	*312.275*	*27.080*	*2.595.778*	*354.640*	*40.488*	*6.160*

country	Fatalities	Serious injuries	Slight injuries	Fatal crashes	Serious injury crashes	Slight injury crashes	PDO crashes
	Values based on value transfer in italics, other values are original values (EUR 2015, PPP corrected)						
Greece	*2.073.052*	*326.936*	*25.730*	*2.361.302*	*375.123*	*35.045*	*3.960*
Hungary	*2.269.346*	*303.130*	*27.418*	*2.579.089*	*350.796*	*37.340*	*3.960*
Iceland	*3.286.828*	*426.474*	*86.735*	*3.747.143*	*511.801*	*118.012*	*3.960*
Ireland	*1.926.445*	*223.237*	*21.460*	*2.177.073*	*257.144*	*29.238*	*3.355*
Italy	*2.624.019*	*390.809*	*34.849*	*2.995.757*	*450.705*	*47.448*	*3.960*
Latvia	*2.269.346*	*303.130*	*27.418*	*2.579.089*	*350.796*	*37.340*	*3.960*
Lithuania	*2.269.346*	*303.130*	*27.418*	*2.579.089*	*350.796*	*37.340*	*3.960*
Luxembourg	*2.269.346*	*303.130*	*27.418*	*2.579.089*	*350.796*	*37.340*	*3.960*
Malta	*2.134.307*	*258.120*	*25.601*	*2.413.488*	*298.680*	*34.870*	*3.960*
Netherlands	2.504.928	269.189	*25.123*	*2.825.445*	*309.854*	*34.168*	*3.376*
Norway	*2.694.031*	*846.225*	*53.489*	*3.172.105*	*962.867*	*72.673*	*2.687*
Poland	*2.269.346*	*303.130*	*27.418*	*2.579.089*	*350.796*	*37.340*	*3.960*
Portugal	*2.269.346*	*303.130*	*27.418*	*2.579.089*	*350.796*	*37.340*	*3.960*
Romania	*2.269.346*	*303.130*	*27.418*	*2.579.089*	*350.796*	*37.340*	*3.960*

country	Fatalities	Serious injuries	Slight injuries	Fatal crashes	Serious injury crashes	Slight injury crashes	PDO crashes
	Values based on value transfer in italics, other values are original values (EUR 2015, PPP corrected)						
Serbia	*2.532.142*	*268.339*	*25.681*	*2.861.308*	*310.532*	*34.854*	*8.435*
Slovakia	*2.204.722*	*337.459*	*34.201*	*2.520.159*	*390.891*	*46.565*	*11.724*
Slovenia	*2.020.686*	*250.529*	*28.879*	*2.305.474*	*292.669*	*42.068*	*6.998*
Spain	*2.158.661*	*280.981*	*17.498*	*2.441.823*	*320.491*	*23.851*	*3.960*
Sweden	*2.110.496*	*294.725*	*17.282*	*2.389.274*	*335.454*	*23.431*	*1.568*
Switzerland	*1.666.155*	*223.155*	*17.543*	*1.891.406*	*255.639*	*23.910*	*3.960*
UK	*2.293.243*	*263.673*	*28.413*	*2.592.437*	*305.087*	*38.694*	*3.516*