Costs related to serious road injuries

Deliverable 7.3

Costs related to serious road injuries

Work package 7, Deliverable 3

Please refer to this report as follows:
Schoeters, A., Wijnen ,W., Carnis, L., Weijermars, W., Elvik, R., Johannsen, H., Vanden Berghe, W., Filtness, A. and Daniels, S. (2017), Costs related to serious injuries, D7.3 of the H2020 project SafetyCube.

Grant agreement No 633485 - SafetyCube - H2020-MG-2014-2015/ H2020-MG-2014_TwoStages

Project Coordinator:
Professor Pete Thomas, Transport Safety Research Centre, Loughborough Design School, Loughborough University, Ashby Road, Loughborough, LE11 3TU, UK

Project Start date: 01/05/2015

Duration: 36 months

Organisation name of lead contractor for this deliverable:
SWOV, The Netherlands

Report Author(s):
Schoeters, A., Vanden Berghe, W., Daniels, S. (BRSI), Belgium
Wijnen, W., Weijermars, W. (SWOV), The Netherlands
Carnis, L. (IFSTTAR), France
Elvik, R. (TOI), Norway
Johannsen, H. (MHH), Germany
Filtness, A., (LOUGH), UK

Due date of deliverable:	**01/05/2017**	**Submission date:**	**30/04/2017**

Project co-funded by the by the Horizon 2020 Framework Programme of the European Union
Version: Final version
Dissemination Level: PU Public

Co-funded by the Horizon 2020
Framework Programme of the European Union

Table of contents

Executive summary

SafetyCube is a European Commission supported Horizon 2020 project that aims to develop an innovative road safety Decision Support System (DSS). Work Package 7 is dedicated to serious road injuries, their health impacts and their costs. The aim of this deliverable is to discuss the costs that are related to serious road injuries. This deliverable will deal with both the cost estimations in different countries and a more detailed discussion on three cost components: human costs, medical costs and costs related to production loss.

Costs related to serious injuries consist of different cost components. Six principal cost components have been defined: medical costs, production loss, human costs, administrative costs, property damage and other costs. The components that are most relevant for serious injuries are medical costs, production loss and human costs. These costs consist of different items and there are internationally recommended methods to estimate these cost components. Furthermore, crashes with serious road injuries also induce crash-related costs, including: property damage, administrative costs and other costs. These costs contribute however to a lesser extent to the total costs related to serious injuries.

Crash cost estimates in 32 European countries (EU28 + Iceland, Norway, Serbia and Switzerland) were collected by means of a survey. The data collection was a joint effort with the InDeV project, within SafetyCube the questionnaires were integrated into a SQLite database and corrections were made. For all countries except Romania and Lithuania, some information on costs of serious road injuries was available.

The survey revealed considerable differences between countries. The individual cost per serious injury varies between €28,205 and €975,074. At a country level, the total costs related to serious injuries varies between 0.04% and 2.7% of the country's Gross Domestic Product (GDP), and accounts for 14 to 77% of the total costs of road crashes. While the values of the cost per serious injury appear to be higher in Northern European countries and in some Eastern European countries, there was no geographical pattern when considering the total serious injury costs per country. Some of the country results might be biased by differences in the methods used for calculating the human costs, differences in the definition of a serious injury and differences in the cost components that are included. Moreover, a higher reporting rate of serious injuries (the proportion of serious injuries to fatalities) appeared to result in lower costs per serious injury. This phenomenon can be explained by the fact that a higher reporting rate of serious injuries usually implies that more injuries of a lower severity are included in the cost calculations. Regarding the effect of the number of serious injuries per inhabitant on total costs, a positive relationship was only found after removing several outliers.

The analysis confirmed that medical costs, production loss and human costs constitute the most important cost components for serious injuries. While medical costs and production loss are generally estimated using the recommended methods, not all countries take all cost items into account. Non-hospital medical costs such as emergency treatments or post-hospital care, as well as non-market production loss resulting from unpaid activities such as household work or voluntary work, are only taken into account by few countries.

Studies with data from Belgium, France, Germany, Greece and Italy reveal more detailed information on medical costs and production loss. The studies show the influence of certain characteristics of traffic victims on the level of medical costs. Age, socio-economic status, type of injury, injury severity, health status (pre-existing comorbidities) and road user type appear to have a significant influence on the medical costs attributable to a road crash. Particularly older victims and people with a worse health status at the moment of the crash have both higher acute costs (related to the initial hospital stay) and higher longer term costs (one year or more after the crash). This implies that when estimating medical costs for cost-benefit analysis, one should ideally take into account certain characteristics of potential traffic victims such as the age, the socio-economic status and the health status. This also means that, due to an increasingly older population in many countries, traffic related healthcare costs might increase in the future, even with a stagnating or decreasing number of road crashes. Also different evolutions of costs over time were found according to the victim's characteristics.

With regards to production loss it is shown that revenue loss increases when injury severity is higher. A French study found a considerably higher average revenue loss for MAIS3 injuries than for MAIS1 and MAIS2 injuries whereas revenue losses for MAIS4 and MAIS5 injuries were only slightly higher than for MAIS3 injuries. Furthermore the revenue loss appears to differ between professional groups such as self-employed persons, employees and students. These differences can further be explained by different levels of labour market participation, average wage and average length of absence between professional groups.

The data analysis showed that - for those countries that take these cost components into account - medical costs and production loss constitute on average 18% of the cost of a serious injury.

Next to material costs such as medical costs and production loss a road crash also involves immaterial costs. These immaterial or 'human' costs are the costs of pain, grief, sorrow and mainly the loss of quality of life due to the injuries caused by the road crash. Contrary to material costs, these costs have no market value. To facilitate inclusion of these costs in a cost-benefit analysis, there are different approaches to attribute a (monetary) value to this type of consequences. Three methods are described and compared: the Willingness To Pay (WTP) method, the Quality Adjusted Life Years (QALY) approach and the court awards approach.

The data analysis of crash costs in 32 countries reveals that immaterial costs represent a share varying from 10% to 91% of the total costs related to serious injuries. Their share depends on the method used to estimate these costs: when the WTP method is applied, these costs tend to be much higher.

While the WTP approach and the QALY approach need complex studies for which there are some methodological issues, the court awards approach makes use of available information on compensation payments awarded by courts to injured road victims. These values are generally much lower than those obtained in WTP and QALY studies. However the values appear to be unpredictable since they are highly dependent on the judicial system. Further it is important that costs as an input for cost-benefit analysis are grounded on economic welfare theory, which means that the values should be based on individual preferences, and that the values are determined ex ante. This is not the case for court awards. Therefore it is recommended to use direct WTP studies or QALYs instead of court awards to estimate the monetary costs of non-fatal injuries.

1 Introduction

SafetyCube aims to develop an innovative road safety Decision Support System. Work Package 7 is dedicated to serious road traffic injuries, their health impacts and their costs. This Deliverable discusses the costs that are related to serious road injuries. It discusses cost estimates in different European countries, as well as a more detailed discussion on medical costs, costs related to production loss and human costs for serious road injuries.

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 accident 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 accident 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.

Work Package 7 is dedicated to serious road traffic injuries, their health impacts and their costs. The main objectives of this work package are to:

1. assess and improve the estimation of the numbers of serious road traffic injuries,
2. determine and quantify health impacts of serious road traffic injuries,
3. estimate economic and immaterial costs related to serious road traffic injuries,
4. identify key risk factors related to serious road traffic injuries and their health impacts.

1.2 PURPOSE OF THIS DELIVERABLE

The aim of this deliverable is to discuss the costs that are related to serious road injuries. It addresses the third objective of Work Package 7: "estimate economic and immaterial costs related to serious road traffic injuries". Next to the cost estimates in different European countries, this deliverable also covers a more detailed analysis of three types of cost components: medical costs, production loss and human costs.

The first part of this deliverable will focus on the estimations of costs related to serious road injuries in 32 countries. First, Chapter 2 will give a theoretical overview of the relevant cost components for serious injuries and the methods to estimate these costs. An overview and comparison of the estimations of different costs of serious road injuries for 32 countries is given in Chapter 3. These estimations were collected by means of a survey together with SafetyCube Work Package 3 for Deliverable 3.2 (Wijnen et al, 2017). While D3.2 deals with crash costs, this deliverable will focus on costs related to serious road injuries.

The second part of this deliverable gives more details on the three types of cost components that are relevant for serious injuries. Chapter 4 will give more detailed information on medical costs and costs related to production loss for serious road injuries in Belgium, France, Germany, Greece and Italy. The human costs related to serious road injury crashes will be discussed in Chapter 5. While Willingness To Pay (WTP) is the most common method used to estimate these 'immaterial costs', two alternative approaches are examined and compared with the WTP-method: the Quality Adjusted Life Years (QALY)-approach and the court award approach. Finally, Chapter 6 presents the conclusions and recommendations.

2 Costs related to serious road injuries

The following components of crash costs are most relevant for serious road injuries: medical costs, costs related to production loss and human costs. Besides, crashes with serious road injuries also lead to property damage costs, administrative costs and other costs. This chapter discusses how these costs related to serious road injuries can be calculated. For a more extensive description of the components of road crash costs and methods for calculating different types of costs, please see SafetyCube Deliverable 3.2.

The components of road crash costs and the recommended methods to estimate them are discussed in detail in *SatefyCube Deliverable 3.2 – Crash cost estimates for European Countries* (Wijnen et al, 2017). This chapter briefly discusses the cost components that are relevant in respect to serious road injuries and the recommended methods for estimating these costs.

In Deliverable 3.2 six cost components are distinguished, based on classifications in the literature (Alfaro et al., 1994; Wijnen & Stipdonk, 2016; Bickel et al., 2006; Trawén et al., 2002). These components are shown in Figure 2-1.

1- Medical costs
2- Production loss: the loss of production or productive capacities
3- Human costs: immaterial cost of lost quality of life and lost life years
4- Administrative costs: police, fire service, insurance, legal costs
5- Property damage: damage to vehicles, infrastructure, freight and personal property
6- Other costs, such as costs of congestion resulting from road crashes, vehicle unavailability and funeral costs

Figure 2-1 Cost components

A common classification of costs of road crashes, that has been introduced in the European COST313 guidelines (Alfaro et al, 1994), distinguishes between injury-related costs and crash-related costs. Following this classification, the six main components can be categorized as illustrated in Figure 2-2.[1]

This Deliverable focuses on costs related to serious road injuries and therefore focuses on injury-related costs, i.e. medical costs, costs related to production loss and human costs. Note that 'other costs' can be either injury-related (e.g. funeral costs) or crash-related (e.g. congestion costs). However, the main injury-related 'other costs' are funeral costs and these are not relevant for serious (non-fatal) road injuries. Therefore, this Deliverable focuses only on medical costs, costs related to production loss and human costs of serious road injuries. For each cost component, we discuss how the costs can be calculated.

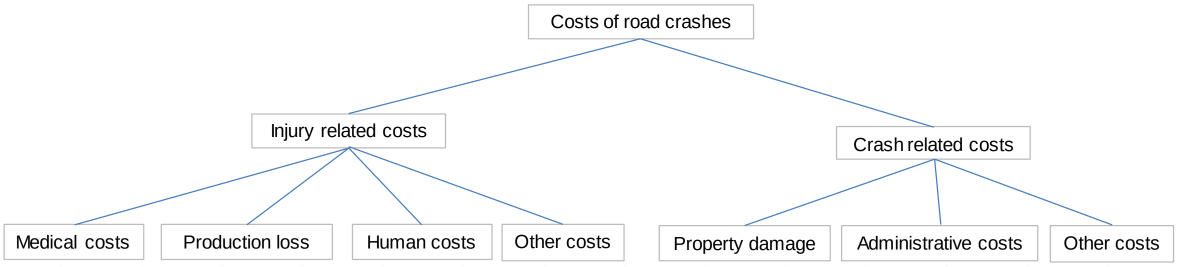

Figure 2-2 Classification of road crash costs: casualty- and crash-related costs

2.1 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 (Wijnen et al, 2017):

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.

Medical costs can be calculated by means of the so called Restitution Costs (RC) method. This means that the actual costs of medical treatment are calculated, such as the costs per overnight hospital stay. In addition to costs per 'unit' (per overnight hospital stay), this requires availability of detailed information about the number of 'units', such as the average duration of hospital stay of serious road injuries.

2.2 PRODUCTION LOSS

Production loss results from road casualties that cannot work anymore, either permanently (fatalities, serious injuries) or temporarily (injuries). The main cost item related to serious road injuries is loss of capacities of casualties to participate in market production due to disability or sick leave.

[1] 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.

These costs can be calculated by means of the so called Human Capital (HC)-approach. The production loss of a casualty is calculated by multiplying the period of time they are not able to work due to the crash with a valuation of the production per person per unit of time. 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). 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.

An issue related to the calculation of production loss is whether to calculate the 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[2], we recommend using the potential production loss approach, mainly because it is argued that economic welfare is determined by all available human capital (Baum et al, 2007) (for more information see D3.2).

Another issue related to the calculation of production loss is discounting. Discounting reflects the fact that people assign a higher value to available goods now than in the future. Therefore, future costs and benefits are given a lower weight in economic analyses, by means of applying a discount rate. This is also recommended for and applied in crash costs studies. On the other hand, a growth rate could 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.[3]

Another cost item related to production loss of serious road injuries is loss of future non-market production due to injuries: household work, taking care of children, and/or voluntary work. Non-market production can be substantial (e.g. 25% of total production loss in the US; Blincoe et al., 2014), and therefore ideally should be included in road crash cost studies. However, it is quite complex to calculate this production loss 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.

Note that road crashes also result in a loss of consumption: injured people may consume less due to their injuries. In this respect the literature makes a distinction between gross and net production loss. Gross production loss includes consumption loss, whilst net consumption loss is defined as gross production loss minus 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. Gross production loss is the most common measure for production loss (Wijnen & Stipdonk, 2016).

[2] Five out of nine countries (Australia, Austria, Germany, Netherlands and UK) in the review by Wijnen & Stipdonk (2016) apply the potential production approach, and the other four (Belgium, New Zealand, Switzerland and US) calculate actual production loss.
[3] 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.

Finally, a minor cost item related to production loss of serious road injuries is friction costs. These are costs for employers for recruiting and training new employees to replace casualties that cannot go back to their old job, and costs of vocational rehabilitation of casualties, such as cost of finding a new job and training.[4] These friction costs are calculated using the Restitution Costs method; the actual cost of resources (mainly labour) spent on recruiting and training new personnel are estimated. These costs can be estimated on the basis of time spent on recruitment and training and wages.

2.3 HUMAN COSTS

Human costs are the costs of pain, grief, sorrow and loss of quality of life. The main cost item relevant for serious injuries is loss of quality of life. There exist different methods to calculate these costs which are discussed in more detail in Chapter 5. The approach that is generally recommended is the Willingness To Pay (WTP) approach (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).

Another cost item that can be relevant for serious injuries is 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, that means that people take into account human costs for relatives and friends when stating their WTP.

2.3.1 Willingness To Pay (WTP) approach

The WTP approach is used to estimate the economic value of lost quality of life, since there is no market price for such impacts. A Willingness To Pay study estimates how much money an individual (individual WTP approach) or the society as a whole (social WTP approach) is willing to pay for a risk reduction. The results of a WTP study are used to derive the so called value of a statistical life (VOSL). This VOSL is subsequently used to calculate human costs of fatalities.

A distinction can be made between social and individual WTP (Alfaro et al., 1994). In a social WTP study, the VOSL can be derived for example from the (public) expenditures to prevent road casualties ('cost per life saved method'; De Blaeij et al., 2003). The individual WTP approach estimates how much individuals are willing to pay for a risk reduction. Reviews (e.g. De Blaeij et al., 2003; Lindhjem, 2010) show that the vast majority of VOSL studies are based on individual WTP. Also the standard value proposed in HEATCO (Bickel et al., 2005) is based on the individual WTP approach. This individual WTP approach is also consistent with economic welfare theory that states that welfare is determined by individual preferences: welfare is a function of the 'utility' of each individual in society (see for example Boardman et al, 2011). This utility is derived from consumption but also from intangible factors that affect the quality of life (e.g. nature, safety). The economic welfare theory constitutes the basis for cost-benefit analysis.

Note that the VOSL also comprises consumption loss (see e.g. Evans, 2001; Wijnen et al., 2009). As gross production loss (see section 2.2) also includes consumption loss, consumption loss should be deducted from the VOSL to obtain human costs and avoid double counting (Figure 2-3).

[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.

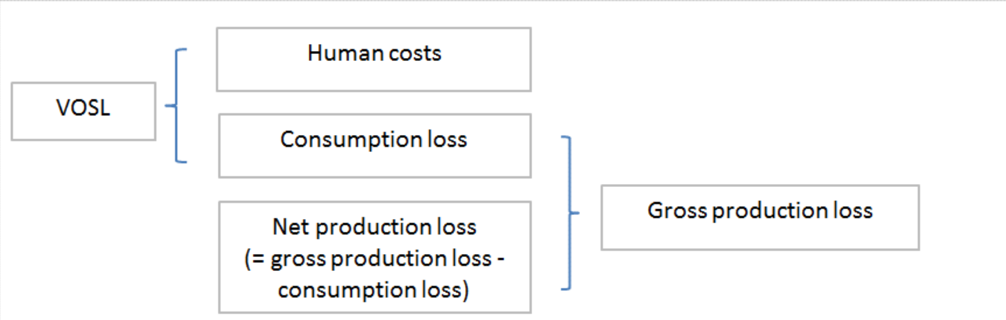

Figure 2-3 Relation between VOSL, human costs, production loss and consumption loss

Information about the human cost of serious and slight injuries is relatively poor compared to human costs of fatalities. WTP studies regarding injuries are very complex, amongst 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 where the WTP for reducing the risk of getting injured is estimated relative to the WTP for reducing fatal risk (ECMT, 1998; Bickel et al., 2006). More information on direct WTP studies to estimate human costs of injuries can be found in Chapter 5.

2.3.2 Other approaches

The US adopts a different approach for human costs of injuries, using the concept of Quality Adjusted Life Years (QALYs). 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 indirectly based on WTP.

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 deduct human costs from premiums people pay for life insurances or from public expenditures on improving (road) safety. Finally, sometimes the Human Capital (HC) approach, that measures the production loss of individuals, is considered as an alternative for the WTP approach. However, as discussed above the HC and WTP approaches 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).[5]

A discussion and comparison of different approaches to estimate human costs of injuries is covered in Chapter 5. 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). Moreover, the WTP approach is common practice in road crash cost studies (Wijnen & Stipdonk, 2016).

[5] Provided that a correction for double counting of consumption loss is made as discussed in section 2.3.1.

2.4 CRASH-RELATED COSTS

Crashes with serious road injuries also lead to property damage costs, administrative costs and other costs. Although these costs are related to crashes and not to injuries, they must be included in the calculation of costs of serious road injuries. Otherwise these costs would not be taken into account in estimating the total costs of road crashes with serious road injuries. Therefore, these costs are discussed briefly in this section. A more detailed discussion can be found in D3.2 (Wijnen et al, 2017).

2.4.1 Property damage

The main cost item related to property damage is damage to vehicles, in particular passenger cars. Wijnen & Stipdonk (2016) show that vehicle damage makes up 90% or more of all property damage. Other, minor property damage related cost items are damage to:

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

Property damage related costs can be estimated by means of the Restitution Costs (RC) method. The actual costs of repairing damage or replacing property is calculated. Vehicle damage costs can either be calculated by multiplying the average cost of car damage by the number of cars involved in crashes (bottom-up approach) or on the basis of insurance data on total payments (top-down).

2.4.2 Administrative costs

The main administrative cost items are (Wijnen et al, 2017):

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) Costs 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.
d) Legal costs, such as costs of prosecution of offenders who caused a road crash, costs of lawsuits resulting from road crashes, and costs of imprisonment.

Administrative costs are also calculated by means of the Restitution Costs (RC) method and these costs can in most cases also be calculated both bottom-up and top-down. In case of a bottom-up approach, the police costs are for example calculated 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). In case of a top-down 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) as a proportion of total time spending.

2.4.3 Other costs

The main other cost items related to crashes with serious road injuries which are usually included in costs studies are (Wijnen et al, 2017):

a) 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:

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

Congestion costs are calculated on the basis of time loss due to traffic jams resulting from crashes and the value of time (based on willingness to pay). Alternatively congestion costs can be calculated on the basis of total congestion costs and the proportion of time loss related to road crashes in total time loss due to (all) traffic jams. Congestion costs may also include costs of unreliability of travel times, costs of adapting travel behaviour to traffic jams, extra fuel costs and environmental damage (pollution). The other cost items can be calculated using the Restitution Costs (RC) approach.

2.5 SUMMARY

The table below summarizes the methodology for estimating costs of serious road injuries according to good practices as discussed in SafetyCube Deliverable 3.2 (Wijnen et al, 2017). The table makes a distinction between the main cost items that should in any case 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 usually not taken into account in cost studies, but the size may be substantial.

Cost component	Subcomponent	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 centers, general practitioners, etc.)	Restitution costs	
Minor	f) Aids and appliances	Restitution costs	
Production loss			
Main	a) Lost market production	Human capital	Calculation: production per person per year (e.g. GDP/capita or income) times lost productive years Gross production loss: including consumption loss Potential production loss Discounting future losses
Other	b) Lost non-market production (household work, taking care of children, voluntary work, etc.)	Human capital	Calculation: time spent on non-market production times 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	Loss of quality of life of serious road injuries	Willingness To Pay	Calculation: %VOSL *number of injuries
Other	c) Human costs for relatives and friends	Willingness To Pay	Not calculated separately: included in WTP injuries

Crash related costs			
Property damage			
Main	a) Vehicles	Restitution costs	Actual costs to repair damage or replace vehicles
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	
Administrative costs			
Main	a) Police costs	Restitution costs	Actual costs of resources of police assistance (labour, equipment)
	b) Fire service costs	Restitution costs	Actual costs of resources of fire service assistance
	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
Other	Other insurance costs	Restitution costs	All administrative costs related to other insurances (e.g. health)
Other costs			
Main	Congestion costs	Willingness To Pay	Time loss due to traffic jams resulting from road crashes
Minor	a)Vehicle unavailability	Restitution costs	Actual costs of replacing the vehicle (e.g. renting car and time costs)
	b)Visiting people in hospital	Restitution costs	Actual costs of visits, in particular travel costs and time costs
	c)Moving and house adaption cost	Restitution costs	Actual cost for moving and for adaptations (equipment, labour)

3 Costs of serious road injuries in European countries

By means of a survey that was distributed in collaboration with the InDeV project, we collected information on costs of crashes in European countries. Costs per serious injury appear to vary from €28,205 to €975,074. The total costs related to serious injuries vary between 0.04% and 2.7% of Gross Domestic Product (GDP) and serious injuries account for 14% to 77% of the total costs of road crashes. Human costs have the highest share in the costs of serious road injuries, followed by costs related to production loss and medical costs.

This chapter discusses the estimation of the costs of serious road injuries in 32 European countries (EU28 + Iceland, Norway, Serbia and Switzerland) that were collected by means of a survey. First the data collection and processing is described. Next the cost estimates are presented for all countries for which this information is available. Total costs of serious injuries, cost per serious injury or per serious injury crash and costs per cost component are presented and compared. For all countries except Romania and Lithuania, some information on costs of serious road injuries was available. While this chapter only focuses on costs related to serious injuries, information on the total cost of crashes and information on costs of other severities (fatalities, slight injuries and property damage only (PDO) crashes) can be found in SafetyCube Deliverable 3.2 (Wijnen et al, 2017).

3.1 DATA COLLECTION AND PROCESSING

Data on crash costs in European countries was collected together with the Horizon2020 project InDeV[6] and Work Package 3 of SafetyCube. Within SafetyCube the data was further processed and analysed for the purposes of comparing and analysing the costs in the different countries.

3.1.1 Data collection

The data collection process is described in more detail in Chapter 5.1 of the final InDev report (Kasnatscheew et al, 2016) and in Chapter 4 of SafetyCube Deliverable 3.2 (Wijnen et al, 2017). The data collection process is shown in Figure 3-1.

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

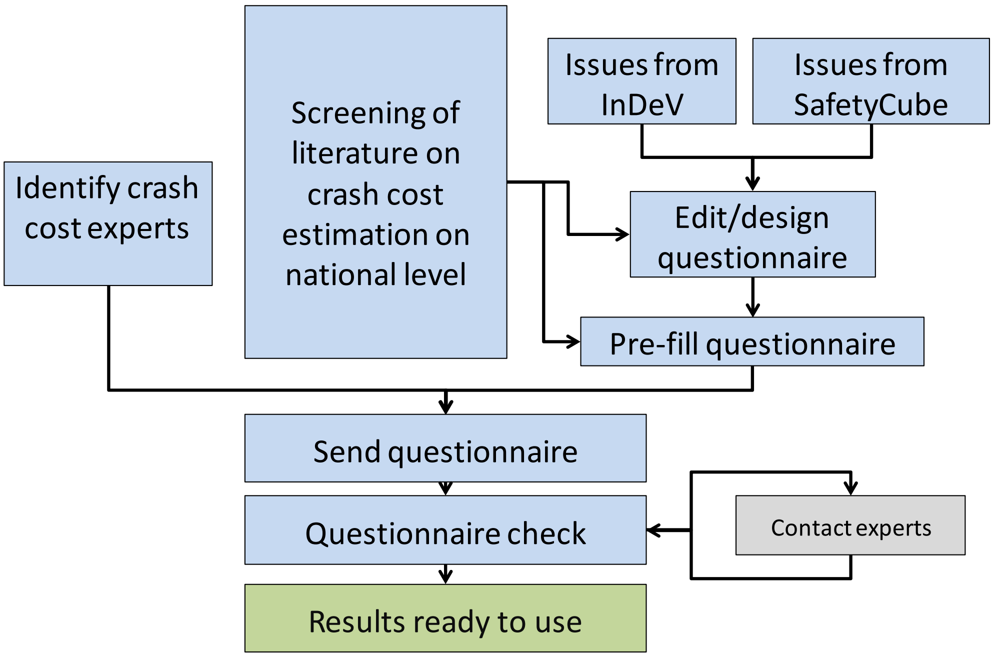

Figure 3-1 Workflow for joint InDeV-SafetyCube Survey (© InDeV)

Information was collected using an Excel based questionnaire. The questionnaire (see Appendix A) contained questions on definitions and methodologies, cost per crash/casualty, total cost of crashes and cost by cost component. Each partner involved in the relevant Tasks in InDeV and SafetyCube was responsible for completing the questionnaire for a number of countries. For each country, the questionnaire was pre-filled by the responsible partner on the basis of available information from reports and other publications. Subsequently, the information was checked and completed by an expert in each country. The experts were identified on the basis of the literature review and through existing contacts among the InDeV and the SafetyCube partners. A first round of validation was performed with a few key indicators and the experts were contacted again in case of suspected errors.

Eventually, experts from 17 countries have completed the questionnaires; 11 questionnaires were pre-filled by the respective InDeV and SafetyCube partners only. Very limited information was initially available from three countries (Bulgaria, Hungary and Greece), but detailed information was later obtained for Greece. No crash costs information could be obtained for Romania.

3.1.2 Data cleaning and analysis

Within SafetyCube, the Excel questionnaires were integrated into an SQLite database and the data was prepared for further 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 had to be made. Finally a standardisation for currency, inflation and Purchasing Power Parity(PPP) was made to prepare the data for a comparison in the descriptive statistics (see Appendix B).The process is described in more detail in Deliverable 3.2 (Wijnen et al, 2017). This section summarizes the main issues relevant for serious road injuries.

The categories 'serious road injuries' or 'serious injury crashes' are two of the seven standard severity categories[7] that are provided by the questionnaire. For some countries extra severity categories were defined. In order to allow integration of the responses, information in the extra

[7] 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) PDO crashes

categories was merged with one of the standard categories[8]. On the other hand there were also countries for which serious and slight injuries were combined. In that case the combined category was split into the standard categories by back-calculation using other elements in the questionnaire. For Lithuania, costs of serious and slight injuries were also combined, but not enough information was available to do the back-calculation. Therefore, no information is provided concerning the costs of serious road injuries in Lithuania.

Secondly the completeness of the questionnaires was examined. For many questionnaires not all the values were filled in, these values were completed when they could be calculated using data from other fields in the questionnaire.

Next the internal consistency of the values filled in on the questionnaire was checked. In case of inconsistencies the experts or the original report was consulted, 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 – than the one that was originally used – was consulted.

Internal consistency checks were used to:

- Check whether the sum of the costs for all (relevant) cost components per casualty/crash is equal to the total cost per crash/casualty for all severity levels.
- Check whether the cost per crash/casualties per severity level multiplied with the number of crashes/casualties equals the total costs per severity level.
- Check whether the sum of the total cost for each severity category is equal to the grand total reported in the questionnaire.
- Check whether the percentage of GDP reported in the questionnaire is equal to the percentage calculated by us.
- Check whether the crash/casualty data and the costs are provided for the same year.

Finally to make costs comparable across countries, all the cost data was standardised to EUR 2015. First the costs were updated to the price level of 2015 in their national currency using GDP deflators (source: Eurostat). 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)[9] (see Appendix B). Purchasing Power Parities (PPPs) 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).This adjustment was done to remove the differences in the cost estimates between countries that can be attributed to differences in purchasing power and thus make the estimates comparable.

3.2 COST PER SERIOUS INJURY (CRASH)

In this section we make a distinction between the cost per serious injury and the cost per serious injury crash. These costs were calculated for each of the countries, and are given in Appendix C. For all countries except Romania, Lithuania and Luxemburg, information on the cost per serious injury and/or the cost per serious injury crash was available. A comparison between countries is discussed in more detail in the sections below. All values are expressed in EUR price level 2015 and adjusted for relative income differences. The uncorrected values can be retrieved in SafetyCube Deliverable 3.2 (Wijnen et al, 2017).

[8] Norway makes a distinction between 'very serious injuries' and 'serious injuries' and Switzerland makes a distinction between 'disabled' and 'moderately injured'. For both countries, the categories were collapsed into the category 'serious road injuries'.

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

3.2.1 Cost per serious injury

The survey shows that the official estimates of the cost per serious injury differ considerably among the European countries. The values range from €28,205 in Latvia to €959,011 in Estonia and €975,074 in Poland (Figure 3-2). The median value[10] is €254,777. Geographically, the values per serious injury appear to be higher in Northern European countries and in some Eastern European countries (Poland, Estonia and Hungary) (Figure 3-3).

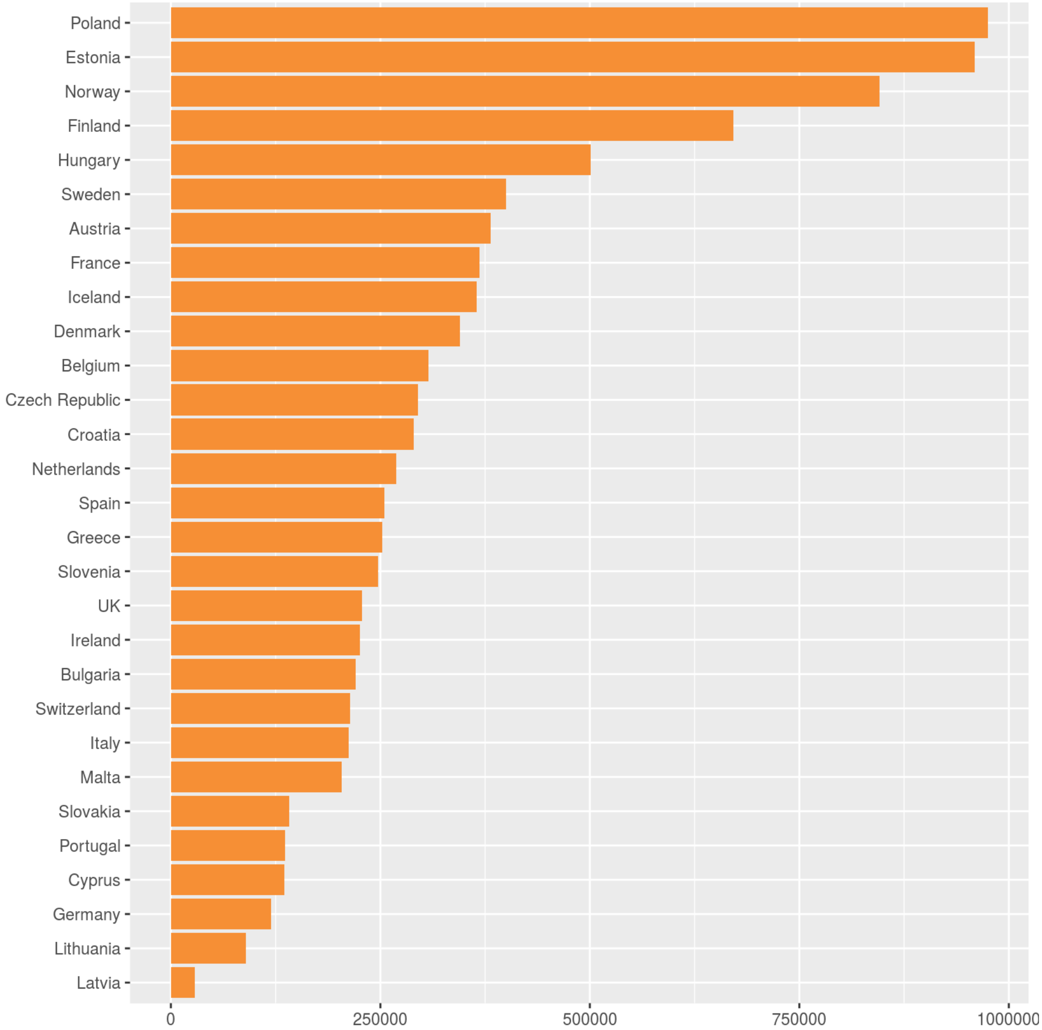

Figure 3-2 Costs per serious injury (EUR 2015, adjusted for PPP)

[10] Medians are used instead of means because means can be heavily influenced by extreme values.

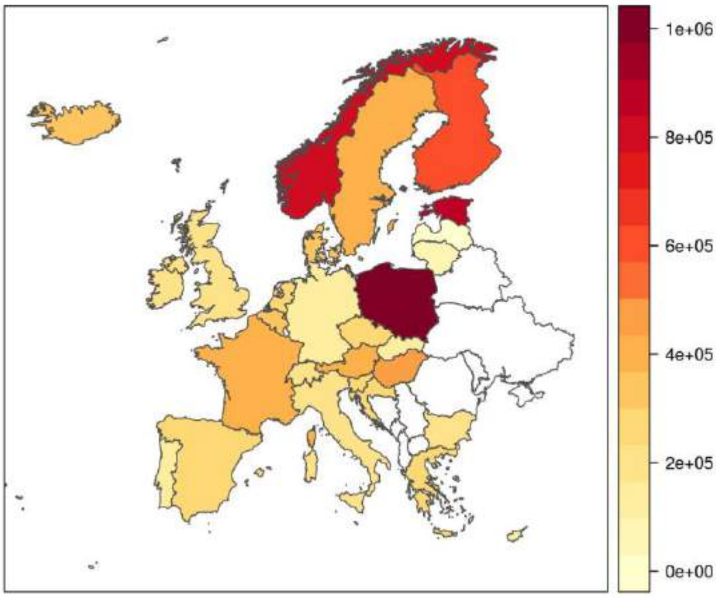

Figure 3-3 Costs per serious injury (EUR 2015, adjusted for PPP)

There are several different factors that could explain the differences in the cost per serious injury among the European countries:

- Differences in the definition of a serious road injury.
- Differences in the cost components that have been included.
- Differences in the methodology to calculate the different cost components.
- Differences in the reporting rate of serious injuries.

Definition of a serious injury

In contrast to the definition of a fatality (SafetyCube D3.2, Wijnen et al, 2017), the definition of a serious injury is very diverse among the included countries. Several countries use a criterion based on hospital admission (at least 24 or 48 hours), while other countries base their definition on the type and severity of the injury. Other countries use the duration of inability to work and whether or not disability payments are paid by insurance companies. The effect of the definition on the cost per serious injury is illustrated in Figure 3-4[11]. While it is difficult to find a pattern, we do find a higher cost per unit when a serious injury is defined by permanent disability payments and a hospital admission of more than 48 hours. Countries that use the definition of a hospital admission of more than 24 hours show average to low costs per unit (€368,029 to €11,948). The large variation in unit costs among countries that use the same definition indicates that there are certainly other elements that influence these differences. An overview of the specific definitions used in each country is given in Appendix D.

[11] Only the countries that had a definition and a cost per serious injury were included in the figure.

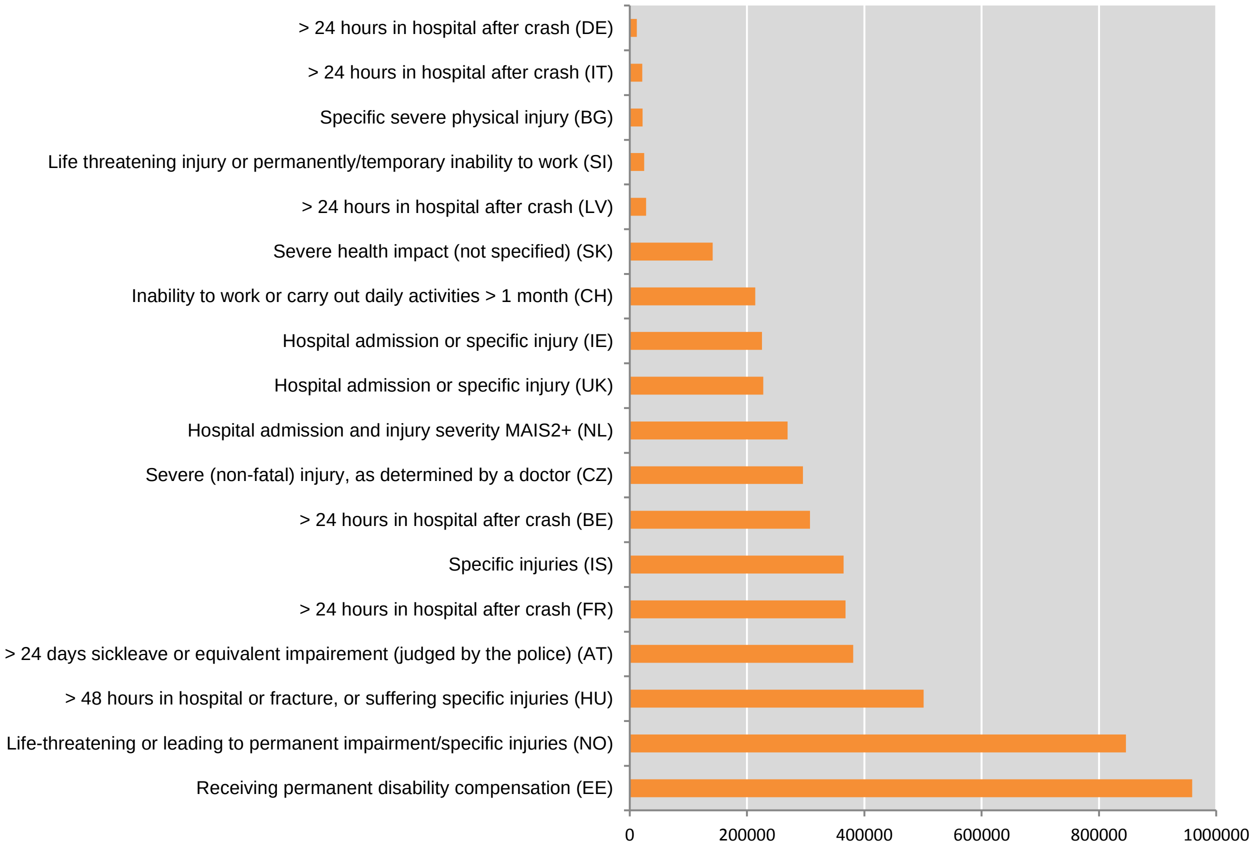

Figure 3-4 Cost per serious injury, according to the country specific definition of a serious injury (EUR 2015, adjusted for PPP)

Cost components included

Figure 3-5 shows how many countries have included each cost component in the cost per serious injury. First, this figure indicates that not all countries have included the same components, which can explain the variability in the cost per unit. Furthermore, most countries have included the injury-related cost components (medical costs, production loss and human costs), while the crash-related costs (property damage, administrative costs and other costs) are only included by 6 to 10 countries. Several countries have strictly separated casualty-related and crash-related costs, by including casualty-related costs only in cost per casualty and crash-related costs only in cost per crash, while other countries have assigned crash-related costs to casualties using information on the number of casualties per crash.

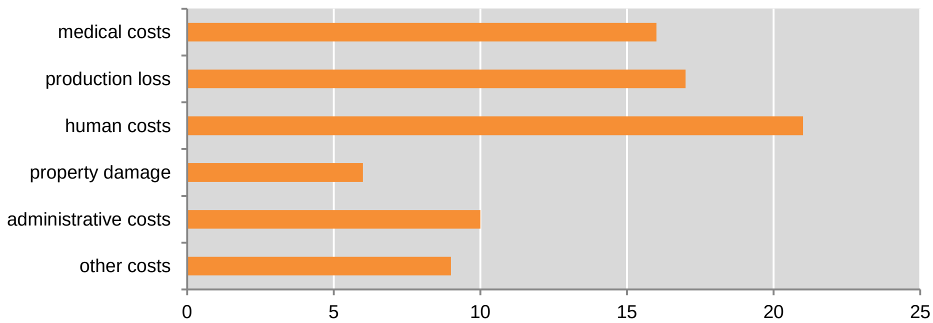

Figure 3-5 Number of countries for which cost components are included in the calculation of the cost per serious injury (EUR 2015, adjusted for PPP)

Methodology

The method used to calculate these components has a clear influence on the cost per serious injury. While all countries use generally the same method to calculate medical costs and production loss (Restitution Cost method and Human Capital method respectively), the method to calculate human costs differs widely among countries (Figure 3-6). This diversity reflects the intense discussion that has been going on over the last decades on the method to calculate human costs of (fatal) injuries, in particular whether or not a Willingness To Pay (WTP) method should be used (see for example Alfaro et al, 1994; Trawén et al, 2002; Wijnen & Stipdonk, 2016). In Chapter 5 different approaches to calculate human costs of injuries will be compared and discussed.

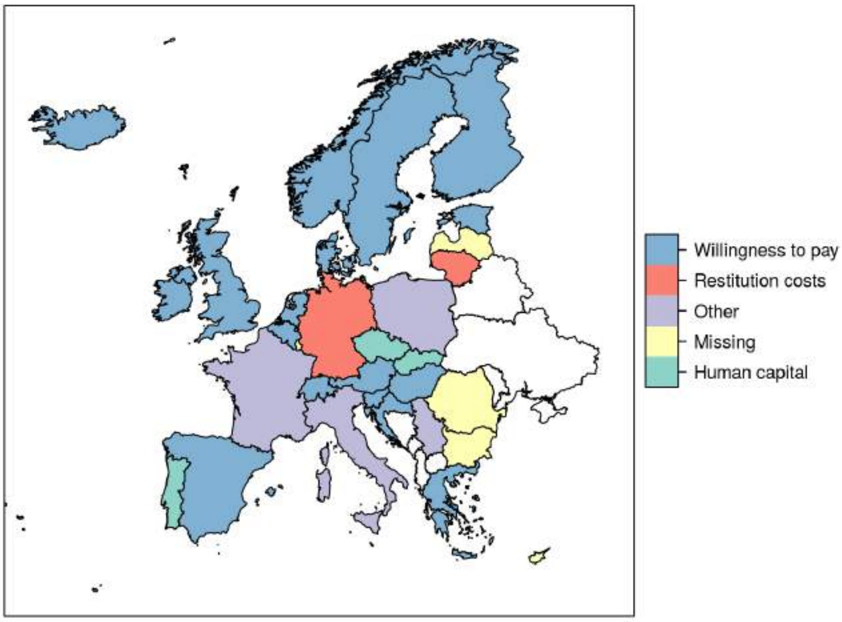

Figure 3-6 Methods used to estimate human costs of serious injuries

The differences in the method used to calculate human costs are all the more important since they represent a very large share of the cost per serious injury, and thus have a great impact on the cost per unit. This positive relationship between the human costs (of a serious injury) and the cost per serious injury is clearly illustrated in Figure 3-7; a linear regression shows that the human cost component explains 67% of the variability in the cost per serious injury (Adjusted R^2=0.67, p<0.001). This figure also shows the influence of the method used. Countries that applied the WTP method show the largest human costs (and thus cost per serious injury); if a factor 'WTP – non-WTP' is included in a linear regression model, the fraction of explained variation increases to 0.88 (Adjusted R^2=0.88, p<0.001).

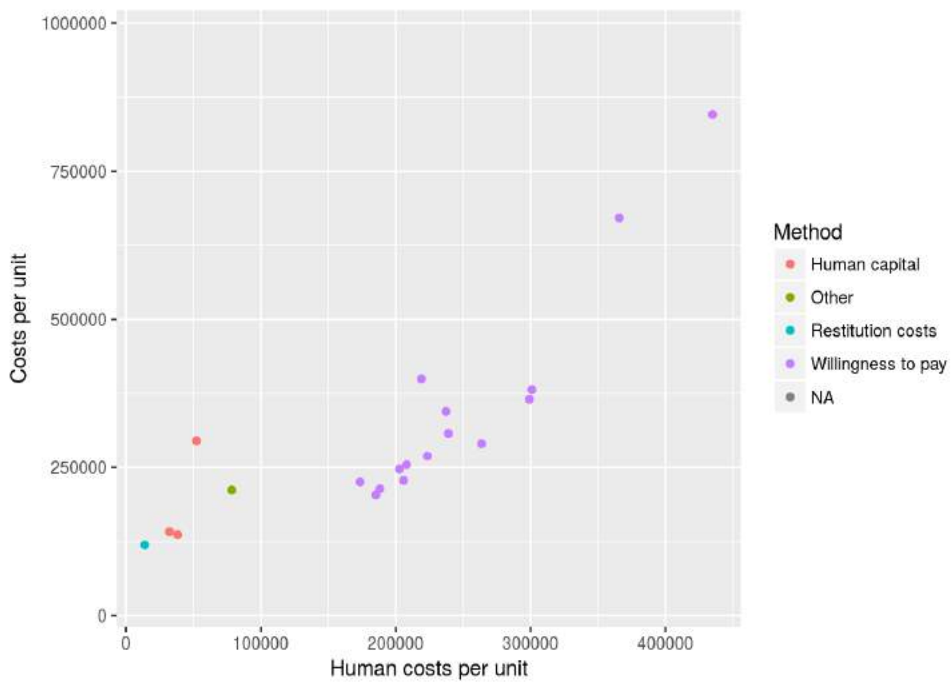

Figure 3-7 Relation between cost per serious injury and human cost per serious injury, for different methods used (EUR 2015, adjusted for PPP)

Several countries have indicated that human costs of serious injuries are determined as a percentage of the human costs of fatalities, but the questionnaire did not reveal detailed information on this issue.

Reporting rate

Finally the variation in the cost per serious injury can be explained by differences in the reporting rate (by the police or hospitals) of serious injuries. A higher reporting rate of serious injuries usually implies that more injuries of a lower severity are included in the cost calculations. This results in a relatively lower value per serious injury. This reporting rate is presented in Figure 3-8 as the number of serious injuries relative to the number of fatalities. The figure shows that a lower reporting rate of serious injuries is accompanied by relatively higher costs of a serious injury; after exclusion of two outliers, a linear regression shows that the reporting rate explains 23% of the variation of the cost of serious injuries (Adjusted R^2=0.23, p<0.01).[12]

[12] Greece and Latvia are regarded as outliers and therefore 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.

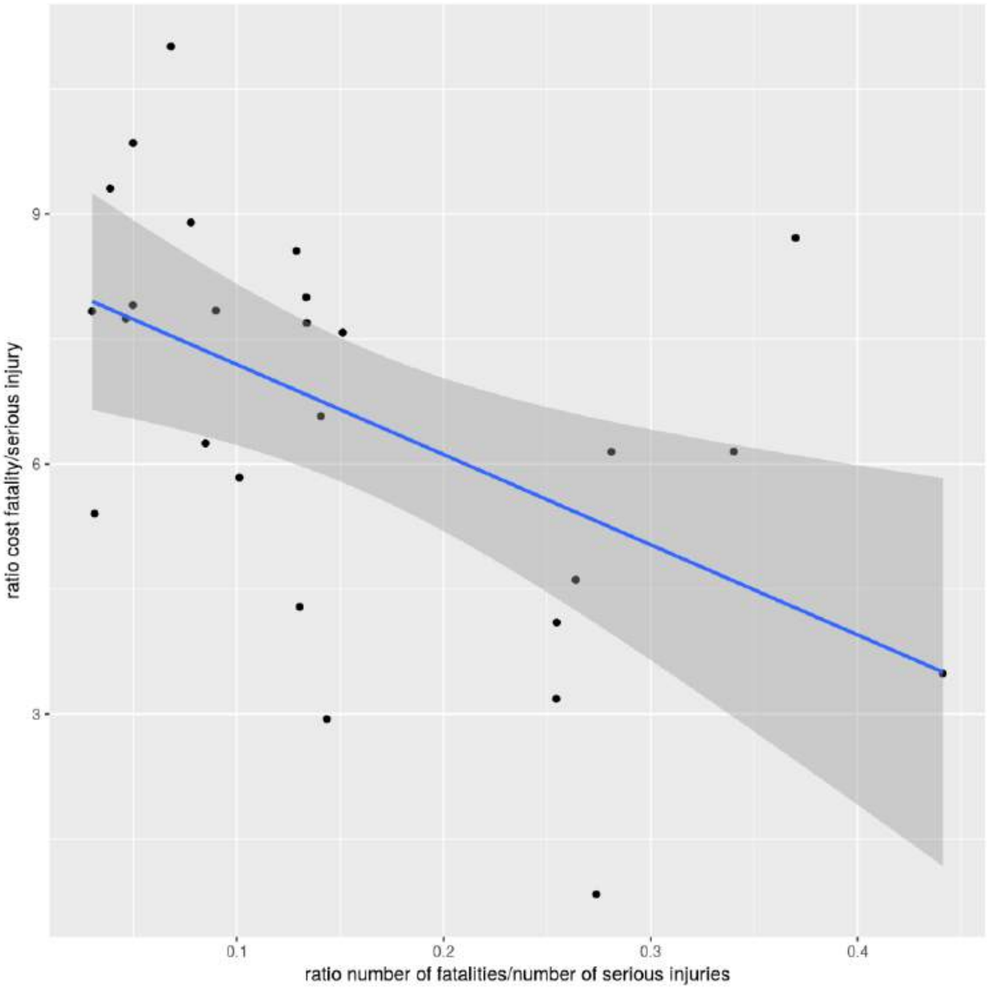

Figure 3-8 Relation between the ratio of number of fatalities and serious injuries and the ratio of cost per fatality and cost per serious injury

3.2.2 Cost per serious injury crash

In the survey almost all countries provided costs per serious injury, but only 12 countries provided information on the cost per serious injury crash. Serbia is the only country for which there is only information on the cost per serious injury crash (and not on the cost per serious injury). A comparison between the cost per serious injury and serious injury crash is presented in Figure 3-9. This figure shows a wide variability of the cost per serious injury crash: the values range between €12,019 in Italy and €945,576 in Norway (Appendix C).

This variability is mainly due to the fact that some countries have strictly separated casualty-related and crash-related costs. These countries only included casualty-related cost components in the cost per casualty, and included only crash-related components in the cost per crash. Other countries have assigned casualty-related costs to costs per crash using information on the number of casualties per crash.

The inclusion of the different cost components is illustrated in Figure 3-10. This heatmap shows how many countries have included each cost component in the cost per casualty and cost per crash by severity level. The red colour indicates that most countries have included a cost component while yellow indicates that few countries have included a cost component. When comparing the cost per serious injury and the cost per serious injury crash, it can be noticed that medical costs, production loss and human costs are not always included in the cost per serious injury crash. Likewise, the cost per serious injury does not always include property damage costs, administrative costs and other costs.

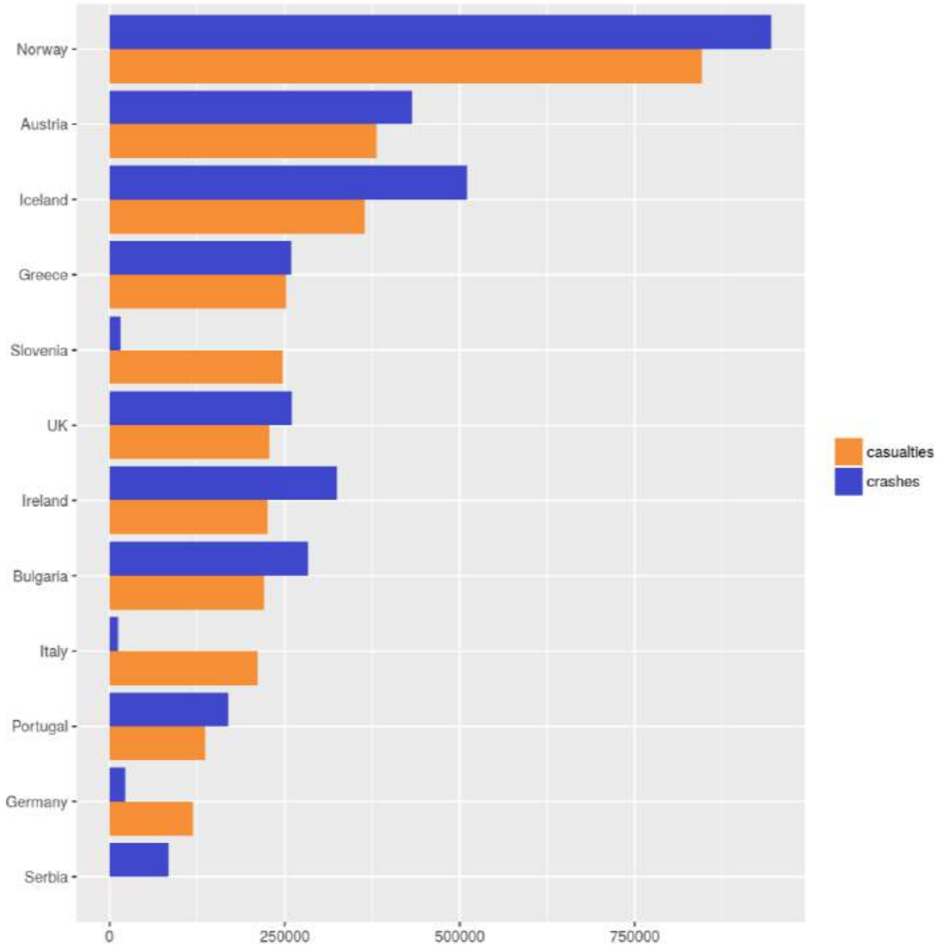

Figure 3-9 Cost per serious injury and cost per serious injury crash (EUR2015, adjusted for PPP)

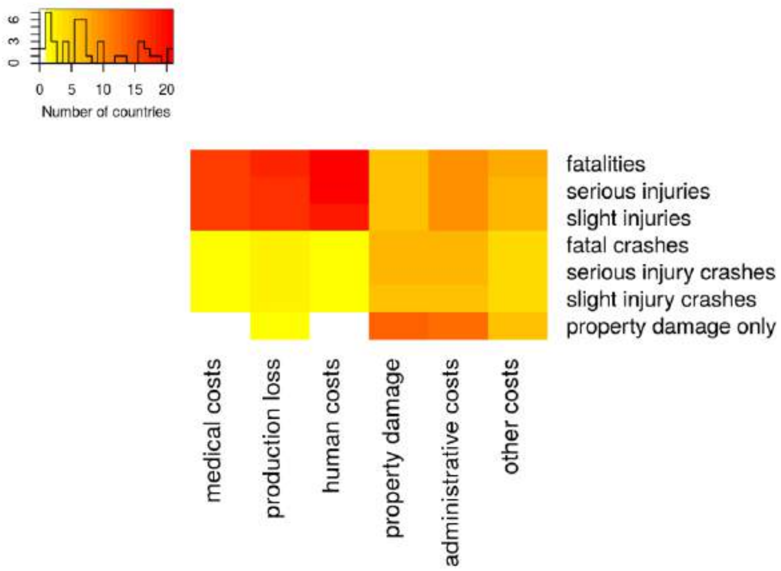

Figure 3-10 Heatmap of the number of countries which have included each cost component in costs per casualty and per crash by severity level; Histogram of the number of countries in each cell (combination of severity level/component)

Both groups of countries can be identified from Figure 3-9. Slovenia, Italy and Germany represent the countries that only included crash-related components in the cost per serious injury crash. The other countries (except Serbia) show a cost per serious injury crash which is slightly higher than the cost per serious injury. This indicates that these countries included the casualty-related cost components in the cost per serious injury crash. The fact that these costs are higher is because a crash often includes more than one victim.

3.3 TOTAL COSTS RELATED TO SERIOUS INJURIES

The total costs related to serious injuries include both the casualty-related and the crash-related costs and are multiplied by the respective number of serious injuries and serious injury crashes.
For all countries except Romania and Lithuania, information on total costs related to serious injuries was available from the survey. A comparison between countries is discussed in more detail in the sections below. All values are expressed in EUR price level 2015 and adjusted for relative income differences. An overview is given in Appendix C.

3.3.1 Percentage of GDP

A comparison between countries of total costs in absolute values does not give much information since total costs are related to the size and number of inhabitants in a country. To correct for these factors, it is common practice to relate the costs of crashes to the Gross Domestic Product (GDP) of a country. Figure 3-11 presents the total costs related to serious injuries as a percentage of GDP. These percentages are based on the survey results and the GDP (source: Eurostat). This figure indicates that the total costs related to serious injuries range between 0.04% of GDP in Ireland to 2.7% of GDP in Poland. The median percentage is 0.3%. There is no clear geographical pattern as shown in Figure 3-12.

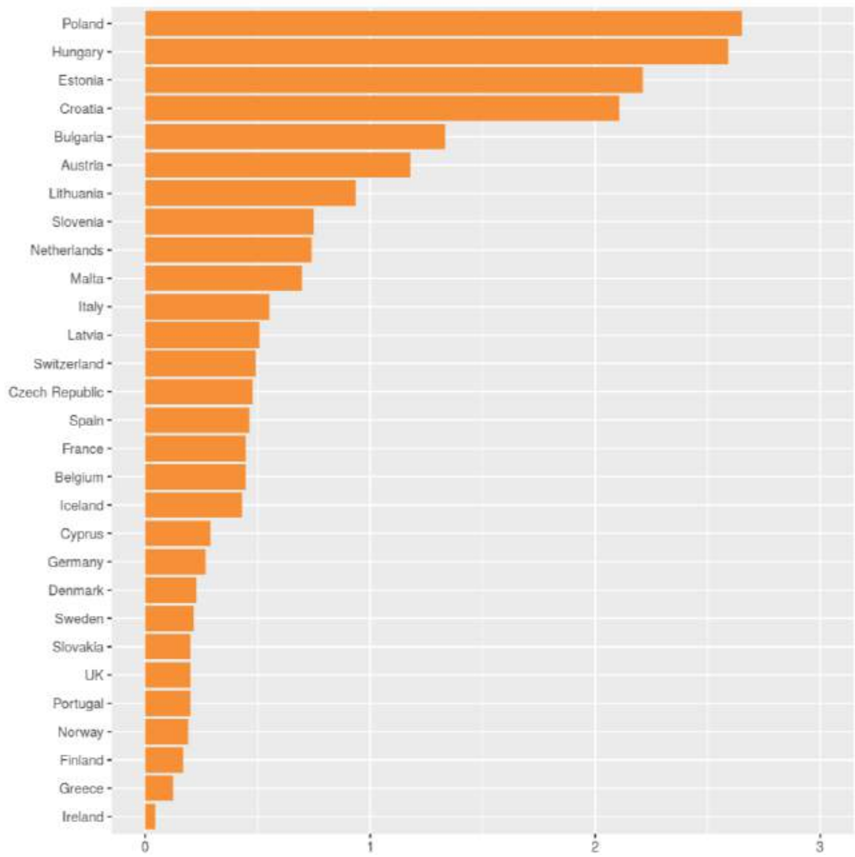

Figure 3-11 Total costs related to serious injuries as percentage of GDP

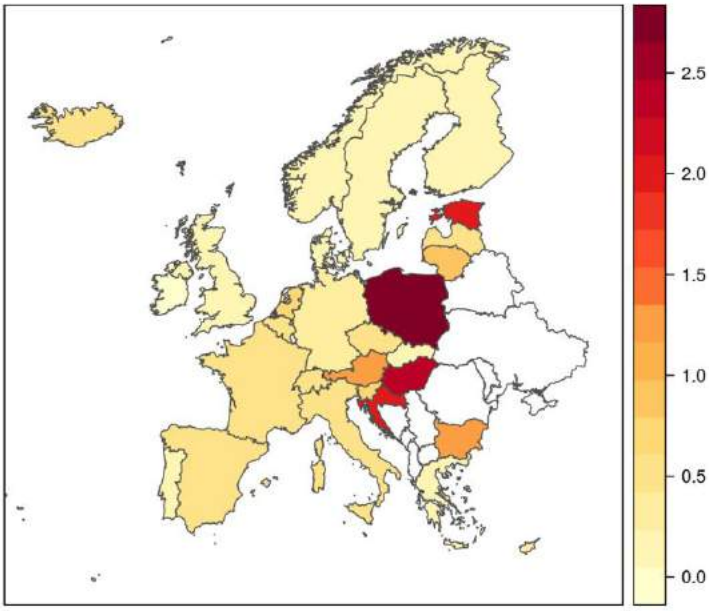

Figure 3-12 Total costs related to serious injuries as percentage of GDP

There are several explanations for the large variation in total costs as a percentage of GDP. Next to variations in the costs per serious injury, for which the explanations are given in section 3.2, these variations can reflect differences in the road safety level, more specifically the number of serious injuries per inhabitant.

Figure 3-13 shows however no relationship between the total costs of serious injuries as percentage of GDP and the number of serious injuries per inhabitant (Adjusted R^2=-0.02, p>0.1). This is surprising since we expect that the total costs increase with an increasing number of serious injuries. A possible explanation for the lack of this expected relationship is the negative effect that was found in section 3.2.1 of the reporting rate on the cost per serious injury. On the one hand the number of serious injuries increases the total costs by its volume, but on the other hand it decreases its unit cost because less severe injuries are included to calculate this unit cost. Next to that, differences in the methods, as discussed earlier, will lead to different costs which will obscure the relationship. When 5 outliers are removed (Poland, Hungary, Estonia, Croatia and Bulgaria), the relationship becomes highly significant and explains 40% of the variability of the costs as a percentage of GDP (Adjusted R^2=0.40, p<0.001). Apart from the fact that all outliers are situated in Eastern Europe, there is not enough information to give an explanation why the effect is absent in these countries. Therefore there is no objective basis to exclude these countries. Further research is necessary to give more insights.

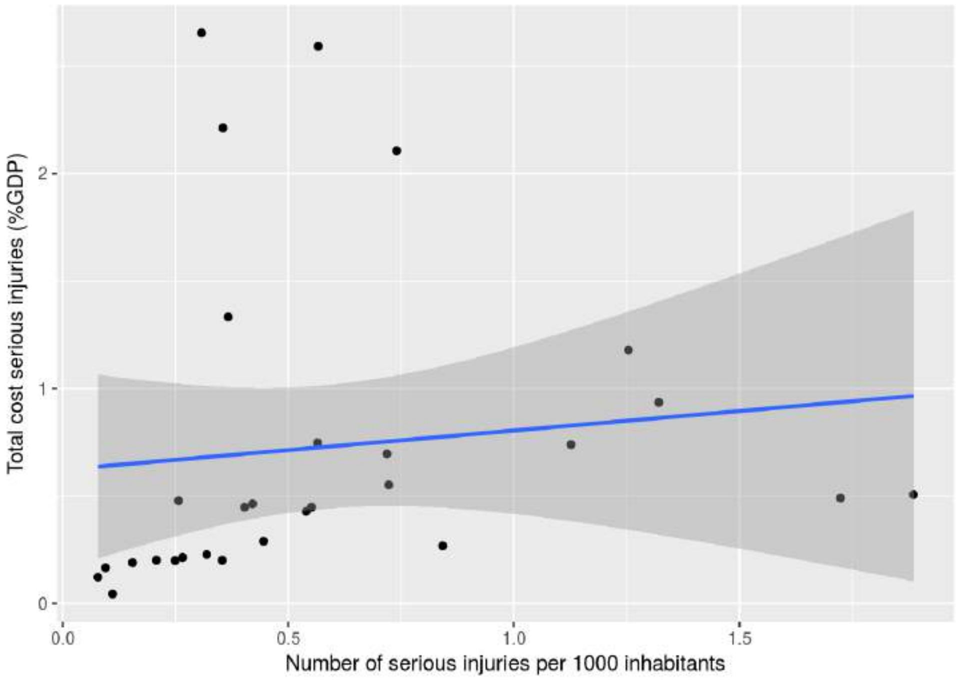

Figure 3-13 Relation between number of serious injuries per million inhabitants, and total costs related to serious injuries as percentage of GDP

3.3.2 Percentage of total crash costs

Furthermore we find differences in the share of serious injuries in the total crash costs. Total crash costs also include costs related to fatalities, slight injuries and PDO crashes. Figure 3-14 presents the distribution of total costs over the different severity categories. This figure shows that in most countries non-fatal injuries have a major share in the total costs: the share of injuries is on average 2.4 times higher than the share of fatalities. 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 a relatively high share of injuries in 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 serious injuries account for 14 to 77% of total costs (Figure 3-15).

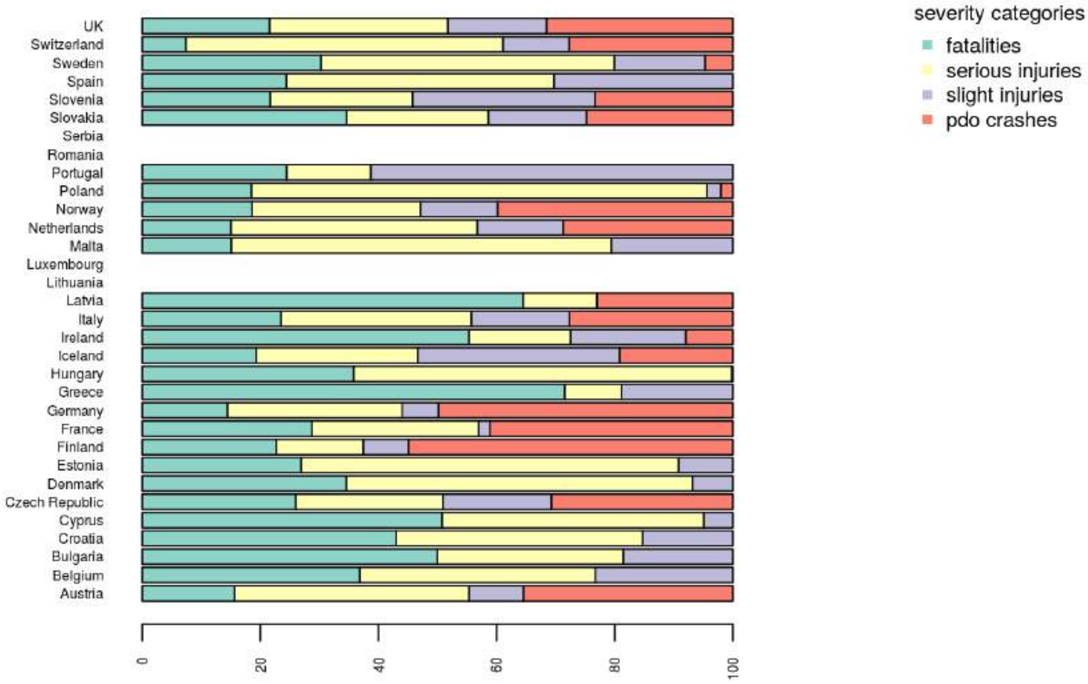

Figure 3-14 Share of fatalities, serious and slight injuries and PDO crashes in total costs

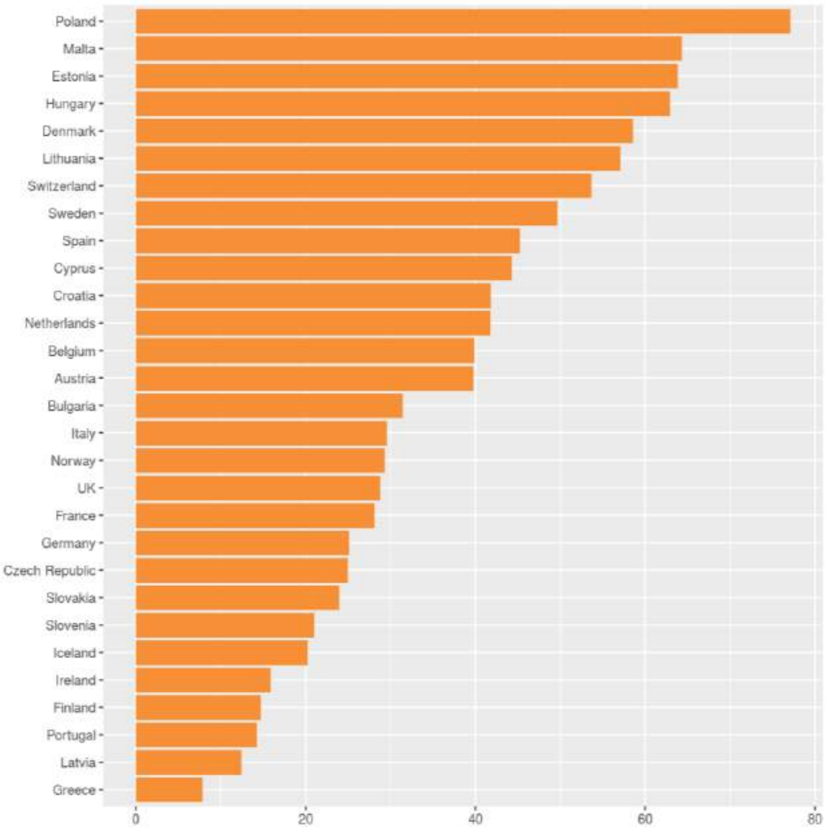

Figure 3-15 Total costs related to serious injuries as percentage of total crash costs

The variability of the distribution of total costs over different components is also reflected in the relative cost of a serious injury compared to the cost of a fatality. Poland is an exceptional case: it is the only country for which the cost per serious injury is higher than the cost per fatality (120%). Since the survey did not reveal more information about the distribution of the costs over the components, we can't provide a clear explanation. Figure 3-16 gives an overview of the relative proportion of the cost of a serious injury compared to the cost of a fatality (excluding Poland). The cost of a serious injury ranges from 2.5% to 34% of the cost of a fatality. Although this is a very wide range, for about three quarters of the countries this value is between 10% and 20%. This is probably explained by the fact that information on the human cost of serious injuries is very limited (see section 2.3), so many countries estimate the human cost of a serious injury as a percentage of the human cost of a fatality (this percentage is mostly 13%), following the results of the HEATCO project.

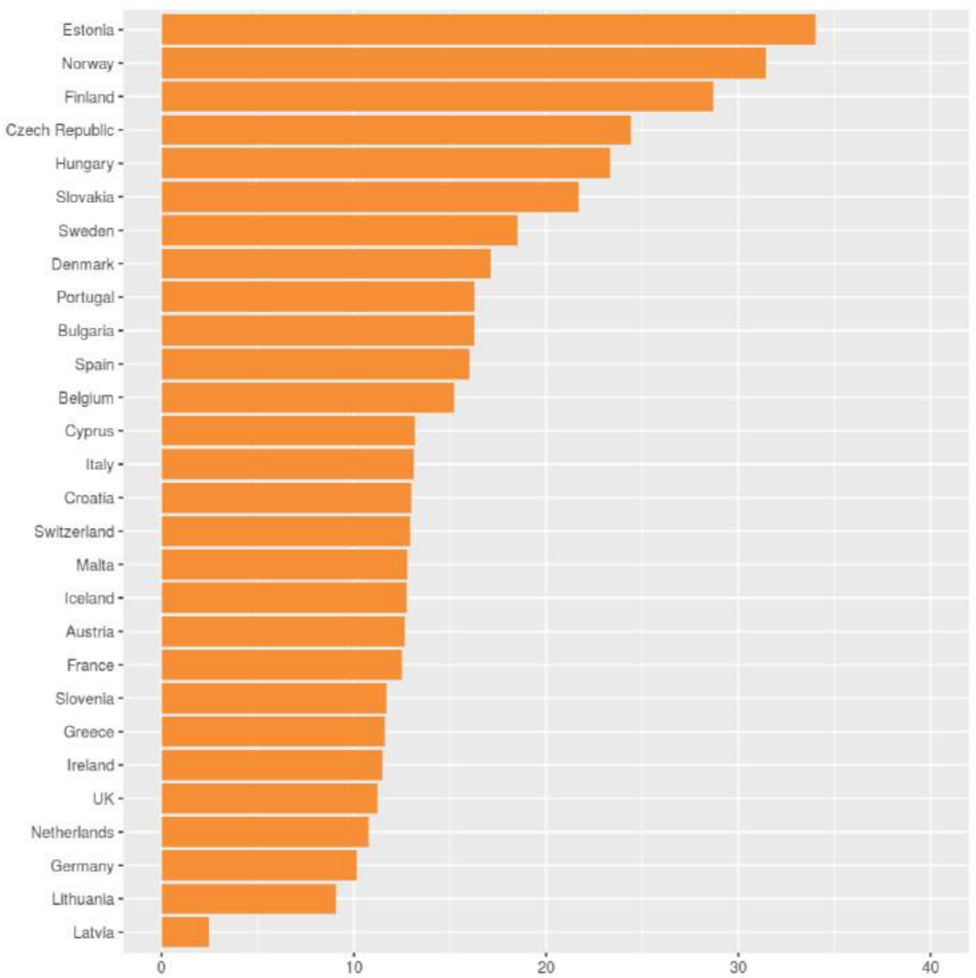

Figure 3-16 Costs per serious injury as percentage of the costs per fatality (excluding Poland)

3.4 COST COMPONENTS FOR SERIOUS INJURIES

This section discusses the different cost components of serious injuries. In the survey, information on the cost components was available for 21 countries. After giving the distribution of cost components over the total costs related to serious injuries, the three most important components for serious injuries (human costs, medical costs and production loss) are discussed in more detail.

The distribution of cost components over the total costs related to serious injuries is presented in Figure 3-17. As discussed above the cost per serious injury mainly consists of medical costs, production loss and human costs.

In most countries, human costs represent the largest share in the cost per serious injury. This is particularly the case for countries that use WTP: here the share of human costs varies between 51% and 91%. Some countries show a high share of human costs because other cost components are not included. This applies particularly to countries that used the HEATCO approach. This approach implies that all costs other than human costs and consumption loss are estimated at 10% of the Value Of Statistical Life (VOSL) (see section 2.3). In other countries human costs still have a large share in the cost per serious injury, typically around 50% or more. As discussed in section 3.2.1, countries that use the WTP method result in higher values of human cost per serious injury. Other methods than WTP, such as the human capital approach or restitution costs (compensation payments) approach, result in much lower values of human costs, which is reflected in a relatively smaller share of human costs in the total costs related to serious injuries. A further discussion on alternative methods to estimate human cost of injuries can be found in Chapter 5.

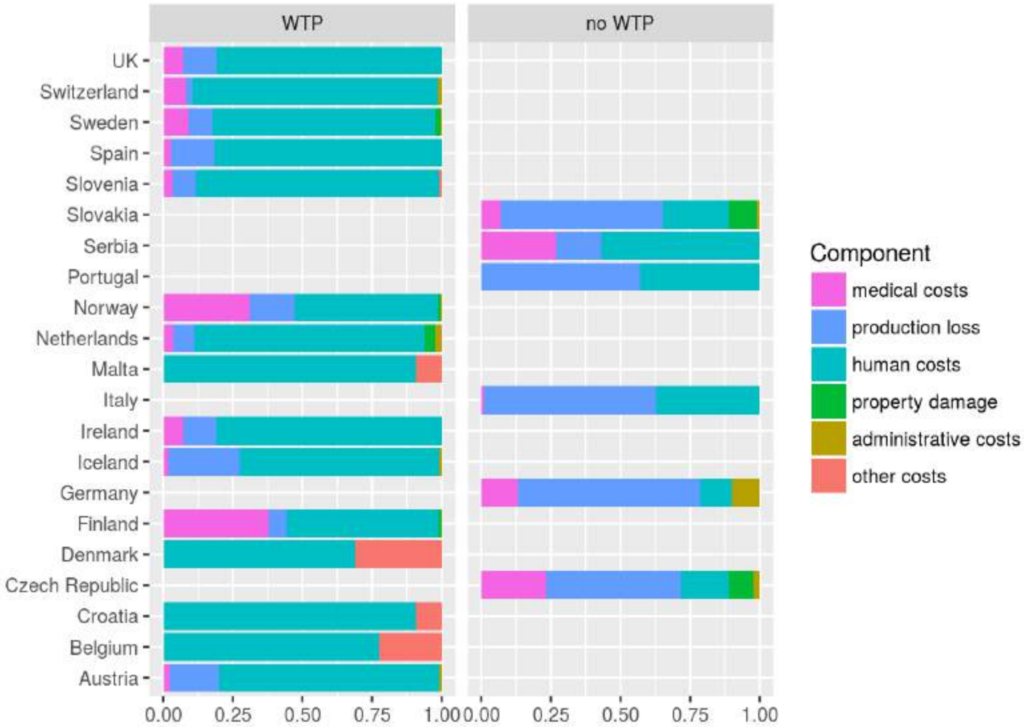

Figure 3-17 Share of cost components in total costs related to serious injuries for WTP and non WTP countries

Medical costs and production loss are the two other main components of the costs related to serious injuries. The share of medical costs in the cost per serious injury varies between 3% and 38%. The share of production loss is relatively small in countries that use WTP (between 3% and 26%), but much larger in countries that use the Human Capital method[13] (between 48% and 58%). Both components have a median share in the total costs of 18% (only taking into account countries that included these components).

While in general all countries use the recommended methods (see section 2.1 and section 2.2) to estimate these costs, there are still differences in the cost items that are included. This is shown in Figure 3-18 and Figure 3-19. Most countries include the costs related to in-patient treatment, out-patient treatment and the emergency department. Non-hospital treatment and costs related to aids and appliances are included in fewer countries. Concerning production loss, it can be noted that most countries only include future (market) production loss and only a few countries also include

[13] Czech Republic, Slovakia and Portugal

non-market production loss and friction costs. More details about factors that influence medical costs and production loss are given in Chapter 4.

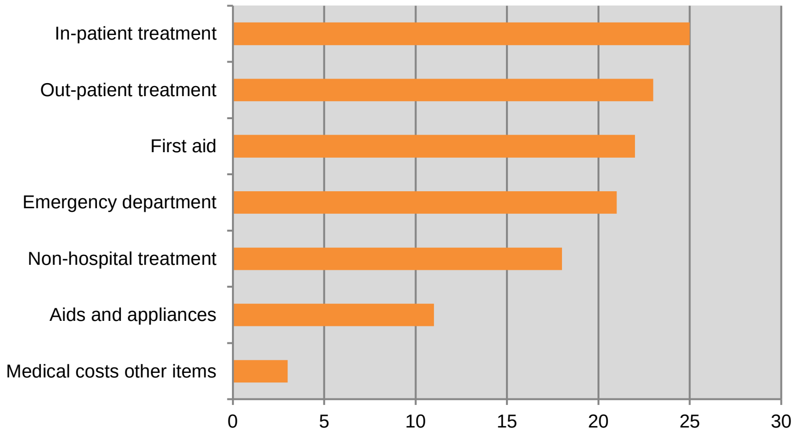

Figure 3-18 Number of countries that include cost items in medical costs of serious injuries

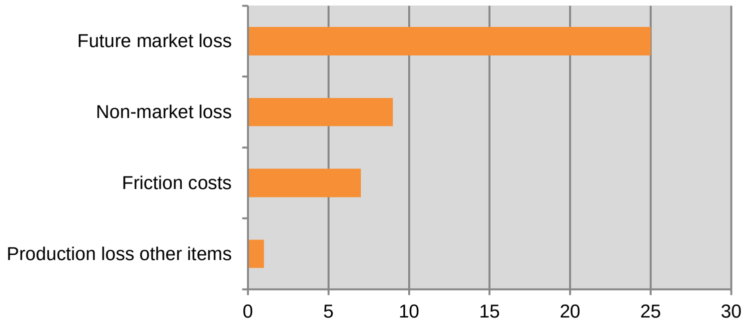

Figure 3-19 Number of countries that include cost items in production loss of serious injuries

3.5 SUMMARY

Information on cost estimates for road crashes in European countries was collected by means of a survey. The data collection was a joint effort with the InDeV project: a common questionnaire was developed to collect information regarding costs per crash/casualty of different severity levels, cost per cost component, total costs of crashes, numbers of crashes/casualties by severity level and the methods on which cost estimates were based. Within SafetyCube, the questionnaires were integrated into an SQLite database, the data was fit into the standard severity categories, completed and submitted to some consistency checks. Finally the data was standardised for currency, inflation and purchasing power parity (PPP) to create comparable figures between countries. The aim was to collect crash costs for 32 European countries (EU28 + Iceland, Norway, Serbia and Switzerland).

The data analysis in this chapter focused on the reported cost estimates related to serious injuries. For all countries except Romania and Lithuania, some information on costs of serious road injuries was available. We found that the cost per unit shows a wide variability among countries. The values vary between €28,205 and €975,074. These values tend to be higher in Northern European countries and some Eastern European countries. Differences are mainly due to whether or not the Willingness To Pay (WTP) method is applied for the calculation of human costs. Also, differences in the definition of a serious injury, in the cost components that are included, and in the reporting rate of serious injuries can explain the differences in the cost per serious injury. The cost per serious injury crash is lower than the cost per serious injury for countries that have strictly separated injury-related and crash-related costs.

The total costs related to serious injuries vary between 0.04 and 2.7% 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, the relation between the number of serious injuries per inhabitant and the costs as a percentage of GDP is only significantly positive after removing several outliers. Furthermore the total costs related to serious injuries represent a major share in the overall total costs in most countries. When selecting for countries that have information on all severity levels, serious injuries account for 14 to 77% of the total costs of crashes. The cost per serious injury relative to the cost per fatality shows a very wide range, but about three quarters of the countries have a value of between 10% and 20% of the value of a fatality. This can be explained by the fact that information on human costs of serious injuries is often estimated as a percentage of the human costs of a fatality, using a percentage from international sources such as the HEATCO project.

Three components make up the bulk of costs for serious injuries. Human costs constitute the largest share of the total costs related to serious injuries and they are much higher when WTP is used. Medical costs and production loss are generally estimated using the recommended methods, but there is a variation in the number of cost items that is included. The share of medical costs and production loss in the total costs varies between countries.

4 More detailed information on medical costs and costs related to production loss

More detailed analyses on medical costs and costs related to production loss in different countries give a better insight into the factors that influence these costs and provide information for a better estimation of these costs. These studies show that medical costs remain significantly higher for at least one year after the occurrence of the crash in comparison with the period before the crash. Furthermore, certain victim's characteristics such as age, health status and socio-economic status appear to have an impact on acute and long term costs. Production loss has been shown to vary with certain characteristics such as injury severity and type of profession.

This chapter discusses more detailed information on two cost components that are relevant for serious injuries: medical costs and production loss. From the data analysis in section 3.4 it was shown that these costs both constitute on average 18%[14] of the cost of a serious injury. The estimation of these costs requires very detailed data and consists of different main cost components. These studies provide insight into factors that influence medical costs and costs related to production loss, which can assist in a better estimation of these costs.

Details on medical costs are discussed using studies that were based on data from Belgium and France. The studies focus on the influence of the victims' characteristics and on the cost trajectories over the long term. A study from France provides more details on production loss according to the severity of the injuries and the profession of the victim. The REHABIL-AID project that collected information from Germany, Greece and Italy explored the distribution of both medical costs and production loss according to different characteristics of non-fatal road victims. Originally a detailed estimation of medical costs and production loss in the UK was also foreseen for this chapter. However, upon investigation it became apparent that although it may be technically possible to accurately determine medical costs and costs related to production loss, it is a very complex process and not practical to be achieved within the scope of this Deliverable. The difficulty of calculating costs related to serious road injuries for the UK demonstrates that, even for countries with an established process for recording road traffic crashes and serious road injuries, it should not be assumed that cost information is readily available.

4.1 MORE DETAILED INFORMATION ON MEDICAL COSTS IN BELGIUM

The information in this section is based on two recent studies in Belgium that used a linked hospital-insurance dataset. Since it is legally required to register for a health insurance, almost 100% of the Belgian population is covered.

The first study (Devos, 2017) focused on the acute hospital costs of traffic injuries. It provided a detailed overview of hospital costs related to serious traffic injuries and analyzed how these costs

[14] Median value for countries that take these components into account.

are impacted by socio-demographic characteristics (age, gender, socio-economic status) and clinical conditions (nature, location and severity of the injury; comorbidities) of traffic victims.

The second study (Devos et al, 2017) focused on the total amount of medical costs attributable to a road injury until one year after the crash. These costs do not only include costs related to hospital stays but also costs related to rehabilitation, long term care, drugs, outpatient care, etc. The cost trajectories over one year after the crash were analysed for different injury severities.

4.1.1 Data

The analyses have been conducted on a database where hospital data and medical insurance data were linked at the individual patient level. The national hospital dataset was provided by the Belgian Federal Public Service Health. Patients were identified as a traffic victim on either the relevant E-codes[15] registered in Minimal Hospital Discharge Data, or by the code 'type of roadway user' in the emergency department files. The health care costs were extracted from a database of the medical insurance, provided by the InterMutualistic Agency (IMA).

The database covers all traffic victims admitted to a hospital between 2009 and 2011. Since registration for health insurance is a legal requirement, almost 100% of the Belgian population hospitalized after a road crash was covered. The first study included 64,304 traffic victims, the second 61,232. Patients were excluded if the match between the hospital and medical insurance funds databases was unsuccessful, or if they were involved in a road crash as passengers of public transport, as equestrians or if their roadway user category was unspecified. For the first study the patients without an injury as the main or secondary diagnosis were excluded and the second study excluded patients that were involved in more than one traffic crash that resulted in hospitalization[16].

The hospital database contained socio-demographic information (age, gender), clinical data (diagnostics including the traffic injury and pre-existing comorbidities, healthcare related information such as the length of stay) and the roadway user type of the patients. Injuries were coded according to ICD-9-CM[17] and injury severity was defined by ICISS[18].

The medical insurance funds database contained detailed information on all medical and allied health treatments reimbursed by the government and the costs borne by the patient. All costs associated with hospitalizations (drugs, clinical biology, radiology, hotel function, etc.), rehabilitation, ambulatory surgery, outpatient drugs and supplies, outpatient visits, nursing, etc. were included. The costs were indexed to EUR2015. Additionally, based on the entitlement to reduced co-payment for health care services, this database provides information on the socio-economic status (SES) of the patients.

4.1.2 Method

To analyse the impact of socio-demographic and clinical characteristics of traffic victims on their acute hospital costs, a Generalized Linear Model (GLM) was used. First a univariate analysis was conducted and the variables with a p-value < 0.10 were included in a multivariate GLM. In the next step all variables with $p < 0.05$ were deleted one by one until no further variables could be deleted without deteriorating the Akaike Information Criteria (AIC). This backward stepwise modelling leads to the most parsimonious model. The variables that were initially included in this analysis are: age, gender, SES, disability, roadway user type, nature of injury, injured body region, injury severity (ICISS), time of the week (week or weekend) and comorbidities. The comorbidities that were

[15] E810, E819, E826, E827, E829
[16] These patients were excluded because there is an overlap of the medical costs before and after the road crash
[17] International Classification of Diseases, 9th Revision, Clinical Modification
[18] ICISS is the product of survival risk ratio, this ranges between 0 (no chance of survival) and 1 (100% chance of survival).

included are: 1) cancer, 2) diabetes, 3) dementia, 4) diseases of the musculoskeletal system and connective tissue, 5) diseases of the circulatory system, 6) diseases of the nervous system and sense organs, 7) anaemia, 8) diseases of the genitourinary system, 9) alcohol abuse, and 10) suffering an acute illness at the moment of hospitalization.

In analysing the total long-term attributable health care costs of a road injury, the attributable costs were defined as the difference between the aggregated health care costs one year after the road injury and one year before. The cost trajectories of the hospitalized traffic victims were modelled within a case-crossover design where weekly average health care costs were compared prior and post hospitalization. Within a case-crossover design, a risk (medical costs) is compared in a single cohort before and after a certain exposure (road injury), so each traffic victim acts as a case and a control. In this design the known variation in the traffic victim's expenditures[19] that is not associated with the injury (age, gender, comorbidities, socio-economic status, etc.) is expected to be controlled for. Next a cost trajectory for the total population is modelled using Generalized Estimation Equations (GEE) methods (Poisson distribution, log link) that controlled for age, seasonal effects and survival status at one year after the injury. Different cost trajectories according to the severity of the injuries (serious (ICISS < 0.85), moderate (0.85 ≤ ICISS < 0.95) and mild (ICISS ≥ 0.95)) were estimated.

4.1.3 Principal results

Impact of socio-demographic and clinical characteristics on acute hospital costs

Concerning the impact of socio-demographic and clinical characteristics on the acute hospital costs, an overview of the mean and median hospital costs for each category of traffic victims can be found in Appendix E. The median cost for the total population was €2,801 (IQR €1,510 – €7,175, EUR2015). Women had a higher median cost (€3,331 (IQR €1,623 – €9,089)) than men (€2,531 (IQR €1,453 – €5,913)). Further, the costs increased with increasing age: for the oldest category (≥ 75 years) the median cost was €8,217 (IQR €3,409 – €17,972), while for the youngest (0-16 years) the median cost was €1,348 (IQR €1,014 – €1,981). The median cost was higher for victims with a low SES (€4,654 (IQR €1,884 – €12,052)) and with a disability (€4,530 (IQR €1,842 – €10,613)). Injuries to the blood vessels resulted in the highest costs (€15,970 (IQR €5,056 – €60,981)) but only 111 victims suffered from these. The majority of the victims had fractures, which also resulted in a relatively high cost (€3,713 (IQR €1,926 – €8,650)). Concerning the location, injuries on the lower extremities had the highest median cost (€5,273 (IQR €2,510 – €11,666)), while traumatic brain injuries resulted in the lowest cost (€1,649 (IQR €1,124 – €3,891)). Further, costs increase with an increasing severity (decreasing ICISS) and the presence of pre-existing comorbidities lead in general to higher costs.

The specific effect of the victim characteristics on the hospital costs was estimated within a GLM, independent of other control variables. Traffic victims with certain types of injuries were excluded from the analysis due to the small number of cases[20]. In designing the model, some variables were excluded. The variable indicating the time of the week (week/weekend) was not significant ($p = 0.43$) in the univariate analysis and thus not included in the multivariate model. Next the comorbidities in the category diseases of the genitourinary system, and that of being a disabled person, were excluded from the multivariate model by backward stepwise modelling. The magnitude and significance of the effects is presented in Table 4-1.

The GLM showed that, controlling for all confounders, there is no longer any significant difference according to gender. The age effect was confirmed: older traffic victims suffered higher costs than

[19] These are all medical and allied health treatments reimbursed by the government and the costs borne by the patient. We assume that these expenditures cover all relevant medical costs.
[20] Traffic victims with injuries to the blood vessels (n = 111), to the nerves (n = 19), and with amputations (n = 112), and crush injuries (n = 337)

younger victims. Traffic victims with low SES incurred 16% higher costs than victims with high SES. A possible explanation, proposed by Perelman and Clorson (2011) is that low SES patients cause a delay in their discharge because they have less access to formal and informal domiciliary care. Concerning the type of injury, the GLM confirms that a fracture was 69% more expensive than a superficial injury, while sprains and strains were only 4% more expensive. Compared to pedestrians, motor vehicle drivers incurred significantly lower costs, while motor vehicle passengers and motorcyclists incurred higher costs. With regard to the severity of the injuries, each unit decrease in the ICISS score (which is an increase in the severity) resulted in an increase of 3% in the total hospital costs. Different comorbidities showed a significant impact on hospital costs, independently of other control variables such as age. The impact was the highest for victims suffering anaemia, diseases of the nervous system and sense organs, and dementia. Their costs were respectively 82%, 59%, and 49% higher than patients that did not suffer from these pre-existing comorbidities. Patients with diabetes incurred 13% higher costs than patients without diabetes, and the hospital costs of victims suffering an acute illness other than their injury were more than double those of traffic victims without an acute illness.

Variable	Exponentiated Coefficient	95% CI	*p*-value
Female	1.01	0.99-1.02	0.324
Year Accident			
2009	1.02	1.00-1.03	0.036
2010	1.00	0.99-1.02	0.807
2011[1]			
Age category			
0-16 years[1]			
17-29 years	1.35	1.32-1.38	<0.001
30-44 years	1.44	1.41-1.48	<0.001
45-59 years	1.51	1.47-1.54	<0.001
60-74 years	1.78	1.73-1.82	<0.001
≥ 75 years	2.28	2.20-2.34	<0.001
Low SES[2]	1.16	1.14-1.18	<0.001
Roadway user			
Cyclist	0.92	0.90-0.93	<0.001
Motorcyclist	1.03	1.01-1.06	0.006
Motor vehicle driver	1.01	.99-1.03	0.603
Motor vehicle passenger	1.04	1.01-1.07	0.008
Pedestrian[1]			
Nature of injury **Fracture**	1.69	1.64-1.74	<0.001
Dislocation	1.19	1.14-1.25	<0.001
Sprain or strain	1.04	1.00-1.09	0.048
Open wound	1.23	1.18-1.27	<0.001
Unspecified injury	1.20	1.11-1.29	<0.001
Internal Injury	1.38	1.33-1.43	<0.001
Contusion/ Superficial Injury[1]			

Injured body region			
TBI	1.03	1.01-1.06	0.010
Head, face, neck	1.01	0.99-1.04	0.309
Spine and back	1.25	1.22-1.28	<0.001
Torso	1.36	1.33-1.40	<0.001
Lower extremities	1.76	1.73-1.79	<0.001
Unspecified	1.24	1.16-1.33	<0.001
Upper extremities[1]			
100-(ICISS*100)	1.03	1.03-1.03	<0.001
Anaemia[3]	1.82	1.78-1.87	<0.001
Diseases of the nervous system and sense organs[3]	1.59	1.51-1.66	<0.001
Dementia[3]	1.49	1.44-1.53	<0.001
Cancer[3]	1.43	1.37-1.49	<0.001
Diseases of the circulatory system[3]	1.43	1.40-1.46	<0.001
Diseases of the musculo-skeletal system and connective tissue[3]	1.42	1.38-1.46	<0.001
Alcohol abuse[3]	1.24	1.22-1.26	<0.001
Diabetes[3]	1.13	1.10-1.16	<0.001
Acute illness[3]	2.06	2.01-2.10	<0.001
Died	0.73	0.70-0.76	<0.001
Intercept	960	926-996	<0.001

Table 4-1 GLM hospital costs; Source: Devos (2017)

[1] Reference Category, [2] High SES is the reference category, [3] Not suffering these diseases is the reference category
Scaled deviance =1.14

Cost trajectories of long-term attributable health care costs

For the total population, the average attributable health care cost for one year after the traffic injury was €9,977 (SD=€22,473). The cost was the lowest for cyclists (€7,258 (SD=€18,353)) and the highest for motor vehicle occupants (€11,453 (SD=€25,274)). The average attributable health care costs were higher according to severity, varying from €7,199 (SD=€16,362) for mild injuries and €8,736 (SD=19,342) for average injuries to €19,546 (SD=€35,390) for serious injuries.

The results of the GEE showed that for the total population of hospitalized road victims, controlled for season, age and survival status, the weekly average health care costs before hospitalization are €54.07 (95%CI €51.97–€56.27). Analyzing the cost trajectory (Figure 4-1) it can be noticed that directly after a road crash there is a sharp and significant increase in the costs, followed by a steady decrease. In the first week the costs are 3608% higher than the average before hospitalization. Until 17 weeks after the road crash, the average health care costs are still at least twice as high as before. The costs remain significantly higher until 51 weeks after hospitalization, although the effect is less strong (31.90%, 95%CI 26.72% – 37.31%). One year after the injury the costs are still significantly higher.

When comparing the cost trajectories of different injury severities, we find similar patterns that are different in magnitude. Serious injuries have a very sharp increase in health care costs that remain at least twice as high until week 45. One year after the injury, the costs are still 74.84% (95%CI 59.06% - 92.21%) higher than before the hospitalization. The increase directly after the crash is less sharp for moderately and mild injuries. Until week 14 the costs of moderately injured victims remain at least twice as high as before, and one year after the crash the costs are still significantly 29% higher

(95%CI 20.68% - 37.81%). For victims with mild injuries the costs remain twice as high until week 11; one year after their hospitalization the costs remain significantly 20% higher (95%CI 13.17% - 27.74%).

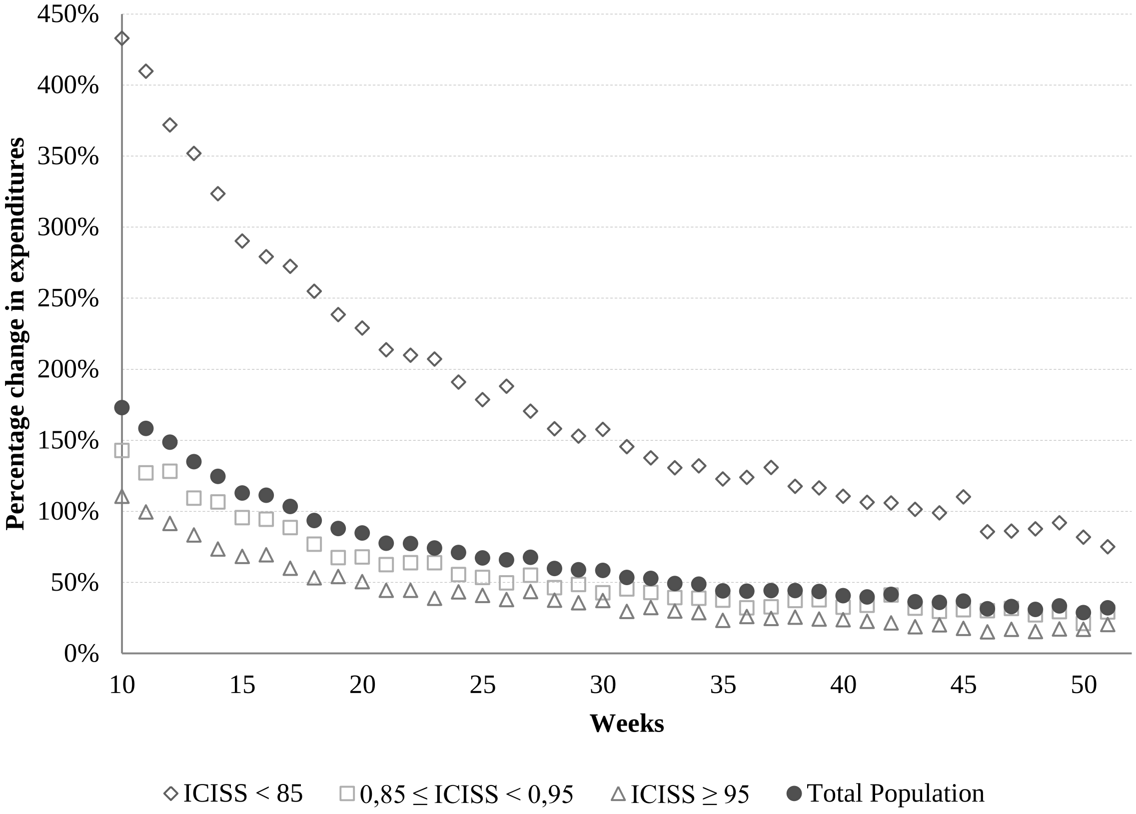

Figure 4-1 Cost trajectories for the total population and by ICISS category, for week 10 until week 51 after hospitalization; Source: Devos et al (2017)

4.1.4 Conclusions

The linking of a national hospital and an insurance database, with an extensive sample and a comprehensive approach (all direct categories of medical costs are included), generated a very rich dataset providing detailed information on the medical costs of road injuries. Devos et al performed two analyses on this database. These analyses provide us with information on the variation of medical costs according to the characteristics of traffic victims (Devos, 2017), and give us a better picture of the total amount of medical costs of road injuries by taking into account long-term expenditures (Devos et al, 2017).

First, the analysis showed that many of the victim's characteristics have a strong predictive value for the acute medical costs, resulting in different costs for different groups. While the median cost for the total population amounted to €2,801, this cost is much higher for older victims (≥ 75 years; €8,217) and victims with certain comorbidities such as anaemia (€25,842), diseases of the nervous system and sense organs (€16,144), or dementia (€19,776). A road safety policy maker should take this broad variability of medical costs into account, and should bear in mind that in an ageing society the medical costs of serious road injuries will increase. The second analysis demonstrated that medical costs, regardless of the severity of the injury, remain significantly higher than before for at least a full year. The average attributable health care costs for one year after the traffic injury was €9,977. This leads to the conclusion that the consideration of medical costs in road safety policy should not be restricted to the short term.

4.2 MORE DETAILED INFORMATION ON MEDICAL COSTS IN FRANCE

In France, recently three studies have been focused on medical costs of serious injuries. Carnis & Achit (2014) showed that the type of injury, the level of insurance coverage, and the previous health state of the victim all influence the level of medical spending for the road crash victim as recorded by public insurance companies. Another study (Achit & Carnis, 2014) showed that also the age of the victim and their socio-economic status were highly correlated with the level of medical spending resulting from a road crash. The results of the study also suggest an interaction between the severity of the injury and the previous health state of the traffic victim, which has an influence on future medical spending. A more recent study by Achit (2015), discussed in more detail below, described further investigations of the dynamics of long term medical costs on a four year period, and identified different groups with different cost patterns.

4.2.1 Data & method

The study by Achit (2015) used the SNIIR-AM (Système National d'Information Inter-Régimes de l'Assurance Maladie) data, collected by a public insurance body (Assurance Maladie) in France. The database provides information concerning the costs related to the road victim, the circumstances of the road crash, sociodemographic information related to the victim, and the type of medical expenditures and their timing. The database covered the medical spending of patients for the period 2007-2014, and Achit selected the victims whose injuries were the consequence of a road crash. The database differs from the official road safety statistics, provided by public authorities, stressing the general and well-known effect of under-reporting in official statistics. However, the database also shows some limitations because not all victims could be retrieved.

The medical spending for roughly 190,000 traffic victims was examined for a four year period after the road crash and is supposed to be an appropriate representation of the whole French population involved in a road crash. For analysing these data, a robust econometric model was used (GLM, Generalized Linear Model), taking into account the asymmetrical distribution of medical spending and some hysteresis effect of this spending through time. The model provided information concerning age, gender, duration of hospitalization and the type of injury, and makes it possible to compare hospitalized road victims and patients that were not involved in a road crash.

4.2.2 Principal results

In Figure 4-2 the average medical spending related to a road crash is presented for four years after the road crash has occurred. On average, the total additional medical costs attributable to a road crash after four years are estimated to be between €2,800 and €2,900 per victim. For the first year, the medical spending increases by 250%. Moreover, this additional spending differs according to the gender of the victim, the type of road user and the type of injury. While the additional total medical costs for car occupants would amount to €1,780, they are estimated to be roughly €2,500 for a motorcyclist. The total additional costs are on average 60% higher for male (€3,995) than for female victims (€2,572). There are also significant differences according to the type of injury: roughly €1,000 for head injuries and around €4,800 for an injury related to the hip. Moreover four types of cost patterns are identified according to their total level of medical expenditures and its dynamics.

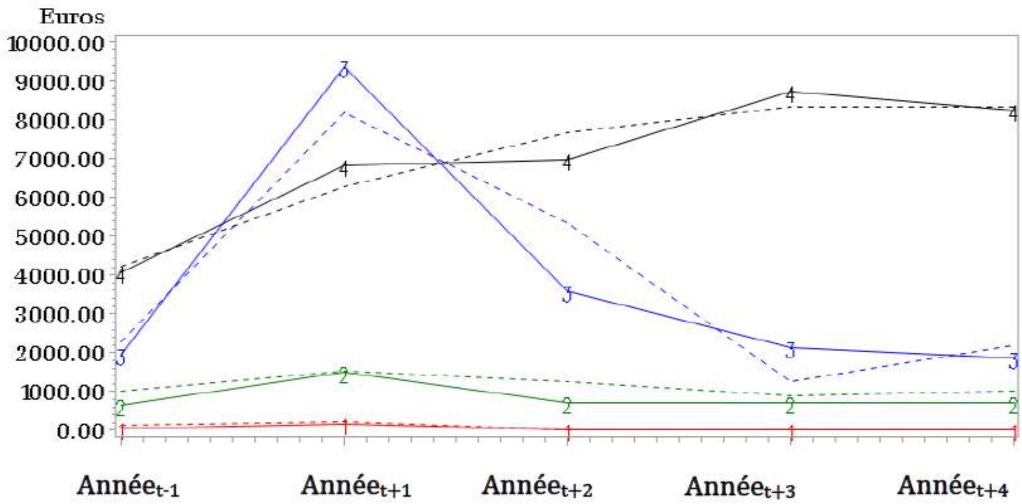

Figure 4-2 Average medical spending after the accident for different types of victims; Source: Achit (2015)

A first finding from this analysis is that medical costs after a road crash show a certain dynamic. This means that a road crash shows an increase in medical costs immediately after its occurrence, but also for a longer period after the crash. There is a *hysteresis* effect.

A second finding is the *existence of different dynamics* and that it is possible to define a typology of victims according to the evolution of their medical costs. The four types of victims can be categorized into three main profiles.

Type 1 and type 2 constitute the first profile: those types are characterized by a rather low level of costs and a quite stable evolution through time. Type 1 is characterized by the lowest level of costs and the most stable evolution. Type 2 on the other hand shows a slightly higher level of costs with a peak one year after the road crash, after which the costs reduce.

For both of those types, the average medical spending per year is lower than €1,000 at three years after the accident. The average age of the victims in this group is 32 years and the length of their hospital stay is relatively short (on average 4.5 days). These victims represent the great majority of the road victims that are included in the study (89%).

The second profile concerns the traffic victims of type 3. This group is characterized by a very high level of medical costs one year after the road crash. While this group reaches a peak at one year after the crash, the level of medical costs decreases afterwards and reaches pre-crash levels after four years. The costs remain high for a long period and this illustrates the lasting effect of a road crash through time. The population of this group is older (on average 46 years) and the average length of the hospital stay is 13 days, which is nearly three times as long as that of the victims of the first profile. The traffic victims in this group represent roughly 8% of the total road victims that are included in the study.

Victims from type 4 constitute the third profile. This population shows a higher level of medical spending before the road crash than victims of the other profiles. This group mainly consists of older traffic victims (average age is 55 years) and represents 3% of the total victims included. This profile is particularly characterized by a high level of medical spending, that increases with the road crash and remains at a high level through time. The average length of hospital stay amounts to roughly 11 days. There is no reduction in the medical spending identified after four years. This result confirms the interaction of road injuries with the previous health state as was found by Achit & Carnis (2014), and a low resilience of this group of victims.

4.2.3 Conclusions

The study by Achit (2015) showed that four years after a road crash the additional medical costs are estimated to be between €2,800 and €2,900 per person. These costs differ according to road user type, gender and type of injury. Furthermore the study found different cost trajectories for four types of victims.

One group, which represents the great majority of traffic victims, face a rather low level of medical spending, which already disappears during the first year after the accident. On the other hand victims of type 3, which are the victims with the more severe road injuries, face a much higher level of medical spending during the first two years after the road crash; this effect lasts for three years. The most problematic are the victims of type 4, for which the medical costs resulting from the road crash are high and remain at this level through time. This group consists mainly of older people, whose vulnerability is translated in terms of additional medical spending.

4.3 MORE DETAILED INFORMATION ON MEDICAL COSTS AND PRODUCTION LOSS IN GERMANY, GREECE AND ITALY BASED ON THE REHABIL-AID PROJECT

The information in this section is based on the EU funded REHABIL-AID project ("REducing the HArm and the Burden of Injuries and human Loss caused by road traffic crashes and Addressing Injury Demands through effective interventions"). This project collected amongst other things information on medical costs and costs related to production loss of non-fatal road victims in Germany, Greece and Italy. The objective of this project was to explore the physical, psychosocial and financial consequences of serious road injuries. The results are presented in Papadakaki et al (2016).

4.3.1 Data & Method

The study was performed by interviewing road traffic victims that were admitted to an Intensive Care Unit (ICU) or Sub-Intensive Care Unit (Sub-ICU) of seven selected study hospitals in Germany, Greece and Italy. The study hospitals are formed by the two project partners; Medizinische Hochschule Hannover (Germany) and University Pavia, Medical School (Italy), as well as all hospitals of Crete (Greece). The road victims participated on a voluntary basis. The interviews took place at 1, 6 and 12 months since the initial admission to the hospital. During the first interview the victims provided sociodemographic information and information on the characteristics of the road crash. Information about the injuries (location, type and extent of the injury) was retrieved from their medical records and information about the costs related to the initial hospital stay was retrieved from hospital electronic data. During the two follow-up interviews the victims retrospectively gave information about the other financial costs related to their injury.

The study distinguishes three types of costs: (1) costs related to the initial hospital stay, (2) direct medical costs (not related to the initial hospital stay) and (3) indirect costs. Direct medical costs include: treatment of the injury (inpatient and outpatient hospital costs), paid carers' costs, ambulance transport, medication, equipment (such as wheelchairs) and medical tests by health professionals other than medical doctors. The indirect costs include: costs related to production loss (both paid and unpaid) of victims and their care givers, childcare arrangements and in-house adaptations. The direct and indirect costs were assessed by a self-reported questionnaire. The costs related to the initial hospital stay were estimated for each study hospital: the personal information of each patient was matched with a DRG (diagnosis-related group) payment in the hospital electronic information systems.

Inclusion criteria were (Papadakaki et al, 2016):

- Injury sustained during road traffic crash.
- Stay for more than 24 hours in ICU or sub-ICU.
- 18 years old or older.
- Sufficiently able to communicate and understand the research question.
- Willingness to participate after written consent.
- Patient survived the reporting period.

In total 120 patients were initially included in the study of which 27 dropped out during the course of the project. Eventually 93 patients were included for the two follow-up interviews of which 38 were from Greece, 20 from Germany and 35 from Italy. Approximately half of the included patients had an injury severity of MAIS3+. The characteristics of the patients in the sample, is shown in Appendix F.

4.3.2 Principal results

The study found significant differences between the three countries that were included in the study (Figure 4-3). The Italian data differed significantly from the German (p=0.001) and Greek (p=0.001) data concerning direct and indirect costs. German and Greek data differed significantly with regards to direct costs (p=0.001). The cost differences between Greece on the one hand and Germany and Italy on the other hand are likely caused by the relatively high number of MAIS 1-2 patients in the Greek sample.

Concerning the costs related to the initial hospitalization, these costs are estimated in the REHABIL-AID project by an estimation approach that uses average payments according to the DRG. For all patients that were included in Germany cost information based on the cost claims of the hospital was available as well. Figure 4-3 shows that the actual hospital costs are approximately twice the estimated hospital costs in Germany. The differences in hospitalisation costs between the different countries are likely caused by different billing approaches resulting from different governmental contributions for hospitals in the different countries that are not considered in the estimation approach.

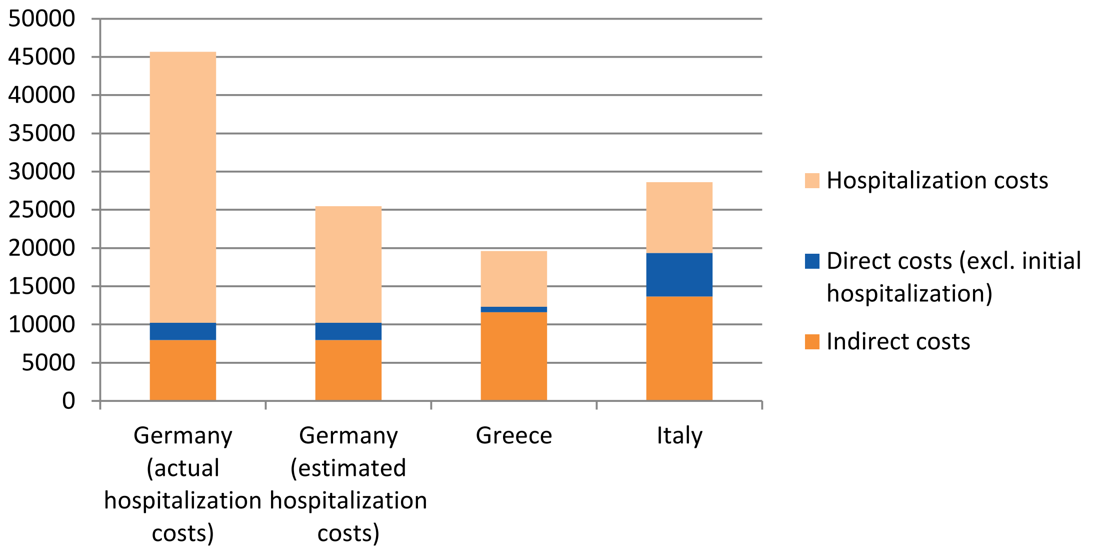

Figure 4-3 Cost per patient in the first year, according to the country and the type of cost (Euro); Source: Papadakaki et al, 2016 & MHH internal data

The study also found differences according to the characteristics of the victim. Males were over-represented in the sample (77.5%), but females had higher average hospitalization costs and higher average direct costs. Men had a higher percentage of indirect costs which is explained in the study by a higher average wage and labour market participation rate of this group. The higher medical costs (hospitalization costs and other direct costs) for females can be due to the fact that they are more often involved in a road crash as a vulnerable road user. The differences were not shown to be significantly different ($p>0.05$).

Concerning the age of the victims, the victims from the age group 50-64 years had the highest average hospitalization costs and the highest average direct costs. This can be due to the fact that ageing is accompanied by increasing comorbidities and longer recovery periods. The indirect costs tend to decrease with increasing age, which can be explained by a decreasing labour market participation. The differences are statistically not significant ($p>0.05$).

With regards to the road user type (Figure 4-4), we find the highest average direct costs among pedestrians. This can be due to the fact that the average age in this group is higher and that it is a vulnerable road user group with a higher injury severity. Truck/bus drivers and car passengers had the highest average indirect costs. The highest average hospitalization cost is reported by motorcyclists. Differences among the groups were not statistically significant ($p>0.05$) and these observations are based on very small samples.

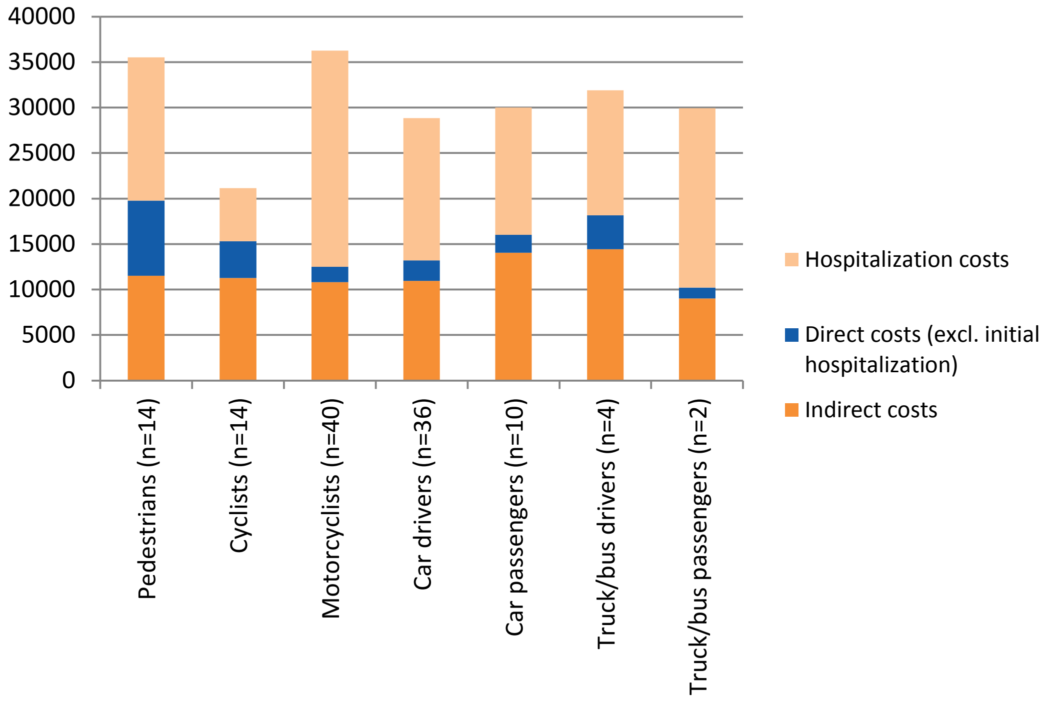

Figure 4-4 Cost per patient in the first year, according to the road user type and the type of cost (Euro); Source: Papadakaki et al, 2016

Concerning the injury severity, the average hospitalization costs were higher among MAIS 3+ victims than for MAIS 1-2 victims (Figure 4-5). Surprisingly the victims with a slight injury (MAIS 1-2) had higher direct and indirect costs than the victims with serious injuries. A possible explanation given by Papadakaki et al (2016) is that "less serious, but more common injuries such as the ones involving ankles, knees and cervical spine can result in chronic physical pain and limit the victims' physical activities for years". Another possible explanation could be that in the study only the costs in the first year are considered. The period appears not to be long enough for complete rehabilitation for a majority of MAIS 3+ victims. Following that, the analysed costs may be complete for the MAIS 1-2 victims but incomplete for the MAIS 3+ patients. In addition, parts of the costs that are included in the indirect costs and direct costs (excluding hospital costs) for the MAIS 1-2 patients are included in the hospital costs for the MAIS 3+ patients due to a longer stay in the hospital. Moreover the MAIS 1-2 victims that are admitted in the study are victims that are treated for at least 24 hours in the Intensive Care Unit (ICU) or Sub-ICU. When comparing average hospitalization costs of MAIS 1-2 patients with the hospitalization costs of MAIS 1-2 patients in the study the latter ones are expected to be considerably higher. This is caused by the fact that all MAIS 1-2 patients in the study were admitted to ICUs resulting in high costs, while most of the MAIS 1-2 patients mostly do not stay in the hospital. If they are admitted to an hospital, they are normally admitted to standard care units, which are less expensive than intensive care units.

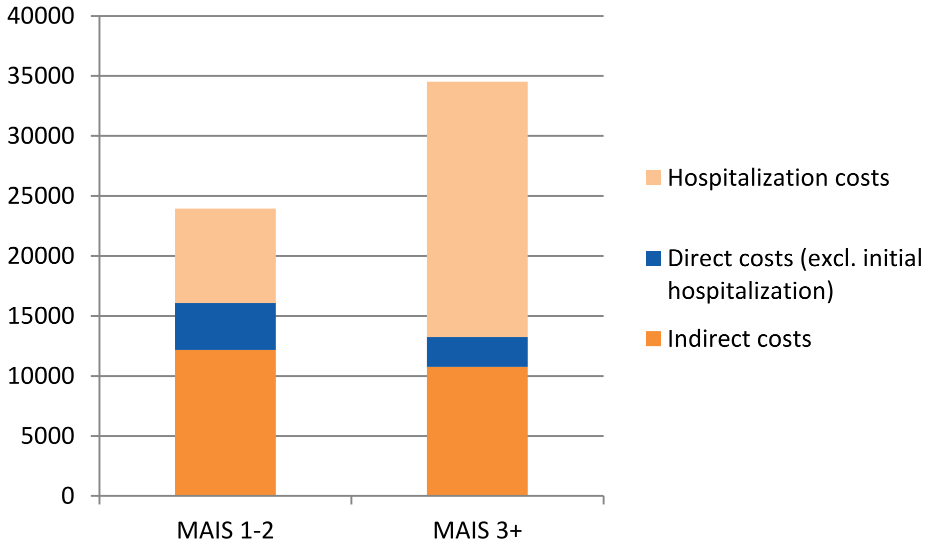

Figure 4-5 Cost per patient according to the injury severity and the type of cost (Euro); Source: Papadakaki et al, 2016

4.3.3 Conclusions

Despite the limitations of this study (e.g. very small sample, not representative, self-reported costs), it gives an indication of the variation of medical costs and production loss according to different characteristics of traffic victims. Apart from the total costs, also the distribution of hospitalization costs, (other) direct medical costs and indirect costs over the total costs varies for different types of victims.

4.4 MORE DETAILED INFORMATION ON PRODUCTION LOSS IN FRANCE

A road crash can drive a road victim out of the labour market for a short or longer period of time, depending on the severity level of their injuries. Next to the severity of the injuries, the length of the period that a traffic victim is absent from the labour market can also be explained by different factors such as the generosity of the insurance benefit system and the type of professional activity. The loss of revenue due to a temporary or permanent withdrawal of the labour market caused by a road crash is an issue that concerns both victims and employers.

A study by Achit & Carnis (2014) explored the level of revenue loss according to the severity of the injury and the type of professional category. This method is generally in line with the Human Capital approach, as income is regarded as an indicator for production.

4.4.1 Data & method

The study used the ESPARR cohort, a database that contained information on the length of absence from the labour market for road victims in the Rhône department of France. The average length of absence, and the average revenue loss related to the withdrawal from the job market, was estimated for three different levels of injury severity and for different types of professional categories.

The ESPARR study is a cohort follow-up study based on the Rhône administrative area Registry of Road Traffic Casualties. All traffic victims that were admitted to an emergency department of the Rhône administrative area, that were a resident in the Rhône area, and that agreed to take part in a face-to-face interview (after six months, one year, two years, three years and five years) were included in the study. The medical data was retrieved from the medical records of the victims. The study was not designed to be representative for France. In total 1,372 traffic victims were included in the study.

The three levels of injury severity were determined by their MAIS level. The first group consists of victims with MAIS 1 or MAIS 2 injuries, the second group are MAIS 3 injuries and the third group are MAIS 4 and MAIS 5 injuries. The different professional categories are determined following the INSEE[21] typology: (1) farmers, (2) self-employed persons, (3) managers and executive staff, (4) an intermediate category, (5) white-collar workers, (6) blue-collar workers, (7) apprentices, and (8) students and non-permanent part-time activities. For each professional category, the monthly net average wage was retrieved from INSEE[22] so the average loss for each victim and for the different severity groups could be determined based on the professional category the victim belonged to.

The average period a victim was absent from the labour market was calculated by determining the ratio of the total number of days absent from the labour market due to a road crash and the number of victims in that category. This figure is then multiplied with the average monthly net wage for the concerned professional category to obtain the average loss of revenue for each category[23].

4.4.2 Principal results

The average length of absence and the average revenue loss for different levels of injury severity is presented in Table 4-2. This table shows that the more severe the injury, the longer the period of absence from the labour market. There is a large gap between MAIS1/2 injuries and higher injury severity levels. While the length of absence for victims with MAIS 1/2 injuries is on average 3 months and 2 weeks, victims with a higher injury severity are on average absent from the labour market for 1.5 years. Consequently the average loss of revenue is also much higher for victims with injuries of MAIS 3 or MAIS 4/5 level. While the revenue loss for the more severe victims amounts to more than €30,000 per person, the revenue loss for the victims with MAIS 1/2 injuries is on average €6,576. The difference in revenue loss between the victims of MAIS 3 injury severity and the victims of MAIS 4/5 injury severity is however very small. This indicates that above a severity level of MAIS 3 there is a certain threshold for revenue loss.

[21] INSEE (Institut national de la statistique et des études économiques) is the governmental agency providing official statistics in France for a broad range of issues.
[22] For 2014
[23] Some victims cannot be withdrawn from the job market, because they have no occupation at the moment of the accident.

	MAIS 1/2	MAIS 3	MAIS 4/5
Average loss of revenue	€6,576	€30,688	€33,049
Average length of absence from the labour market	3 months and 2 weeks	17 months and 2 weeks	18 months and 1 week

Table 4-2 Average length of absence from the labour market for road crash victims for different levels of injury severity

Table 4-3 presents the average loss of revenue for the different professional categories. In total, the average loss of revenue due to a temporary withdrawal from the labour market amounts to €13.2 K. There are however large differences between the different professional categories. We can distinguish four groups based on their level of revenue loss.

Professional category	Average
(1) farmers	€14.6 K
(2) self-employed persons	**€19.4 K**
(3) managers and executive staff	€14.8 K
(4) an intermediate category	€15.9 K
(5) white-collar workers	**€12 K**
(6) blue-collar workers	€16.9 K
(7) apprentices	€16.6 K
(8) students and non-permanent part-time activities	**€2.4 K**
Total	*€13.2 K*

Table 4-3 Average loss of revenue per casualty due to the withdrawal of the job market for different socioeconomic categories

Category 8, students and non-permanent part-time activities constitute the first group and are characterized by a relatively low level of loss of revenue (€2.4 K). This is explained by their low participation in the labour market and their low wage level. A second group is a heterogeneous group populated by different professional categories: farmers, managers and executive staff, the intermediate category, blue-collar workers and apprentices. The average revenue loss varies between €14 K and €16 K. Although the average revenue loss of these categories lies in the same range, there are large differences in the average length of absence and the average wage. Category 5, the white-collar workers, differs from the latter group by a relatively lower level of loss of revenue (€12 K). Their average loss of revenue is between 15 and 25% lower than that of victims from the second group. The fourth group consists of self-employed people (category 2) and is characterized by a relatively high average revenue loss, rising to nearly €20 K. This level of revenue loss is 20 to 43% higher than that of the types in the second group.

4.4.3 Conclusions

The average revenue loss of traffic victims that were included in the ESPARR study amounted to €13.2 K. The study found different levels of average revenue loss depending on the severity of the injury. Generally the average revenue loss increases with increasing severity level; however, there is a threshold at a severity level of MAIS 3 after which the increase slows down. Furthermore, the study found a large heterogeneity among the different professional categories. Their loss of revenue depends on the absolute level of the average wage which evolves through time and depends on the type of job, the occurrence of their involvement in a road crash, their severity level and the type of job they perform. This result can help authorities in accurately targeting their interventions by taking into consideration those differences.

4.5 DISCUSSION AND CONCLUSIONS

Medical costs and production loss are two cost components that are highly relevant for serious injuries. From the data analysis in Chapter 3 we know that they constitute on average 18% of the cost of a serious injury (for countries that take these cost components into account). Since the estimation of these costs requires very detailed data, not all countries take into account the main cost items and some countries have no estimations at all. A more detailed analysis of these costs that is provided in this chapter gives more insight into the factors that influence the medical costs and costs related to production loss. Therefore it can contribute to a better estimation of these costs and can assist policymakers in improving policy aimed at reducing these costs.

4.5.1 Medical costs

To estimate medical costs of serious injuries the appropriate method is the Restitution Costs (RC) approach (see section 2.2). The five main cost items identified are: (1) first aid and transportation to the hospital, (2) treatment at the location and in the emergency department, (3) in-patient hospital treatment (overnight stay), (4) out-patient hospital treatment (no overnight stay) and (5) non-hospital treatment. A minor cost component is the aids and appliances, such as wheelchairs and medicines.

In the previous chapters (section 2.2 and section 3.4) we find that:

- The RC method requires a large data availability: in addition to the cost per unit (ambulance trip, treatment, hospital care), detailed information about the number of units (number of ambulance trips, average duration of hospital stay, frequency of non-hospital treatment) is necessary.
- Not all countries take non-hospital treatment into account. This means that many countries only include the acute hospital costs and don't account for longer term medical costs.
- Not all countries have values for medical costs.

The study by Devos (2017) showed that certain characteristics of traffic victims have a significant influence on the amount of acute hospital costs. An older age, a low socio-economic status, the severity of the injuries, certain types of injuries and certain pre-existing comorbidities lead to significantly higher costs. The influence of most of these characteristics of traffic victims was confirmed in studies by Achit & Carnis (2014), Carnis & Achit (2014), Achit (2015) and Papadakaki et al (2016). The effect of age was also confirmed in a study in the United States by Shen & Neyens (2015).This implies that when estimating medical costs for cost-benefit analysis, one should ideally take into account certain characteristics of potential traffic victims such as the age, socio-economic status and health state. This also means that an increasingly older population (with more comorbidities) can increase future medical costs.

Moreover the cost trajectory of medical costs on a longer term was identified. Both the study of Devos et al (2017) and Achit (2015) found that medical costs were still significantly higher one year after the occurrence of the road crash. This finding stresses the importance of including non-hospital costs, and more generally non-acute medical costs, in the estimation of medical costs.

Both studies also identified different cost trajectories for different groups. Devos et al (2017) found a large increase in medical costs immediately after the crash; this increase was larger for more severe injuries. Achit (2015) identified three groups on the basis of the cost pattern over the four years after the crash. While for the majority of the traffic victims the medical costs have disappeared after two years, this is not the case for two types of victims. The first of these types shows a very high increase of medical costs during the first year after the crash, which only disappears after four years. This group consists of slightly older and more severely injured victims. The second group are the victims that previous to the crash already had higher medical costs and were in a worse health state. They are characterized by an older age and a longer hospital stay. For these victims the medical costs increase further after the occurrence of the crash and remain on a higher level, even after four years. When estimating longer term medical costs, one should also take into account different trajectories according to the characteristics of the victim population.

This detailed information allows policy makers and researchers to estimate medical costs more accurately by taking into account the variation for different subgroups of traffic victims and the total amount of costs on the long term. It also serves as an additional source of information when calculating the total burden of road injuries. Here the variation and total long-term costs should be taken into account. For example, the analyses show the high impact on medical costs of certain comorbidities. With an increasingly older population, the proportion of victims with comorbidities will increase, resulting in higher costs even if the total number of traffic victims stagnates or decreases. Furthermore this detailed analysis can assist policymakers in improving policy aimed at reducing these medical costs.

4.5.2 Production loss

Regarding costs related to production loss, the appropriate method is the Human Capital (HC) approach. In general, production loss of a road injury is calculated by multiplying the period of time the victim is not able to work due to the crash with a valuation of the production per person per unit of time. This period of time ranges from a few days absence from work, to all remaining working years until retirement if someone is permanently disabled.

The study by Achit & Carnis (2014) gave a detailed overview of the average revenue loss according to the severity of the injury and the type of professional category. Using the average revenue loss as an indicator for production is in line with the HC approach. The average revenue loss appeared to increase with increasing injury severity, with a threshold at a severity level of MAIS 3. Furthermore the study found a large variation in production loss according to the professional category. This has to do with the participation in the labour market, the average length of absence and the average wage of that specific category. Further, the study by Papadakaki et al (2016) indicates a lower level of indirect costs (including production loss) among women, older victims, pedestrians and - contrary to the findings of Achit & Carnis (2014) - among victims with MAIS 1-2 injuries. Especially this last finding needs further research.

These results provide insight into the determinants of production loss. They can help policymakers and researchers in estimating the production loss for different types of injury severities by taking into account the victim's characteristics such as the professional category.

4.6 SUMMARY

To assist researchers in estimating the medical costs and production loss related to serious injuries, and to help policymakers in improving their policy aimed at reducing these costs, a more detailed analysis of these costs was given in this chapter using studies from Belgium, France, Germany, Greece and Italy. These analyses provide more insight into the factors influencing these costs.

Studies by Devos (2017), Achit & Carnis (2014), Carnis & Achit (2014) , Achit (2015) and Papadakaki et al (2016) showed the influence of certain characteristics of traffic victims on medical costs, such as age, socio-economic status, type of injury, injury severity, road user type and health status. More specifically, older victims with a worse health status (and more comorbidities) show higher acute and long-term costs.

Further, the study by Devos et al (2017) and Achit (2015) found a significantly higher level of medical costs more than one year after the occurrence of the crash. This finding makes it clear that the estimation of medical costs should not be limited to acute (hospital) costs. Moreover the authors found different cost trajectories for different types of groups, correlated with the injury severity, the age and the pre-existing health state of the victim. This implies that when estimating long-term medical costs, policymakers should not assume that these trajectories are the same for all victims.

Concerning production loss related to serious injuries, a study by Achit & Carnis (2014) and Papadakaki et al (2016) showed differences according to certain characteristics of the victims. Achit & Carnis (2014) concluded that these costs increase according to the injury severity, but that this increase slows down after reaching a certain severity level (MAIS 3). Achit & Carnis (2014) also found a variation of these costs according to the type of profession. This variation is influenced by the participation in the labour market, the average wage and the length of absence inherent to a certain profession.

5 Human costs of serious road injuries: alternative approaches

The Willingness To Pay (WTP) method is the most common approach to estimate human costs of injuries. This chapter explores two alternatives: the Quality Adjusted Life Years (QALY) approach and the court awards approach. For future cost-benefit analyses, we recommend to use direct WTP studies or QALYs to estimate the monetary values of human costs of non-fatal road injuries.

In Chapter 2, it was shown that, next to material costs (medical costs, production loss, property damage and administrative costs) a road crash also involves immaterial costs. These immaterial or 'human' costs are the costs of pain, grief, sorrow and mainly the loss of quality of life due to the injuries caused by the road crash. Contrary to material costs, these costs have no market value. To facilitate inclusion of these costs in a cost-benefit analysis, there are different approaches to attribute a (monetary) value to this type of consequences. From the data analysis of crash costs in 32 countries in Chapter 3, we know that these immaterial costs represent a high share of the total costs related to serious injuries. Their share varies between 10% and 91%.

The method generally recommended to calculate human costs is the Willingness To Pay (WTP) approach. From the data analysis we know that out of 32 countries this method is used in 16 countries. It was also noticed that for the countries that use the WTP method, the share of the human costs in the total crash costs is much higher than countries that use other methods (see section 3.4).

The survey showed that, besides the WTP method, the Restitution Costs (RC) method and the Human Capital (HC) method are used to estimate human costs (of both fatalities and injuries). In the case of human costs, the RC method means that financial compensations paid to casualties are used as an indicator for human costs. This is also known as the 'court award approach'. As discussed in Section 2.3.2, the HC method is the appropriate method to estimate production loss, but cannot be used to estimate human costs. Another recent international review of road crash costs (Wijnen & Stipdonk, 2016), which included also non-European countries, showed that in addition to these methods also the Quality Adjusted Life Years (QALY) approach is used (in the US). Therefore, in this chapter we explore the two alternative approaches to estimate immaterial costs of (serious) road injuries. First the WTP method and its application to injuries is explained, next we discuss the QALY approach, where monetary values are put on Quality Adjusted Life Years. Finally we will discuss the court awards approach, in which 'pretium doloris' compensations awarded to traffic victims are used as an indication of human costs. These approaches are illustrated with examples from the literature and compared to the results of immaterial costs that are estimated using the WTP method.
Finally we conclude with a discussion where the different methods are compared according to different criteria concerning their quality and practicability. From this discussion a recommendation for estimating human costs of non-fatal injuries is made.

5.1 WILLINGNESS TO PAY APPROACH

5.1.1 Theoretical background

An (individual) Willingness To Pay (WTP) study estimates the amount of money a potential victim is willing to pay for a risk reduction. This amount will be determined by the probability an adverse event (such as a road crash) occurs and the amount of distress the victim would suffer from this event. A WTP study gives a monetary value that potential victims are 'willing to pay' for a specific risk reduction. This value will be the result of a trade-off between money and loss of quality of life, and could be determined through a utility maximization process (Jones-Lee, 1976). This value for a risk reduction gives an indication of the value of life (or the value of quality of life) as assigned by society. A WTP study does not measure the value of a specific individual life, but of a statistical (i.e. unspecified) life. The valuation occurs ex ante, before the incident occurs: the willingness to pay for reducing the probability of becoming a victim is estimated (Bahamonde-Birke et al, 2015).

Different methods are being used to asses this trade-off between money and the reduction of risk. The methods can be divided into two groups. One group concerns the 'revealed preference' (RP) methods: here the value of a risk reduction is derived from actual behavior. Examples are hedonic pricing (wage compensation for riskier jobs) and people's purchasing choices to reduce risks, e.g. the amount of money they pay for safety equipment (e.g. airbags). Next to RP methods, there are the 'stated preference' (SP) methods where the trade-off between money and risk reduction is simulated by questionnaires in which people are asked how much they would pay for more safety. On the one hand there are direct SP methods such as contingent valuation (where researchers create an hypothetical market in which respondents are asked how much they are willing to pay for a hypothetical instrument that reduces a certain risk). On the other hand there are indirect SP methods where the risk reduction of a certain type of adverse event is derived from choices between several types of adverse events (for example higher crash risks versus more travel time). An example is the standard gambling method or the stated choice where respondents choose the alternative that gives them the highest utility. Although all methods have their advantages and limitations, several researchers (e.g. Bahamonde-Birke et al, 2015; De Blaeij, 2003) have stressed the advantages of indirect SP approaches, in particular the stated choice approach. Indirect approaches are less prone to several types of bias that are related to the way people are asked how much they are willing to pay, for example bias related to the fact that hypothetical situations are assessed and bias related to the range of amounts respondents can choose from (when respondents are not asked to just state an amount but instead choose an amount from a number of amounts presented to them, which is often applied in contingent valuation studies).[24]

Most WTP studies focus on the value of a statistical life (VOSL) and thus on the estimation of human costs of fatalities. Information about the value of the quality of life and thus about the human cost of serious and slight injuries is relatively poor compared to the 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 (see section 5.1.2). In these studies, WTP methods are used, in which valuations for health impacts of non-fatal road crashes are derived in an indirect way. Using surveys, respondents are asked to make choices between different scenarios regarding health states resulting from a road crash. In these studies the value of an injury is determined relative to the VOSL. Another approach is to ask directly how much money people are willing to pay for a lower non-fatal crash risk (contingent valuation).

[24] See De Blaeij (2003) for a detailed overview of types of bias and how they are related to different SP methods.

5.1.2 Examples

UK

In the UK (O'Reilly et al, 1994) a standard gamble approach was applied. Respondents were asked to imagine that they were a casualty in a road crash, and to make a choice between two (hypothetical) treatment options. The treatments resulted in different (probabilities of) health outcomes, including the risk of not surviving. The study determined the value of human costs of injuries ('value of a statistical injury'), relative to the VOSL. Valuations for nine health states were determined. The health states were described in terms of number of days in hospital, severity and duration of pain, ability to do work and leisure activities, time period until complete recovery and permanent health consequences (if any). All were regarded as health states resulting from serious injuries. They were given a description of their health prognosis if they were medically treated in a normal way. Then they were asked to imagine that an alternative treatment is available that would return them to their normal health state, but if unsuccessful would worsen their health state or even result in death. From these questions the value of human costs of injuries ('value of a statistical injury') is derived, relative to the VOSL. This study estimated the human costs of a serious injury at 10% of the VOSL. For slight injuries a value of 0.9% of VOSL was estimated.

Sweden

In the Swedish study (Persson et al, 1995; Persson, 2004), contingent valuation studies were performed to derive valuations for seven types of injuries, of which four were serious and three were slight. Two of the serious injury types resulted in permanent disability, and the other two required a period of one year and six months respectively until complete recovery. The slight injuries included in this study were whiplash, fractured wrist and concussion. The study showed that the injuries resulting in permanent disability were valued at 40% of the VOSL, and the injuries resulting in temporary disability at 13% of the VOSL. Slight injuries were valued at 1% to 2% of the VOSL. A weighted average value of 16% of the VOSL was calculated for serious injuries, and a value of 1.5% of the VOSL for slight injuries.

Belgium

In Belgium (De Brabander, 2004) an approach known as the 'risk-risk' method was applied to value the human costs resulting from injuries. In this approach respondents are asked to make trade-offs between a decrease of the risk of being killed in a road crash and an increase of the risk of getting injured. Respondents were asked to consider a road safety measure on their most common route that would decrease the number of fatalities from 10 to 5, but increase the number of serious injuries from 10 to a number above 10. This latter number was varied among the respondents. The choices that the respondents made regarding these trade-offs enabled the researchers to estimate the valuation of an injury relative to the value of a fatality. Three categories of injury severity were used.

Concerning serious injuries, the value of a 'more severe' injury (several weeks hospital admission, severe pain the rest of your life, and not being able to carry out activities like working) was estimated at 83% of the VOSL. A 'less severe' injury (two weeks hospital admission with severe pain, no pain after these two weeks, and being able to work but unable to carry out some (other) activities) was estimated at 7% of the VOSL. The author regarded an average of 15% for serious injuries, which was proposed in the EU project UNITE, as 'not unrealistic'. The value of a slight injury (one day hospital admission with slight to considerable pain, mild pain for several weeks, unable to carry out some activities for several weeks, after three months fully recovered) was estimated at 1.6% of the VOSL.

5.2 QALY APPROACH

5.2.1 Theoretical background

This section discusses the use of Quality Adjusted Life Years to estimate the human costs of road injuries. These values are derived from YLDs (years lived with disability). First the related and more general concept of DALYs (Disability Adjusted Life Years) is discussed, followed by a brief discussion on methods to calculate YLD. Finally the methods to estimate human costs on the basis of YLDs are presented.

The concept of DALYs

A Disability Adjusted Life Year (DALY) expresses impacts of diseases or injuries on the quality of life, combining impact of mortality and morbidity. In relation to mortality, the number of years of life lost (YLL) is calculated, and for morbidity the years lived with disability (YLD). YLL and YLD combine the duration of loss of quality of life with the severity of the quality of life loss. Severity is expressed in disability weights, ranging from 0 (perfect health) to 1 (death). The YLD for a specific injury is calculated by multiplying the number of years lived with quality of life loss due to an injury, with a disability weight for this impact on quality of life.

A simple example can illustrate the approach. Suppose that a road casualty suffers from an injury that results in a loss of life of 25% (disability weight 0.25) for 8 years. In this case the YLD of one casualty is 2 years: 8 years multiplied with 25% quality of life loss. Concerning mortality, the disability weight is by definition 1, implying that the quality of life loss is equal to the number of life years lost. The number of DALYs related to road casualties, or a specific group of casualties, can be calculated by summing the YLD and YLL for these casualties.

DALYs are mainly applied in the field of public health. The concept was originally developed by the World Health Organization and the World Bank to estimate the 'Global Burden of Disease' (Murray & Lopez, 1996; GBD, 2015; DALYs and HALE Collaborators, 2016). In the Global Burden of Disease studies, DALYs of all kinds of diseases and injuries are calculated, enabling the ranking of diseases and injuries according to the impact on quality of life. The strength of the DALY concept is the ability to compare diseases and injuries with different impacts on mortality and morbidity, or in the case of road safety, fatalities and injuries of different severities. The Global Burden of Disease studies include transport injuries, showing that they represented 3% of the total health burden of all diseases and injuries in 2010 (Bhalla et al, 2014). The DALY approach is relatively new in road safety research and is barely used in road safety policy making. However, studies into the YLD of road injuries have been carried out in Sweden (Tainio et al, 2014), The Netherlands (Weijermars et al, 2016), Belgium (Dhondt, 2013) and France (Lapostolle et al., 2009).[25] Within SafetyCube, YLD have been calculated for six EU countries (Weijermars et al, 2016 (D7.2)).

The concept of Quality Adjusted Life Years (QALYs) is closely related to DALYs. Whereas DALYs represent a loss of quality of life, QALYs represent quality of life gains. QALYs can be regarded as negative DALYs. Like DALYs, QALY can be broken down into YLL and YLD gains and the calculation method is basically identical. However, in the QALY concept the interpretation of disability weights is inversed: 0 represents death and 1 represents perfect health. QALYs are the common measure used in cost-utility analysis of treatments aimed at improving health. In cost-utility analysis treatments can be ranked according to the cost of the treatment per QALY gained. Although cost-utility analysis is mainly applied to health care interventions, there are also applications to road safety interventions (Miller & Levy, 2000; Banstola & Mytton, 2016).

[25] See Weijermars et al. (2016) for a discussion of these studies.

In the remainder of this section we concentrate on YLD, as this Deliverable is focused on injuries only.

Methods to calculate YLD

In general, calculating YLDs requires the following steps (Haagsma et al, 2012):

1. Selecting the 'cases' (patients, injured people) to include; in the case of road safety this refers to a selection of road injuries (e.g. by severity, transport mode, etc.).
2. Grouping cases into injury categories. Several classification systems are available, for example International Classification of Diseases (ICD), the Barell Injury Diagnosis Matrix and the EUROCOST system. In the SafetyCube project the EUROCOST classification, consisting of 39 injury categories, is used to estimate YLD of serious road injuries (Weijermars et al, 2016).
3. Choosing disability weights. The sets of disability weights should be available for the injury categories defined in step 2. For example, disability weights are available for each of the 39 EUROCOST categories. Several methods are available to determine disability weights, as discussed below.
4. Calculating YLD by multiplying the number of cases per injury category by the disability weights and the duration of quality of life loss.

An essential element in calculating DALYs, which is also included in studies into monetary valuation of DALYs (see below), is determining disability weights. In general four methods are available to derive disability weights (Brent, 2014: Boardman et al, 2011):

1. Health rating method: respondents[26] are asked to rate a specific health state, e.g. on a scale from 0 (death) to 1 (perfect health).
2. Time trade-off method: respondents are asked to state their preference for different combinations of quality of life and longevity, in particular a reduction of remaining life years versus a longer life with a lower quality of the remaining life years.
3. Standard gamble method: respondents are asked to make choices between two alternatives. In the first alternative, for example a medical treatment, there is a probability of returning to normal health and a probability of not surviving. In the second alternative (without the medical treatment) a certain number of remaining life years is specified as well as the quality of these life years.
4. Health Index method: in this approach one of the other three methods is used to derive disability weights for standard health scales. These health scales belong to instruments for quantifying quality of life loss. An example of such an instrument is EuroQol (EQ-5D), which is commonly used in Europe and which is appropriate for application to road injuries (Elvik, 1995). The EUROCOST method applied by Weijermars et al (2016) is also based on the EQ-5D instrument. In this method disability weights, retrieved from health rating and time trade-off studies, are available for each of the 39 injury categories. These disability weights are based on EQ-5D quality of life scores for each injury category.

Using YLD to estimate human costs

In WTP studies the monetary valuation of road injuries is determined in a direct way either by asking people to make choices related to fatal and non-fatal crash risk (e.g. using the standard gamble method), or asking directly how much money people are willing to pay for a lower non-fatal risk (contingent valuation) (see Chapter 5.1). A different approach, that also uses WTP, is to calculate human costs related to injuries using the YLD of road injuries and the monetary valuations of a

[26] Respondents in these methods can be either the general public or patients with a specific disease, discussed below.

QALY (which is equal to the value of a YLD). Below we discuss the specific valuation methods for QALYs.

In general there are two approaches to estimate a WTP value of a QALY (Ryen & Svensson, 2014). Firstly, the WTP can be derived directly by applying a stated preference method. In this approach people are asked about the amount of money they are willing to pay for a specific health improvement (contingent valuation). Respondents are typically asked to imagine that they are in a certain health state (e.g. resulting from a disease), and they are asked their willingness to move to a better health state (e.g. after medical treatment). Several methods to elicit the WTP can be used, such as open ended questions (respondents state an amount), payment cards (respondents choose an amount from card), bidding games or a sequence of dichotomous choices (higher/lower than the presented amount). These studies include one of the four disability weights methods discussed above to estimate QALYs, enabling someone to link the WTP to a health improvement in terms of QALYs. Each of the four methods were used in several studies.

In principle other stated preference methods, such as stated choice, could be used as well, but reviews show that only contingent valuation has been used until now (Nimdet et al, 2015; Ryen & Svensson, 2014).[27] In a stated choice approach, respondents could be asked to make choices between several alternatives (e.g. alternative medical treatments) which are different in terms of the price and the health outcomes.

Secondly, a monetary value of a QALY can be derived from the value of a statistical life (VOSL). The VOSL represents the value of all remaining life years at a specific age, and thus the VOSL can be translated into a value per life year (which is equal to a QALY or a YLD) on the basis of (average) age, life expectancy and a discount rate. See for example Hirth et al (2000), who translated a large number of VOSL estimates into values per QALY.

WTP studies (just as QALY-studies in general) can either concentrate on the general public or patients with a specific disease, which both have pros and cons (Brent, 2014; Boardman, 2011). Patients have the advantage of having a better understanding of the consequences of a disease or injury. On the other hand, they may have adapted themselves to their limitations. Also, patients might give strategic answers by overestimating their quality of life loss, as this might help to allocate more public resources to medical treatment or prevention or their disease. Boardman (2011) states that patients are the most appropriate target group for determining the WTP for a health *gain* (e.g. resulting from a medical treatment), while the general public is the more appropriate group for estimating WTP for health *loss*. Regarding costs of road crashes, this implies that the respondents in a WTP survey should be the general public, as crashes result in a loss of health. Moreover, if it concerns issues of public spending, which is often the case for road safety, the general population is usually regarded as the most appropriate group of respondents. The majority of studies into the WTP for a QALY focus on the general population (Nimdet et al, 2015; Ryen & Svensson, 2014). In most of these studies the WTP for health in general is determined, while most studies among patient groups concern the WTP for health loss due to specific diseases (Ryen & Svensson, 2014).

WTP studies can apply an individual or a societal perspective. Regarding WTP for a QALY, this means that the valuation concerns the respondent's own health or the health of a certain population. Almost all WTP studies on QALYs apply the individual perspective, which is in line with economic welfare theory on which cost-benefit analysis is based. Ryen & Svensson note that the social perspective could result in higher values if respondents also have a valuation for other

[27] Ryen & Svensson classify one study (Gyrd-Hansen, 2003) as a choice experiment (stated choice), but in fact this is also a contingent valuation study as Nimdet et al. (2015) note. Gyrd-Hansen uses stated choice to derive QALY-estimates, but not the monetary value of a QALY.

people'shealth. On the other hand, WTP studies on mortality risks usually show higher valuations for individual safety.[28]

5.2.2 Examples and comparison

Quite recently, two reviews of monetary valuations of a QALY were published. Nimdet et al (2015) reviewed 14 stated preference studies published between 1995 and 2011, from which 167 WTP estimates were obtained. The review included 7 European studies, 3 Asian studies, 3 studies from the US and one international study covering countries in Europe, America, Asia and Australia. They found a wide range of QALY values: $2,019 to $282,821, with a mean value of $34,309 and a median of $9,921.[29] The ratio of the QALY value and GDP per capita ranged from 0.05 to 5.4, with a mean of 0.77 and a median of 0.43. Several explanations for the different values were found, including:

- Health scenarios concerning an improvement of quality of life resulted in lower values (ratio QALY value to GDP/capita 0.59) than scenarios about extending or saving lives (2.03).
- Studies that used a societal perspective found higher values (2.16) than studies using the individual perspective (0.63)[30].
- A shorter duration of a health scenario results in higher values.
- A larger sample size results in lower values.

The type of health scenario, for example recovering from a specific disease or a general health improvement, did not affect the results.

Ryen & Svensson (2014) reviewed 24 studies containing 363 WTP estimates of a QALY. Nine of them were also included by Nimdet et al (2015). Most of the 24 studies were carried out in a European country (12) and the other studies were in the US (5), Asia (3) or in a combination of countries (4) including two studies in nine European countries. Both stated preference studies (21 studies) and studies which used VOSLs to derive QALY-values were included (3 studies). The QALY-values ranged from €632 to €4,864. The mean for QALY-SP studies was €26,189 and the median was €19,196.[31] The studies using VOSLs resulted in much higher values: the mean value per QALY was €242,371 and the median €109,858. Ryen & Svensson (2014) found that studies aimed at the WTP for quality of life improvements result in higher QALY values than studies aimed at extending life (also the same applies if VOSL-based studies are excluded). Regarding quality of life improvements, they found that larger health impacts result in lower values per QALY. These findings are in line with the conclusions of Nimdet et al (2015).

Monetary values are (explicitly or implicitly) assigned to a QALY when a threshold for cost-utility is determined. For example, WHO recommends a threshold of three times the Gross Domestic Product (GDP) per capita per QALY. This threshold was introduced in the World Health report 2002 (WHO, 2002) and is still used in the WHO-CHOICE (CHOosing Interventions that are Cost-Effective) project. The threshold means that a health intervention is regarded as cost-effective if the costs per QALY gained are lower than three times GDP per capita. For EU-countries this would be a threshold of about €80,000 per QALY (price level 2015). A criticism on the WHO threshold is that the value per QALY does not reflect the WTP for a QALY (Marseille et al, 2014; Nimdet et al, 2015). In that sense it is regarded as an arbitrary value aimed at decision making about health interventions. In the US a threshold of $50,000 has been used since the 1990s (Grosse, 2014). This threshold is not based on WTP, but instead on the cost-effectiveness of a specific treatment (kidney dialysis). The threshold

---

[28] This issue is also addressed a recent Dutch study, where respondents are asked to state their WTP for reducing fatal crash risk from a consumer perspective and from a government perspective (discussed in D3.2).

[29] These values were not adjusted for income or purchasing power differences and the price levels were not the same as the price level of the year of the study was used.

[30] The number of studies using the societal perspective is very limited however (two studies).

[31] Excluding a SP study on foodborne risk, which the authors of the review consider to be methodologically different from the other studies. This study was also excluded by Nimdet et al. (2015).

has been criticized as being too low (Ubel et al, 2003; Neumann et al, 2014), and a threshold of $100,000 is sometimes used by researchers (Neumann et al, 2014). There is no common EU threshold, but some individual countries have determined a cost-effectiveness threshold. For example, in the UK a threshold of £20,000 per QALY is used by the National Institute of Health and Care Excellence (NICE, 2012). In the Netherlands a threshold of €20,000 is used as a minimum for prevention, although also higher values have been discussed (Pomp et al, 2014). All these values have in common that they are not based on WTP, and therefore are not very useful to determine human costs of road injuries

United States

In the US, human costs of injuries are calculated on the basis of QALYs. Per MAIS severity category (1-5) the number of QALYs lost is determined, and human costs are estimated using a value per QALY. The number of QALYs lost is based on the Injury Impairment Index (III), an instrument to determine functional losses resulting from injuries using six health dimensions and four severity levels per dimension. In the latest road crash cost study (Blincoe et al, 2014), disability weights for each dimension and severity level were updated using disability weights from other instruments such as EQ-5D and the Health Utility Index (Spicer & Miller, 2010). This resulted in a value per injury for each MAIS-category as a percentage of the VOSL, ranging from 0.3% for MAIS1 casualties to 59.1% for MAIS5 casualties. Costs per injury were calculated by multiplying these percentages by the human costs per fatality ($7.7 million). The (implicit) value per QALY is $340,000. Table 5-1 shows the results. Human costs of injuries have a share of 57% in total human costs. Particularly lower severity injuries have a large share in total costs (MAIS1-2: 33%, MAIS1-3: 46%).

	Value per casualty		QALY loss per injury	Number of casualties	Total human costs
	% VOSL	$			
MAIS 1	0.3%	23,241	0.07	3,459,200	80,395
MAIS 2	4.4%	340,872	1.00	338,730	115,464
MAIS 3	10.4%	805,697	2.39	100,740	81,166
MAIS 4	26.3%	2,037,483	6.04	17,086	34,812
MAIS 5	59.1%	4,578,525	13.59	5,749	26,322
Fatal	100%	7,747,082		32,999	255,646
Total					593,805

Table 5-1 Human costs in the US in 2010; Sources: Blincoe et al (2014) and Spicer & Miller (2010)

Comparison of QALY-values and direct WTP-values for road injuries

To determine which QALY-values are applicable to road injuries, we selected WTP studies from the two reviews discussed above, using the following criteria:

- WTP is derived for an improvement of quality of life.
- WTP is derived for general health.
- The target group is the general population.
- The individual perspective is applied.

This implies that studies aimed at deriving WTP for extending life or saving life, studies focusing on a specific disease or specific groups of patients as well studies taking the societal perspective are excluded. WTP studies on extending life or saving life are regarded as less relevant for road injuries, because we are interested in valuation of non-fatal injury. Studies aimed at specific diseases are neither relevant, because road injuries can have several kind of health consequences. Studies applying the societal perspective are excluded because this perspective is not in line with economic welfare theory (see Section 3.2.1). Table 5-2 shows the values per QALY found in the selected studies. In each study, several values were determined (e.g. for different health scenarios or different countries). The lowest, highest and mean values are included for each study. This shows that there is a very wide range of QALY values: €1,213 to €244,768. The lowest and highest values were both found in the Netherlands, but in different studies. Also within the same study, sometimes large variations were found. The mean values range from €4,760 to €114,665. If the results of Bobinac et al (2014) are excluded, this range is €4,760 to €42,499. The mean value found by Bobinac et al (2014), which is 2.7 times higher than the higher mean value of the other studies (€114,665), can be regarded as an outlier.

Study	Country	Value per QALY (€2010)		
		Lowest	Highest	Mean
Gyrd-Hansen (2003)	Denmark	11,892	14,121	13,007
Pinto-Prades et al (2009)	Spain	4,654	125,588	30,843
Bobinac et al (2010)	Netherlands	9,838	25,108	16,627
Zhao et al (2010)	China	3,671	5,693	4,760
Bobinac et al (2012)	Netherlands	1,213	21,959	9,389
Gyrd-Hansen & Kjær (2012)	Denmark	3,040	107,688	38,844
Pennington (2013)	Denmark, France, Hungary, Netherlands, Norway, Poland Spain, Sweden, UK	6,266	23,049	12,210
Robinson (2013)	Denmark, France, Hungary, Netherlands, Norway, Poland Spain, Sweden, UK	7,841	43,279	20,161
Shiroiwa et al (2013)	Japan	15,597	77,986	42,499
Bobinac et al (2014)	Netherlands	54,132	244,768	114,665

Table 5-2: Values for a QALY found in WTP studies. Source: Ryen & Svensson (2014)

To compare the direct WTP approach with the QALY approach, Table 5-3 shows the human costs in countries for which the YLD per serious injury (with injury severity MAIS3+) is estimated by Weijermars et al (2016). By dividing the WTP value for serious injuries by the YLD per serious injury, the value per YLD is calculated. Only countries that have estimated human costs using a direct WTP method have been included. This shows that the value per YLD as derived from direct WTP values and YLD per serious injury (Table 5-3) is much higher than the QALY values found in the literature (as summarized in Table 5-2). Moreover, the values are an underestimation because most direct WTP values concern hospital admissions or MAIS2+[32], while the implying YLD per serious injury refers to MAIS3+ casualties.

Country	WTP value serious injury (€2015)	YLD per serious injury^	Value per YLD (€2015)
Austria	301,160	3.2	94,113
Belgium	239,171	2.7	88,582
Netherlands	223,450	3.2	69,828
Spain	208,560	2.4	86,900
UK*	205,952	3.1	66,436

Table 5-3: Direct-WTP values of serious injuries, YLD per serious injury (MAIS3+) and resulting value per YLD

^taken from Weijermars et al (2016)
** YLD has been estimated for England*

5.3 COURT AWARDS APPROACH

5.3.1 Theoretical background

A second alternative approach to estimate human costs of road injuries is to use the compensation payments that are awarded to road victims or their relatives by insurance companies or courts. Instead of grounding these values on individual preferences as is done in the WTP and QALY approach, human costs are estimated by a value that is decided by an institutional body. In the court awards approach, these compensation payments are regarded as an indication of the cost that society attributes to the loss of quality of life (World Bank, 2005).

Damage payments by courts consist of compensations for patrimonial damage, which can be appraised in monetary values, and compensations for extra-patrimonial damage, for which the value can't be estimated with a market approach. Consequently the attribution of a compensation for the loss of quality of life consists of a judgement of a fair value by the judicial system. With this payment the judge aims to restore the victim to their original state before the occurrence of the road crash. This judicial decision is illustrated in Figure 5-1. On the horizontal axis, the (loss of) quality of life is given, while the vertical axis reflects units of money. After a road crash a victim's quality of life worsens, which is illustrated by a shift from A to B. This shift brings the victim upon a lower utility curve (from U_1 to U_0). The judicial decision consists of restoring the victim in their original position, and thus bringing the victim back on the original utility curve U_1. This means a shift from B to C where the amount of the compensation that will be awarded to the victim is given by DE. The victim will be on the same utility curve but the amount of money and the health state are different than before the road crash. The compensation DE reflects the value a potential victim is willing to pay for a risk reduction, which is the trade-off between money and loss of quality of life and is determined by a utility maximization process (Jones-Lee, 1976).

[32] See Wijnen et al. (2017), Appendix E, which includes an overview of the definitions of serious injuries in road crash cost studies in European countries. In Belgium and the UK hospital admission is used as criterion, while the definition in the Netherlands MAIS2+ injury severity. The official definition in Austria is related to sick-leave (more than 24 days), so this may include only more severe injuries. For Spain no information on the definition of a serious injury was available.

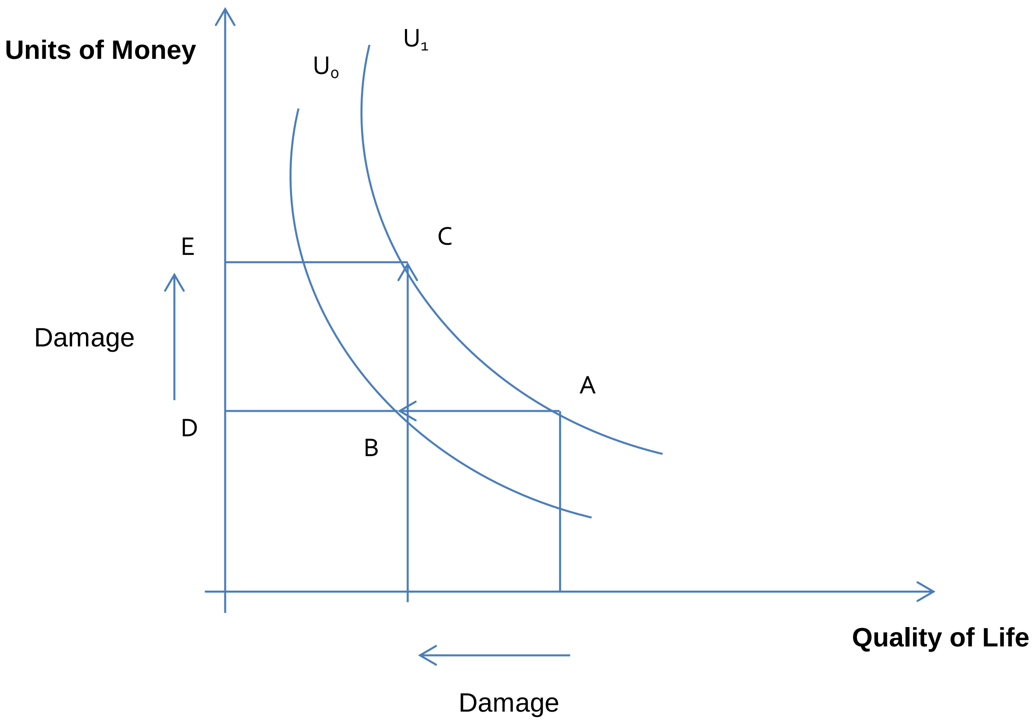

Figure 5-1 Trade-off between money and loss of quality of life expressed as a utility maximization process

These compensation payments can give an indication for the value of fatal and also of non-fatal injuries. As mentioned by Cohen and Miller (2003), "the VOSL implied by a jury award for a non-fatal injury can be extracted as the award amount divided by the fractional loss in lifetime QALYs resulting from the injury".

The values for the quality of life estimated by courts will however differ from those estimated by WTP studies, which implies that the trade-off illustrated in Figure 5-1 is not always correctly approached by judges. There are different elements that explain this difference:

(1) A first difference is that judicial decisions have a different objective than WTP studies. The objective of judges is to compensate the victim for the damage caused by a road crash. The objective is not to assist policy makers in determining the value of a statistical life.
(2) A second difference is that the value of quality of life results from an economic trade-off (utility maximization for instance) while the compensation is an outcome of a judicial process (to restore the victim to their original state).
(3) Further, the trade-off made by the road user happens before the occurrence of the crash (ex ante); while a judge will bear in mind the trade-off shown in Figure 5-1, the decision is only taken after the crash. Therefore a compensation does not reflect the amount of money one is willing to pay to reduce the chance of being involved in a road crash.
(4) A final difference, related to the previous one, is that a judge will determine a compensation for a specific individual, while in the WTP studies the value of a statistical, and thus an unspecified, life is determined.

Furthermore it is not always clear if the judicial system bases its decision on the trade-off made by road users. The literature shows a wide variation in the decisions of judges, and the basis upon which these are taken is not always very clear. Much depends on the type of judicial system, the type of settlement (is there a conflict or an agreement) and whether judges take information from WTP studies into account. A study of Smith (2000), where awards provided by juries to non-fatal road injuries in alcohol-related accidents were analysed, showed that juries are not perfectly unbiased when assessing compensation awards. They tend to increase compensatory awards for punitive damages and for more wealthy defendants. In Germany the human costs are only included in the compensation payments to the extent that they influence the costs related to the resource costs of crashes. Three types of costs are distinguished: (1) the psychological impacts of road crashes that can restrict someone from performing their job, (2) restrictions on the choice of education or occupation, and (3) increased risk of illness. These cost elements are only justified by their potential for productivity loss (Baum et al, 2010).

Awards could be useful to determine other cost components such as the material damage or medical and rehabilitation costs. It could also be helpful for assessing the non-pecuniary costs of an injury, especially for pain, suffering loss, loss of amenities and enjoyment of life (Bitre, 2009, p. 58). Those components are part of the quality of life dimension, so that court awards could provide useful details for understanding a more general and aggregate figure given through the value of quality of life.

5.3.2 Examples and comparison

The wide variety of amounted awards is presented in this chapter by means of examples from three countries. Two studies from the United States calculated the VOSL through court awards given for non-fatal injuries and compared this value with values from WTP studies. A study from France gives a detailed description of how compensation payments by judges are organized through different categories of immaterial damages, and how the distribution of different components over the total compensation differs according to the severity level. In Germany the court awards include an element of 'pain compensation' which is used to compensate the victim for the human costs. Germany is one of a few countries that uses the values from courts as an official value for human costs in cost-benefit analyses. The values in France and Germany are compared to the standard values that were calculated in SafetyCube Deliverable D3.2 (using WTP) (Wijnen et al, 2017).

USA

Smith (2000) designed a statistical model to estimate the value of life through court awards. His model is based upon the concept of present value of impairment (PVIMP), which represents the impairment suffered by the victim, a coefficient ranging from 0 (no impairment) to 1 (death). This PVIMP is given a value for different types of impairment (mobility, cognitive, sensory, daily living, cosmetic, and pain) which are given a weight. The total level of impairment is attributed a monetary value according to the work disability and the income loss, which depend on the socio-economic status of the victim. While the author takes into consideration some variables for the plaintiff (mental status, employment status, etc.), the case (contributory negligence, liability, etc.), the defendant characteristics (personal wealth, DUI) and a regional dimension, he is able to estimate a value for the VOSL.

In this study, the awards for non-fatal injuries arising from lawsuits in 666 drunk driving cases in the United States during the 1980s were examined. From this analysis, the value of life based on the ex post valuation of juries was deducted and compared to the value of life estimated in other studies that used ex ante data (WTP studies). It was shown that the awards varied significantly, the statistical model could only explain 35 to 50% of the variation. This means that the amounts awarded are not only explained by the objective variables in the model. The ex post value of life is between $2.3 million to $4.9 million, which is consistent with the value of life found in other (WTP) studies.

Cohen and Miller (2003) used a similar approach for estimating the VOSL through court awards given for non-fatal injuries related with assault and consumer product deficiencies. They also use the concept of PVIMP, defined as the present value of future utility loss, because of its links with QALYs. The authors show that figures issued from court awards are aligned with estimates provided by other methods: the implied value of a statistical life in court awards is between $1.4 and $3.8 million. Their results raise some other issues, such as the variability of awards, their good predictability, but also the possibility of reducing uncertainty by providing to the court some estimates of the VOSL. It implies that there is a recursive relationship between the compensations awarded by courts and the values determined by other methods such as WTP.

France

In France (Carnis, Vaillant & Dervaux, 2013) the payment of immaterial costs (or extra-patrimonial damage) is organized through four different categories. The first is 'PPI' (Partial Permanent Incapacity), the permanent psychological and physical damage; the second is 'solatium', the emotional and physical suffering or pain; the third is the aesthetical damage (damage to the physical appearance); and the fourth is the loss of amenity that limits the victim in their recreational activities.

The insurance companies and mutual insurance bodies collect statistical information related to the victims for which they have to pay compensations (AFA, 2014). Concerning the extra-patrimonial damage, insurances distinguish victims with and without PPI. Victims without PPI could be considered as slightly injured. It is interesting to note that extra-patrimonial damage represents roughly 55% of the total compensations paid to these slightly injured road accident victims. This category of victims represents however only 5% of the total amount of compensations paid to road victims. This means that the great majority of compensations are paid to the more severe road injuries.

Concerning the different categories of immaterial damage, it can be noticed that compensation for 'pain' (solatium) is the most important component in the total compensation for slightly injured victims (45%). Medical spending (23%) and revenue loss (12%) represent a much smaller share.
The distribution of compensations over cost components is different for victims with PPI. Extra-patrimonial damages constitute only a minor component of total compensations (30%). Table 5-4 shows that the more severe an injury is, the less important the share of the extra-patrimonial costs is. This is because the cost of the other components increases at a higher rate.

Type of damage	% of the total damages paid	1-5 % PPI Rate	6-49 % PPI Rate	50 % and above PPI Rate
Solatium	6.4%	20.2%	7.2%	2.2%
Aesthetic damage	1.5%	2.4%	2%	0.8
Loss of amenity	1.4%	0.6%	1.9%	1.1%
PPI	20.7%	24.2%	19.2%	14.3%

Table 5-4 Shares of different categories of damages in the total amount of paid damages

Another observation is that the PPI compensations (compensating for functional deficits) are the main component of extra-patrimonial costs for these victims. Aesthetic damage and loss of amenity only represent a very small part of compensations. A further analysis provided by AFA showed that the more severe the (extra-patrimonial) damage, the more important the compensations paid are. Moreover, for a level of severity of a specific extra-patrimonial damage, the more important the PPI is, and the more important the compensations awarded for those extra-patrimonial damages are. Consequently, there is an interaction between the categories of compensations awarded (Carnis et al, 2012).

For the settled cases of the year 2012, the average compensation for suffering ("solatium") amounts to €6,150, for aesthetic damage €1,050, and €970 for loss of amenity. The average cost for the functional deficit is more complex to analyse, because it depends on the rate of PPI. The average costs are respectively €2,410 for a PPI rate below 5%, €33,780 for a rate between 20% and 29%, and €209,310 for a rate above 50%.

The total cost (including compensations for patrimonial and extra-patrimonial damage) of a slight injury for insurance companies in France for the year 2012 amounts to €1,500, while a serious injury costs on average more than €66,500. The latter category shows a huge variability in the average costs of each component, emphasizing the need of a careful approach for analysing the costs of road crashes in this category.

Despite the detailed estimation of human costs by courts, these values are still much lower than those obtained in WTP studies. In Table 5-5 the total court awards are compared to the human costs of serious and slight road injuries calculated in SafetyCube Deliverable 3.2. Here, a standard value for each cost component for each severity category was obtained by taking the median value for all countries that use the recommended method. In the case of human costs, this means that only countries that use the WTP approach are taken into account. While the court awards also include other cost components, the values are still much lower than the value of human costs calculated by the WTP approach.

	Compensation for patrimonial and extra-patrimonial damages awarded by courts (€2012)	**Human costs, SafetyCube D3.2 (value transfer) (€2015)**
Serious injury	66,500	230,384
Slight injury	1,500	15,514

Table 5-5 Comparison of human costs of road injuries awarded by courts and defined in HEATCO, France

Germany

In Germany (Baum et al, 2010) the amounts awarded by courts as 'pain compensation' are used as an indicator of human costs. It is not clear how the amounts awarded are related to the three cost items discussed in section 5.3.1. No evidence is presented to show that pain compensation awarded by courts adequately compensates individuals for the losses of welfare associated with the components of human costs.

The pain money awarded in case of death refers to the suffering the victim sustained between the road crash and the moment of death. In most cases, death is immediate but some victims survive for a certain period of time and may be in pain during this period. The mean amount, based on 12 court cases is €31,542.59. Based on 390 court cases, the valuation of human costs for a seriously injured victim is €12,278.53. Based on 303 court cases, human costs for a slightly injured victim amount to €1,952.24.

These costs are much lower than those obtained in WTP studies. Moreover it is not known whether victims regard the compensation given as adequate, the report states clearly that individual preferences should not count and should be disregarded as far as the provision of road safety is concerned. It would therefore seem to be irrelevant whether the "pain compensation" actually compensates or not. In Table 5-6 the human costs as awarded by courts are compared to the standard values for human costs that are calculated in SafetyCube Deliverable 3.2 (using the median value of countries that use the WTP approach) (Wijnen et al, 2017). From the table it can be seen that the values resulting from pain compensation are clearly lower than the costs resulting from the WTP approach.

	"Pain compensation" awarded by courts (€2005)	Human costs, SafetyCube D3.2 (value transfer) (€2015)
Fatality	31,543.15	1,587,001
Serious injury	12,278.53	230,384
Slight injury	1,952.24	15,514

Table 5-6 Comparison of human costs of road injuries awarded by courts and defined in HEATCO, Germany

5.4 DISCUSSION AND RECOMMENDATIONS

In this chapter three different approaches to estimate human costs of road injuries are presented. While WTP is the most common method, the QALY and court awards approaches are also used in different studies to estimate these immaterial costs. The theoretical background of each of these approaches was described and illustrated by some examples. This final section includes a discussion of the different approaches by comparing their strengths and weaknesses according to different criteria concerning their quality and practicability. From this discussion a recommendation for estimating human cost of non-fatal injuries is made.

The criteria on which the different approaches are compared are on the one hand related to the quality of the resulting estimates. Is the method reliable and valid? How much do the results differ between studies? How detailed is the information? Are the estimates fair or ethical? Is the method consistent with economic welfare theory? Are the values estimated ex ante (before the crash)? Consistency with economic welfare theory is crucial since this is the basis of cost-benefit analysis. Therefore costs of road crashes as an input for cost-benefit analysis should ideally be grounded on this theory. In economic welfare theory economic values are recognized as expressions of individual/household preferences of willingness to pay (see for example Boardman et al, 2011). An ex ante evaluation of the value of the quality of life is necessary because a cost-benefit analysis should be based on risks (Schelling, 1968; Mishan, 1671).

Next to that the practicability of the estimations is assessed. Is the data readily available? How complex is the data collection? Can the values be used for cost-benefit analysis? Has this method already been used for road safety?

An overview of the strengths and weaknesses of each approach is presented in Table 5-7.

Methods	Strengths	Weaknesses
(direct) WTP	• Sound theoretical background (economic welfare theory) • Operational value (for cost-benefit analysis and costs of road crashes) • Consensus among researchers (concerning the importance of individual choices) • Most used technique for eliciting the value of risk reductions in different research areas	• Complex method for eliciting values, several potential biases • Variability of results • Only provides global information (no different components)
QALYs	• Sound theoretical background (economic welfare theory) • Possibility of comparing different types of injuries and levels of disability • Ability to utilize detailed information on type and severity of injuries and consequences for quality of life • Ability to value different health states of the victim • More detailed than direct WTP	• Two stage process (first determining a disability weight, then a valuation): an extra level of uncertainty • Relatively new method for the road safety field, no generally supported monetary values • Variability of monetary values, several possible biases in eliciting value • Only uses contingent valuation: prone to several types of bias • Ethical issues
Court awards approach	• Decomposition of the award provides more detailed information about the total damage borne and their relationship. • Information is already available, no complex study has to be conducted • Additional information on awards for some specific damages (aesthetic damages, pain, loss of amenity, non- pecuniary costs, etc.)	• Does not reflect a VOSL since the purpose of judicial decisions is only to compensate the victim and not supply information for decision-makers. • Often more related to production loss than to the actual human costs. • Variability of the value related to the contingency of the judgement, dependent on the judicial system • Variability of the value related to characteristics of the victim and defendant • It is not always certain if victims are actually compensated fairly. • Not possible to use in cost-benefit analyses since individual preferences are not used, and the value is determined ex post instead of ex ante.

Table 5-7 Weaknesses and strengths of different approaches to estimate human costs of road injuries

Willingness To Pay approach

The WTP approach is the most commonly used method to estimate human costs of injuries. A valuation by road users of the reduction of a chance of being involved in a road crash is derived by direct or indirect methods. Since the method is based on individual preferences of willingness to pay, it is consistent with economic welfare theory. Besides the values are determined ex ante, before the occurrence of the crash, so they can be used as an input for cost-benefit analyses. There is a large consensus among researchers concerning the importance of individual choices. This technique is therefore used in different research areas to elicit the value of a risk reduction, for example environmental, transport, occupational and fire risks (Lindhjem et al, 2011: Miller, 2000).

However we can also find different points of criticism on the WTP approach in the literature (Elvik, 2016). Baum et al (2010) and Bahamonde-Birke et al (2015) criticize the complex method to elicit values for quality of life. They criticize the survey nature of WTP studies, and argue that the results depend on the design and implementation of the survey. Furthermore, people can have difficulties understanding changes in 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 leads to a wide variability of results of WTP studies. Next to that Baum et al (2010) argue that there can be a large difference between the hypothetical and actual willingness to pay. This discrepancy is likely to be particularly great when it concerns human health and survival. Yet there are methods, for example the certainty scale, where respondents indicate how sure they are about their answers. It is also possible to design WTP studies so that respondents have to make real payments (Dubourg, 1995).

Furthermore there are also points of criticism on the WTP method that are not valid and can be countered. For example it is stated that the valuation of pain and suffering embodies a different concept of cost than the concept used when estimating the costs of accidents, according to which costs represent the use or loss of material resources (Baum et al, 2010). However, it can be argued that the loss of welfare associated with pain, grief and suffering can be considered as a real cost even if it does not involve the consumption of material resources. As for loss of life, it is reasonable to think that the principal reason why most people want to increase the prospects of survival is simply because they enjoy life. It is very restrictive, and not consistent with economic welfare theory, to limit the concept of cost to the use of material resources, like hospital beds, cars, or production loss (Elvik, 2016).

Indeed, the real issue is whether all results of valuation research are anomalous or whether this body of research contains any results at all that make sense. The list of anomalies that have been found again and again is large. For SP studies the main anomalies include (only those discussed extensively in the literature are listed):

1. Insensitivity to scope (WTP does not vary “sufficiently” with the size of the change in risk).
2. Disparity, often very large, between willingness-to-accept and willingness-to-pay.
3. Inconsistent relationship between respondent age and willingness-to-pay (different studies find different shapes of the relationship).
4. Hypothetical bias, since no real payment is involved, amounts can be greatly overstated.
5. Starting point bias in studies relying on iterative bidding.
6. Payment range bias in studies relying on payment cards.
7. Payment vehicle bias in studies using taxes as the means of paying.
8. Strategic answers when safety is provided as a public good (free-riding).
9. Lexicographic choices in stated choice tasks.
10. Inconsistent choices in stated choice tasks.
11. Discrepancy between actual and perceived risk in studies that have investigated perceived risk.

It is not possible to find a single stated preference valuation study which is not affected by one or more of these problems. Each of them represents a sufficient reason for rejecting the findings of the study (Elvik, 2016).

QALY approach

Although QALYs have not been commonly used until now to estimate human costs of road injuries (only used in the US), the QALY approach clearly has several advantages above the direct WTP approach that is currently applied in most countries (mostly by transferring values from the few studies that have been conducted in some countries). A main advantage of the QALY approach is the level of detail. Direct WTP studies distinguish between only three to nine injury types or health states after a crash. Consequently, a value is derived only for this limited number of injury types or health states, which does not reflect the great diversity in types of road injuries, severity of injuries and health consequences of injuries. The QALY approach is much more detailed in that respect. For example, the INTEGRIS method, that has been applied in SafetyCube to determine YLD in several countries (Weijermars et al, 2016), distinguishes between 39 EUROCOST injury categories. For each EUROCOST injury category disability weights are available, that reflect the impact on quality of life on the short and long term as a consequence of the injury. Each road injury can be categorized into one of the 39 categories using ICD codes, which enables calculating YLD for each casualty in a more detailed way than in the direct WTP approach. Next, human costs can be calculated using a WTP for an YLD.

Calculating human costs on the basis of YLD requires availability of a valid monetary value of an YLD. To be consistent with economic welfare theory, this value should reflect individual preferences and therefore it should be based on individual WTP. Reviews of studies on the WTP-value of a QALY (which is the same value as the value of a YLD), show that QALY-values related to improving quality of life are 1.4 to 3.3 times lower than QALY-values related to extending life (Nimdet et al, 2015; Ryan & Svensson, 2014). This means, for example, that a loss of 10% of quality of life suffered by 10 people is valued lower than losing one life, even if the number of lost QALYs is exactly the same (1 QALY). From these results, it can be argued that QALY-values related to extending life, including values deducted from the VOSL, would result in an overestimation of human costs of non-fatal injury.

This conclusion is strengthened by the fact that human costs of injuries calculated on the basis of direct WTP studies – that means mostly as a percentage of the VOSL – are higher than QALY-based values per injury. Interestingly, in direct WTP studies the same method is used as in some studies aimed at determining disability weights for QALY calculations: people are asked to trade-off fatal risk and non-fatal risk, for example by applying the standard gamble approach. Apparently, when people trade-off fatal and non-fatal risks in for example a standard gamble experiment, their valuation of non-fatal risks is higher than when they are asked how much they are willing to pay for reducing fatal and non-fatal risks separately.The fact that different methods are used for eliciting QALY preferences (disability weights) than for eliciting monetary values may be an explanation. As Elvik (2016) discusses, QALY-methods and WTP-methods use different assumptions regarding the utility functions underlying individual preferences, resulting in different outcomes.

As discussed above, SP methods have several limitations and potential biases, for example related to the design of the survey. It is remarkable that only the contingent valuation is used in monetary valuation studies on QALYs, while this method is known to be prone to several types of bias, e.g. related to the direct way of asking how much people are willing to pay (see e.g. De Bleaij, 2003). In VOSL-research, other methods, such as the stated choice approach, are often preferred above contingent valuation (Bahamonde-Birke et al, 2015; Lindhjem et al, 2010). In the stated choice 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. Applying this approach to health would be an interesting new direction for monetary valuation of QALYs.

Ethical issues should be considered when applying YLD to estimate human costs of road injuries, in particular regarding age and distributional effects. Regarding permanent disability, using YLD implies that a higher value is assigned to younger casualties because they have more remaining life years (with quality of life loss). Using different values for casualties with the same injury severity, and consequently a higher benefit-cost ratio of road safety measures aimed at younger road users, can be regarded as undesirable from an ethical perspective. In addition, one very serious injury, for example with lifelong disability consequences, is regarded as equal to a large number of slight injuries that result in the same number of lost QALYs. From the perspective of distribution of health impact among people, this can be regarded as ethically undesirable: preventing the serious injury might be preferred to preventing the larger number of slight injuries.

The QALY-approach is a promising approach for future application, but 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).

Court awards approach

While in the WTP and QALY approach the human costs of injuries are estimated based on values from studies that are specifically undertaken to estimate these costs, this is not the case for the court awards approach. Here the compensations awarded by a judicial decision are taken as an indication of the value of the quality of life. While this information can contain additional information on awards by specifying different types of immaterial damages (e.g. France), there are many limitations to this approach.

First of all the judicial decisions reflect principally a compensation for certain damages and do not give us any information on the VOSL. The purpose of judges is actually not to assist policy makers in their decision process, but to compensate victims for their damages.

Second, the examples discussed in section 5.3.2 show that the amounts awarded by judges vary widely. While the amounts found in the US are very close to those found in WTP studies, the amounts in other countries are much lower. The level of compensation payments for immaterial costs is very dependent on the type of judicial system and the type of settlement (conflict or agreement). It is not always very clear how court amounts are defined (e.g. Germany) and whether they actually compensate the victims. In some cases the judicial decisions are based on WTP studies (e.g. examples for the US), but in most cases the compensated awards are more related to production loss than to human costs.

Lastly, the most important limitation of the court awards approach is that it cannot be applied in cost-benefit analyses. This is because the values for human costs are not based on individual preferences and therefore are not consistent with economic welfare theory underlying cost-benefit analysis. Furthermore, court award values are determined ex post and thus do not reflect the value of a risk reduction of the occurrence of an uncertain event, and they concern a specific individual case, and do not reflect the value of a statistical life.

Recommendation

Globally there exists very little information on the human costs of injuries. For future cost-benefit analyses, we recommend to use direct WTP studies or QALYs to estimate the monetary values of non-fatal road injuries, since these approaches accord to the principles of the economic welfare theory. QALYs are more complex to estimate but have the advantage of giving more detailed information on different types of injuries. We advise against using the court awards approach because of its unpredictability (the awards are among others highly dependent on the type of judicial system) and it has no foundation in the economic welfare theory.

5.5 SUMMARY

This chapter discussed three approaches to estimate the human cost of serious injuries, which is also referred to as the value of quality of life. The WTP method, that is most commonly used and recommended, is compared to the QALY approach and the court awards approach. Several examples are used to identify the main strengths and weaknesses of these approaches.

Direct WTP studies to estimate human costs of injuries appear to be very rare because of their complexity. Existing WTP studies calculate the human costs of injuries relative to the value of a statistical life. These values for serious injuries range between 10 and 16% of a VOSL. These studies are however rather limited in the specification of road injuries.

Another approach is to use WTP studies to estimate the value of QALYs (Quality Adjusted Life Year). A QALY for a non-fatal injury consists of YLD (Years Lived with Disability) which reflect the severity of the injury (by determining a severity weight) and the number of years lived with a reduced quality of life. This approach enables someone to estimate WTP values for a large diversity of injury types. However it was found that values based on QALYs were lower than values based on direct WTP studies. This is because the valuation of improving the quality of life appears to be lower than the estimation of extending life, and the direct WTP approach uses the value of life to derive human costs of injuries. Therefore, it can be argued that QALY-values that are based on extending a life would result in an overestimation of human costs of non-fatal injuries. However, more research into the question of why the direct WTP approach results in higher values than the QALY approach is recommended.

While the WTP approach and the QALY approach use complex studies, for which there are some methodological issues, the court awards approach makes use of existing information. In this approach the value of quality of life is estimated by the compensation payments awarded by courts to injured road victims. These values are generally much lower than those obtained in WTP and QALY studies. Moreover the values appear to be unpredictable since they are highly dependent on the judicial system. The aim of courts is to compensate the victims and not to provide information for cost-benefit analyses. Since this approach is not based on individual preferences and the valuation is done ex post instead of ex ante, the values from court awards are not estimated in accordance with the economic welfare theory and can’t be applied in cost-benefit analyses. We therefore recommend using direct WTP studies or QALYs to estimate the monetary values of non-fatal road injuries. QALYs have the advantage of giving more detailed information on different types of injuries.

6 Conclusions and recommendations

Costs per serious injury vary between €28,205 and €975,074 in European countries. Human costs generally constitute the largest share of the costs related to serious injuries and are recommended to be estimated using the WTP method, either by calculating a direct WTP-value for injuries or by using QALYs. Medical costs and production loss also constitute an important part of the cost of serious road injuries. The impact of certain victim's characteristics and the severity of the injuries should be accounted for when estimating these costs. Additionally it is recommended to assess medical costs on the long term.

6.1 CONCLUSIONS

The cost information that was collected by means of a survey in 32 European countries revealed that the cost per serious injury varies considerably between countries. The reported cost per serious injury varies between €28,205 and €975,074. Differences can be explained by whether or not the WTP method is used for calculating the human costs, differences in the definition of a serious injury and differences in the cost components that are included. Moreover, the reporting rate of serious injuries appeared to have a negative effect on the cost per serious injury. Considerable differences between countries were also noticed when estimating the total costs of serious injuries. These costs vary between 0.04% and 2.7% of a country's Gross Domestic Product (GDP).

Furthermore it appeared that serious injuries constitute an important share in the total crash costs, they account for 14 to 77%. While this share can be influenced by the relative numbers of fatal, serious and slight injuries, we also find a variation of the cost per serious injury relative to the cost of a fatality. The cost per serious injury varies between 2.5% to 34.0% of the cost of a fatality[33]. However for the large majority of the countries this value lies between 10% and 20%. This is due to the fact that many countries apply a fixed percentage - from an international source - to the human cost of fatalities to estimate the human cost of a serious injury.

When analysing the cost components, it was found that three components make up the bulk of costs for serious injuries. Human costs constitute the largest share and they tend to be much higher when WTP is used. Medical costs and production loss together make up around 18% of the total costs related to serious injuries.

More detailed information on medical costs and production loss is given by several studies from Belgium, France, Germany, Greece and Italy. Age, socio-economic status, type of injury, injury severity, health status (pre-existing comorbidities) and road user type appear to have a significant influence on the medical costs attributable to a road crash. Particularly older victims with a worse health status (and more comorbidities) show higher acute and long term costs. This has implications for researchers and policymakers in assessing the (future) medical costs of potential traffic victims.

[33] Poland is an exceptional case since it is the only country where the cost of a serious injury is higher than the cost of a fatality.

Next to the influence of a victim's characteristics, the importance of assessing medical costs on the long term was shown. The studies found a significantly higher level of medical costs attributable to the road crash the first year after the crash. Also different cost trajectories over time were found according to the victim's characteristics. Serious injuries lead to a higher increase of medical costs that lasts longer while older victims, and victims with a worse health state, show an increase that does not disappear over time.

Concerning production loss, it was shown that revenue loss increases when injury severity is higher, although MAIS4 and MAIS5 injuries do not lead to much higher production losses than MAIS3 injuries. Furthermore, the revenue loss differs between professional groups. These differences could be explained by the labour market participation, average wage and the average length of absence inherent to a certain profession.

While Willingness To Pay (WTP) is used in most countries to estimate the human costs of serious injuries, two alternative approaches were explored. Whereas WTP studies are mainly constituted to measure the human costs of fatalities, WTP studies that specifically estimate the human costs of non-fatal injuries are rare and rather limited in the specification of road injuries. Using the WTP method to estimate the value of QALYs on the other hand gives the possibility of providing values for a large diversity of injury types.

While the WTP approach and the QALY approach use complex studies, for which there are some methodological issues, the court awards approach makes use of existing information. The compensation payments to road injuries awarded by courts are in most cases however much lower than the values obtained in the other methods, and are characterized by a huge unpredictability since they are highly dependent on the judicial system. Since these values are not based on individual preferences, and they are determined ex post and apply to a specific case, they cannot be used in a cost-benefit analysis.

6.2 RECOMMENDATIONS

6.2.1 Recommendations for cost studies

In order to provide a complete picture of the socio-economic costs related to serious injuries we recommend including all relevant cost items in costs studies and to use the internationally recommended methods. This also enhances international comparability of costs estimates, which is encouraged by several international road safety organizations (Wijnen et al, 2015).

Concerning the medical costs of serious injuries, we recommend including the following cost items: first aid at the location and transportation to the hospital, treatment at the location and emergency departments, in-patient hospital treatment, out-patient hospital treatment and non-hospital treatment. It is recommended to take the victims' characteristics (such as age, pre-existing health status and socio-economic status) and the severity and type of injuries into account when estimating these costs. We also recommend estimating the medical costs on the long term rather than limiting estimates to the acute hospital costs.

Regarding the production loss of serious injuries, we recommend to include at least loss of future market production. Further, it is recommended to use gross production loss (which also includes consumption loss) and to use potential production instead of actual production. Differences according to the severity level and the type of profession can be taken into account in estimating these costs. Preferably the non-market production should also be included.

With respect to human costs related to serious injuries, we recommend to use a WTP study since this is in accordance with the economic welfare theory. A WTP study can either be performed by doing a direct WTP study or by using QALYs. The QALY approach has the advantage of providing values for a wide variety of injury types. We advise against using the court awards approach because of its unpredictability and as it has no foundation in the economic welfare theory.

Furthermore we recommend that these costs studies are regularly updated.

6.2.2 Recommendations for further research

While the studies discussed in this deliverable provide useful information on the medical costs of road injuries, there is less detailed research about the production loss. Especially research on non-market production loss is scarce. Studies that investigate this cost item could provide an improvement of the quality of the cost calculations since non-market production loss is potentially a large cost item.

Furthermore we find that there are only a few studies to estimate the human costs of injuries. Contrary to studies into the value of a statistical life, just a few WTP-studies have been carried out regarding injuries. Since it is shown that human costs of injuries have a major share in the total costs, the quality of the estimations would improve if there would be more research that specifically addresses the human costs of injuries. We recommend performing WTP-studies, either direct or by estimating QALYs. Also the differences between these two approaches (direct WTP and QALY), including ethical aspects, should be further explored.

7 References

Achit, H. (2015), *Analyse économique des préjudices et des indemnisations des accidents de la circulation routière : une approche par la victime*, Thèse de doctorat, Université Paris-Est.

Achit, H., & Carnis, L. (2014). Physical Impairment and Medical Care Spending for Road Crash Victims. *Securitas Vialis*, *18*, 36–53.

ADB. (2003). *Road Safety Guidelines for the Asian and Pacific Region*. Manila, Philippines. Retrieved from http://www.adb.org/Documents/Books/Road-Safety-Guidelines/chap4-13.pdf

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

Association française des assurances (2014), *Assurance automobile, les sinistres corporels en 2012, Indemnités allouées aux victimes d'accidents de la circulation*. Dossiers réglés en 2012, étude, avril.

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), 488–511.

Banstola, A. & Mytton, J. (2016): Cost-effectiveness of interventions to prevent road traffic injuries in low- and middle-income countries: A literature review. *Traffic Injury Prevention*, *18*(4), 357-362.

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

Bax, C., Leroy, P., & Hagenzieker, M. P. (2014). Road safety knowledge and policy: A historical institutional analysis of the Netherlands. *Transportation Research Part F: Traffic Psychology and Behaviour*, *25*, 127–136. https://doi.org/10.1016/j.trf.2013.12.024

Becker, G. S. (1968). *Crime and Punishment: An Economic Approach*. *Journal of Political Economy* (Vol. 76). University of Chicago and National Bureau of Economic Research. https://doi.org/10.1086/259394

Bickel, P., Friedrich, R., Burgess, A., Fagiani, P., Hunt, A., Jong, G. De, … Tavasszy, L. (2006). HEATCO - Developing harmonised European approaches for transport costing and project assessment. Deliverable 5. Proposal for Harmonised Guidelines. *IER University Stuttgart*, 1–193.

Blincoe, L. J., Miller, T. R., Zaloshnja, E., & Lawrence, B. A. (2015). *The economic and societal impact of motor vehicle crashes, 2010 (Revised)*. Washington, DC. https://doi.org/10.1016/j.annemergmed.2015.06.011

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.

Brent, R.J. (2014). *Cost-benefit analysis and health care evaluations.* Second edition. Edward Elgar Publishing, Cheltenham, UK

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

Bureau of Infrastructure, T. and R. E. [BITRE]. (2009). *Road crash costs in Australia 2006*. Canberra.

Carnis, L., & Achit, H. (2014). The injured victim's health care spending: is there an effect of the origin of accident? *Applied Economics Letters*, *21*(5), 350–355. https://doi.org/10.1080/13504851.2013.861576

Carnis, L., Vaillant, N., & Dervaux, B. (2013). Is injury compensation inequitable? Evidence from road accidents victims in France. *Applied Economic Letters*, *20*(March 2015), 28–33. https://doi.org/10.1080/13504851.2012.671917

Cohen, M. A., & Miller, T. R. (2003). "Willingness to award" nonmonetary damages and the implied value of life from jury awards. *International Review of Law and Economics*, *23*(2), 165–181. https://doi.org/10.1016/S0144-8188(03)00025-5

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.

W. R. Dubourg (1995). Are preferences for safety too imprecise for contingent valuation? in N. G. Schwab Christe and N. Soguel (Eds): *Contingent Valuation, Transport Safety, and the Value of Life*. Boston, Kluwer Academic Publishers, 1995.

de Blaeij, A. T. (2003). *The Value of a Statistical Life in Road Safety; stated preference methodologies and empirical estimates for the Netherlands.* Amsterdam: Tinbergen Instituut

de Blaeij, A., Florax, R. J. G. M., Rietveld, P., & Verhoef, E. (2003). The Value of Statistical Life in Road Safety : A meta-analysis. *Accident Analysis & Prevention*, *35*(6), 973–986.

de Blaeij, A. T., Koetse, M. J. J., Tseng, Y., Verhoef, E. T., & Rietveld, P. (2004). *Valuation of Safety, Time, Air Pollution, Climate Change and Noise: Methods and Estimates for Various Countries.* Amsterdam: Vrije Universiteit / Afd. Ruimtelijke Economie.

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

De Brabander, B., Nuyts, E., & Vereeck, L. (2005). Road safety effects of roundabouts in Flanders. *Journal of Safety Research*, *36*(3), 289–296. https://doi.org/10.1016/j.jsr.2005.05.001

Department for Transport. (2012). *Reported Road Casualties in Great Britain: 2012 Annual Report - A Valuation of Road Accidents and Casualties in Great Britain in 2012*. London, United Kingdom. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/9275/rrcgb2011-02.pdf

Devos, S. (2017). *Direct medical costs of transport: The case of air pollution and traffic injuries*. Brussels, Belgium.

Devos, S., van Belleghem, G., Van Lier, T., Annemans, L., & Putman, K. (2017). Attributable health care costs of traffic victims until 1 year after hospitalisation. *Journal of Transport & Health*. https://doi.org/10.1016/j.jth.2016.12.009

Dhondt, S., MacHaris, C., Terryn, N., Van Malderen, F., & Putman, K. (2013). Health burden of road traffic accidents, an analysis of clinical data on disability and mortality exposure rates in Flanders and Brussels. *Accident Analysis & Prevention*, *50*, 659–666. https://doi.org/10.1016/j.aap.2012.06.019

Dionne, G., & Lanoie, P. (2004). Public Choice about the Value of a Statistical Life for Cost-Benefit Analyses The Case of Road Safety. *The Journal of Transport Economics & Policy*, *38*, 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. (1995a). An analysis of official economic valuations of traffic accident fatalities in 20 motorized countries. *Accident Analysis & Prevention*, *27*(2), 237–247. https://doi.org/10.1016/0001-4575(94)00060-Y

Elvik, R. (1995b). The validity of using health state indexes in measuring the consequences of traffic injury for public health. *Social Science and Medicine*, *40*(10), 1385–1398. https://doi.org/10.1016/0277-9536(94)00264-T

Elvik, R. (2016). *The value of life - The Rise and Fall of a Scientific Research Programme*. Oslo, Norway.

Elvik, R. (2000). How much do road accidents cost the national economy? *Accident Analysis & Prevention*, *32*(6), 849–851. https://doi.org/10.1016/S0001-4575(00)00015-4

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*(5), 379–385. https://doi.org/10.1016/j.tranpol.2006.01.002

European Road Safety Observatory. (2006). *Cost-benefit analysis*. Brussels, Belgium.

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

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.

Gitelman, V., Vis, M., Weijermars, W., & Hakkert, S. (2014). Development of road safety performance indicators for the European countries. *Advances in Social Sciences Research Journal*, *1*(4), 138-158.

Grosse, S. D. (2008). Assessing cost-effectiveness in healthcare: history of the $50,000 per QALY threshold. *Expert Review of Pharmacoeconomics & Outcomes Research*, *8*(2), 165–78. https://doi.org/10.1586/14737167.8.2.165

Gyrd-Hansen, D. (2003). Willingness To Pay for a QALY. *Health Economics*, *12*, 1049–1060. https://doi.org/10.1002/hec.799

Haagsma, J., Polinder, S., Lyons, R. a., Lund, J., Ditsuwan, V., Prinsloo, M., … Van Beeck, E. (2012). Improved and standardized method for assessing years lived with disability after injury. *Bulletin of the World Health Organization*, *90*(7), 513–521. https://doi.org/10.2471/BLT.11.095109

Hagenzieker, M. P., Commandeur, J. J. F., & Bijleveld, F. D. (2014). The history of road safety research: A quantitative approach. *Transportation Research Part F: Traffic Psychology and Behaviour*, *25*, 150–162. https://doi.org/10.1016/j.trf.2013.10.004

Hammitt, J. (2007). Valuing changes in mortality risk: Lives saved versus life years saved. *Review of Environmental Economics and …*, *1*(2), 228–240. https://doi.org/10.1093/reep/rem015

Hirth, R. A., Chernew, M. E., Miller, E., Fendrick, A. M., & Weissert, W. G. (2000). Willingness To Pay for a quality-adjusted life year: in search of a standard. *Medical Decision Making*, *20*(3), 332–342. https://doi.org/10.1177/0272989X0002000310

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., & Spackman, M. (2013). The development of road and rail transport safety valuation in the United Kingdom. *Research in Transportation Economics*, *43*(1), 23–40. https://doi.org/10.1016/j.retrec.2012.12.010

Kasnatscheeuw, 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* . Bergisch Gladbach, Germany.

Kassebaum, N. J., Arora, M., Barber, R. M., Bhutta, Z. A., Brown, J., Carter, A., … Murray, C. J. L. (2016). Global, regional, and national disability-adjusted life-years (DALYs) for 315 diseases and injuries and healthy life expectancy (HALE), 1990-2015: a systematic analysis for the Global Burden of Disease Study 2015. *The Lancet*, *388*, 1603–1658. https://doi.org/10.1016/S0140-6736(16)31460-X

Koopmanschap, M., Rutten, F., van Ineveld, B. M., & van Roijen, L. (1995). The friction cost method for measuring indirect costs of disease. *Journal of Health Economics*, *14*, 171–189 The. https://doi.org/10.1016/0167-6296(94)00044-5

Korzhenevych, A., Dehnen, N., Bröcker, J., Holtkamp, M., Meier, H., Gibson, G., … Cox, V. (2014). *Update of the Handbook on External Costs of Transport*. Brussels, Belgium. https://doi.org/Ref:

ED 57769 - Issue Number 1

Lapostolle, A., Gadegbeku, B., Ndiaye, A., Amoros, E., Chiron, M., Spira, A., & Laumon, B. (2009). The burden of road traffic accidents in a French Departement: the description of the injuries and recent changes. *BMC Public Health*, *9*, 386. https://doi.org/10.1186/1471-2458-9-386

Lindhjem, H., Navrud, S., & Braathen, N. A. (2011). *Valuing lives saved through environmental, transport and health policies: A Meta-analysis of stated preference studies*. Paris, France. Retrieved from http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?doclanguage=en&cote=env/epoc/wpnep(2008)10/final

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. *Risk Analysis*, *31*(9), 1381–1407. https://doi.org/10.1111/j.1539-6924.2011.01694.x

Maibach, M., Schreyer, C., Sutter, D., van Essen, H. P., Boon, B. H., Smokers, R., ... Bak, M. (2008). *Handbook on estimation of external costs in the transport sector*. *Internalisation Measures and Policies for All external Cost of Transport (IMPACT)*. Delft, the Netherlands: CE Delft. https://doi.org/07.4288.52

Marseile, E., Larson, B., Kazi, D.S., Kahnd, J.G. & Rosen, S. (2015). Thresholds for the cost–effectiveness of interventions: alternative approaches. *Bulletin World Health Organization, 93*, 118–124.

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

Mishan, E. J. (1971). Evaluation of life and limb: a theoretical approach. *Journal of Political Economy*, 79, 687-705.

Miller, T. R. (2000). Variations between Countries in Values of Statistical Life Variations between Countries in Values of Statistical Life. *Journal of Transport Economics and Policy*, *34*(2), 169–188.

Miller, T.R. & Levy, D.T. (2000). Cost-outcome analysis in injury prevention and control: 84 estimates for the United States. *Medical Care*, *38*, 562-582.

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 & Prevention*. https://doi.org/10.1016/j.aap.2014.05.026

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

Murray, C. J. L., & Lopez, A. D. (1996). *The global burden of disease: a comprehensive assessment of mortality and disability from deceases, injuries and risk factors in 1990 and projected to 2020*. *Harvard University Press*. Cambridge. https://doi.org/10.1186/1471-2458-13-863

Nellthorp, J., Sansom, T., Bickel, P., Doll, C., & Lindberg, G. (2001). *Unification of accounts and marginal costs for transportation efficiency, UNITE (UNIfication of accounts and marginal costs* *for Transport Efficiency) Working Funded by 5th Framework RTD Programme*. https://doi.org/Work Funded by 5th Framework RTD Programme

Neumann, P. J., Cohen, J. T., & Weinstein, M. C. (2014). Updating Cost-Effectiveness — The Curious Resilience of the $50,000-per-QALY Threshold. *New England Journal of Medicine*, *371*(9), 796–797. https://doi.org/10.1056/NEJMp1405158

NICE. (2012). *The guidelines manual*. London, United Kingdom. Retrieved from http://www.nice.org.uk/aboutnice/howwework/developingniceclinicalguidelines/clinicalguidelinedevelopmentmethods/GuidelinesManual2009.jsp

Nimdet, K., Chaiyakunapruk, N., Vichansavakul, K., & Ngorsuraches, S. (2015). A systematic review of studies eliciting willingness-to-pay per quality-adjusted life year: Does it justify ce threshold? *PLoS ONE*, *10*(4). https://doi.org/10.1371/journal.pone.0122760

O'Reilly, D., Hopkin, J., Loomes, G., Jones-Lee, M., Philips, P., McMahon, K., … Kemp, R. (1994). The Value of Road Safety - UK Research on the Valuation of Preventing Non-Fatal Injuires. *Journal of Transport Economics and Policy*, *28*(1), 45–59.

Papadakaki, M. et al. 2016. *Hospitalization costs and estimates of direct and indirect economic losses due to injury sustained in road traffic crashes: Results from a one-year cohort study in three European countries (The REHABILAID project).* Traum Prepublished November, 11th, 2016. DOI: 10.1177/1460408616677564

Perelman, J., & Closon, M. (2011). Impact of socioeconomic factors on in-patient length of stay and their consequences in per case hospital payment systems. *Journal of Health Services Research & Policy*, *16*(4), 197–202.

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). V*aluing reductions in the risk of traffic accidents based on empirical studies in Sweden*.Lund Institute of Technology, Lund.

Pomp, M., Schoemaker, C. G., & Polder, J. J. (2014). *Op weg naar maatschappelijke kosten-batenanalyses voor preventie en zorg. Themarapport Volksgezondheid Toekomst Verkenning 2014*. Bilthoven, Nederland. Retrieved from http://www.rivm.nl/dsresource?objectid=rivmp:246026&type=org&disposition=inline&ns_nc=1

Posner, E., & Adler, M. D. (1999). *Implementing Cost-Benefit Analysis when Preferences are Distorted (John M. Olin Program in Law and Economics Working Paper)*.

Ryen, L., & Svensson, M. (2014). The Willingness To Pay for a Quality Adjusted Life Year: A Review of the Empirical Literature. *Health Economics*, *24*(10), 1289–1301. https://doi.org/10.1002/hec

Schelling, T.C., (1968). The life you save may be your own. In: Chase, S.B. (Ed.), *Problems in Public Expenditure Analysis*. The Brookings Institution, Washington, DC, pp. 127–176.

Schreyer, C., Schneider, C., Maibach, M., Rothengatter, W., Doll, C., & Schmedding, D. (2004).

External Cost of Transport. Update study. Zurich/Karlsruhe, Switzerland. https://doi.org/citeulike-article-id:1309894

Smith Stan V. (2000), “Jury Verdicts and the Dollar Value of Human Life”, *Journal of Forensic Economics, 13(2)*: 169-188.

Sommer, H., Brügger, O., Lieb, C., & Niemann, S. (2007). *Volkswirtschaftliche Kosten der Nichtberufsunfälle in der Schweiz. Strassenverkehr, Sport, Haus und Freizeit*. Bern.

Spicer, R., & Miller, T. R. (2010). *Uncertainty Analysis of Quality Adjusted Life Years Lost*. Calverton.

SWOV. (2012). *SWOV Fact sheet - The valuation of human losses of road deaths*. Leidschendam, the Netherlands.

SWOV. (2014). *SWOV Fact sheet - Road crash costs*. Leidschendam, the Netherlands.

Tainio, M., Olkowicz, D., Teresi, G., de Nazelle, A., & Nieuwenhuijsen, M. J. (2014). Severity of injuries in different modes of transport , expressed with disability-adjusted life years (DALYs). *BMC Public Health*, *14*(765), 1–10. https://doi.org/10.1186/1471-2458-14-765

Trawén, A., Maraste, P., & Persson, U. (2002). International comparison of costs of a fatal casualty of road accidents in 1990 and 1999. *Accident Analysis & Prevention*, *34*(3), 323–332. https://doi.org/10.1016/S0001-4575(01)00029-X

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

Twisk, D. A. M., Vlakveld, W. P., Commandeur, J. J. F., Shope, J. T., & Kok, G. (2014). Five road safety education programmes for young adolescent pedestrians and cyclists: A multi-programme evaluation in a field setting. *Accident Analysis & Prevention*, *66*, 55–61. https://doi.org/10.1016/j.aap.2014.01.002

Ubel, P. A., Hirth, R. A., Chernew, M. E., & Fendrick, A. M. (2003). What is the price of life and why doesn’t it increase at the rate of inflation? *Archives of Internal Medicine*, *163*(14), 1637–1641. https://doi.org/10.1001/archinte.163.14.1637

Van Petegem, J. W. H., & Wegman, F. (2014). Analyzing road design risk factors for run-off-road crashes in the Netherlands with crash prediction models. *Journal of Safety Research*, *49*, 121–127. https://doi.org/10.1016/j.jsr.2014.03.003

Van Wee, B., Hagenzieker, M., & Wijnen, W. (2014). Which indicators to include in the ex ante evaluations of the safety effects of policy options? Gaps in evaluations and a discussion based on an ethical perspective. *Transport Policy*, *31*, 19–26. https://doi.org/10.1016/j.tranpol.2013.11.002

Weijermars, W., Bos, N., & Stipdonk, H. L. (2016). Health burden of serious road injuries in the Netherlands. *Traffic Injury Prevention*, *17*(8), 863–869. https://doi.org/10.1080/15389588.2015.1042577

Weijermars, W., Meunier, J.-C., Bos, N., Perez, C., Hours, M., Johannsen, H., & Barnes, J. (2016). *Physical and psychological consequences of serious road traffic injuries*.

WHO. (2002). *The world health report 2002 - Reducing Risks, Promoting Healthy Life*. Geneva, Switzerland. https://doi.org/10.1080/1357628031000116808

Wijlhuizen J, G., van Gent, P., & Stipdonk L, H. (2014). Sport cycling crashes on public roads: the influence of bunch riding and experience. In *Proceedings, International Cycling Safety Conference 2014*. Götenborg, Sweden. Retrieved from http://www.icsc2014.eu/program/program-proceedings\nhttp://trid.trb.org/view/1343705

Wijnen, W., & Aarts, L. (2014). *Financieringsmogelijkheden voor "Opschakelen naar meer verkeersveiligheid": een verkenning. Kostendragers en baathebbers in de verkeersveiligheid*. Den Haag, Nederland.

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.

Wijnen, W., & Stipdonk, H. (2016). Social costs of road crashes: An international analysis. *Accident Analysis and Prevention*, *94*, 97–106. https://doi.org/10.1016/j.aap.2016.05.005

Wijnen, W., Verster, N., & WWesermann, P. (2016). Economische waardering van invoering, aanscherping en handhaving van wettelijke snelheidslimieten in het verkeer. *TPEdigitaal*, *10*(1), 72–87.

Wijnen, W., Weijermars, W., Vanden Berghe, W., Schoeters, A., Bauer, R., Carnis, L., Elvik, R., Theofilatos, A., Perez, C. and Martensen, H. (2017), Crash cost estimates for European countries, D3.2 of the H2020 project SafetyCube.

Wijnen, W., Wesemann, P., & de Blaeij, A. (2009). Valuation of road safety effects in cost-benefit analysis. *Evaluation and Program Planning*, *32*(4), 326–331. https://doi.org/10.1016/j.evalprogplan.2009.06.015

World Bank. (2005). *Valuation of accident reduction*. Washington, D.C.

World Bank, & Institute for Health Metrics. (2014). *The Global Burden of Disease from Motorized Road Transport*. Washington, D.C/Seattle. https://doi.org/10.1016/S0140-6736(05)61851-X

Wren, J., & 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*. Wellington, New Zealand.

Abbreviations

AIC	Akaike Information Criteria
DALY	Disability Adjusted Life Year
DRG	Diagnosis-Related Group
DSS	Decision Support System
ECMT	European Conference of Ministers of Transport
EU	European Union
GDP	Gross Domestic Product
GEE	Generalized Estimation Equations
GLM	Generalized Linear Model
HC	Human capital
ICISS	ICD-based Injury Severity Score
ICD	International Classification of Diseases
ICU	Intensive Care Unit
MAIS	Maximum Abbreviated Injury Scale
PDO	Property Damage Only
PPI	Partial Permanent Incapacity
PPP	Purchasing Power Parity
PVIMP	Present Value of Impairment
QALY	Quality Adjusted Life Year
RC	Restitution Costs
RP	Revealed Preferences
SNIIR-AM	Système National d'Information Inter-Régimes de l'Assurance Maladie
SP	Stated Preferences
SES	Socio-Economic Status
UK	United Kingdom
US	United States
VOSL	Value Of a Statistical Life
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	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
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 (PPP)	The rates of currency conversion that equalize the purchasing 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
Utility maximization	Economic concept that explains the decision process where a consumer tries to get the greatest value ("utility") possible for the least amount of money.
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 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 B Standardisation of cost data

To compare the costs across countries in the data analysis, all the cost data was standardised for inflation and Purchasing Power Parity (PPP). All the data was standardised 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).

Gross Domestic Product (GDP) in local currency and GDP deflator index (GDI) were downloaded from official EuroStat site on 24 Nov 2016 (together with a number of other statistics), and written to the SQLite database. Both GDP and GDI are available for different years between 1975 (limited set of countries) to 2015. Also Exchange rates between local currency and Euro were downloaded and handled as GDP and GDI (downloaded in Jan 2017).

To standardise the cost data, the following equation is used:

$$Y=XGDI(2015)prl(2015)*GDI(ply)*exr(cur,2015)Y=XGDI(2015)prl(2015)*GDI(ply)*exr(cur,2015)$$

Where **Y** is the standardised value, **X** is the original value that was filled in on the questionnaire, **ply** is the price level year, **prl** is the price level and **exr(cur,2015)** is the exchange rate of 2015, for the relevant currency.

Appendix C Cost information per country

Country	Cost per serious injury (€2015)	Cost per serious injury crash (€2015)	Total costs related to serious injuries (millions, €2015)
Austria	381,285	432,355	10,083
Belgium	307,364		4,613
Bulgaria	220,390	282,696	1,920
Croatia	290,042		2,211
Cyprus	135,535		115
Czech Republic	295,199		3,197
Denmark	344,536		1,058
Estonia	959,011		701
Finland	671,383		2,361
France	368,029		34,725
Germany	119,480	21,622	32,374
Greece	252,277	259,628	2,748
Hungary	501,194		4,440
Iceland	364,914	510,584	320
Ireland	225,511	323,845	722
Italy	211,860	12,020	30,609
Latvia	28,205		989
Lithuania	89,804		611
Luxembourg			-
Malta	203,913		95
Netherlands	269,149		11,990
Norway	845,812	945,576	2,259
Poland	975,074		14,792
Portugal	136,365	168,983	2,535
Romania			-
Serbia		84,058	792
Slovakia	141,504		663
Slovenia	247,550	15,192	1,373
Spain	254,777		11,019
Sweden	399,728		1,928
Switzerland	214,023		5,528
UK	227,979	260,543	18,019

Table B-1 Cost per serious injury, cost per serious injury crash and total costs related to serious injuries in 32 European countries (EUR2015, adjusted for PPP)

Appendix D Definition of a serious injury per country

Country	Definition serious injury
Austria	> 24 days sickleave or equivalent impairment (judged by the police)
Belgium	> 24 hours in hospital after crash
Bulgaria	Severe physical injury (specifications available, eg. loss of a limb or arm, blindness, life threatening health problems)
Croatia	-
Cyprus	-
Czech Republic	Severe (non-fatal) injury, as determined by a doctor
Denmark	-
Estonia	Receiving permanent disability compensation
Finland	-
France	> 24 hours in hospital after crash
Germany	> 24 hours in hospital after crash
Greece	-
Hungary	> 48 hours in hospital or fracture, or suffering specific injuries (eg. facture, internal injuries, burn)
Iceland	Specific injuries, eg. fracture, concussion, shock requiring medical treatment
Ireland	Hospital admission or specific injury (eg. fracture, concussion, internal injuries, crushings)
Italy	> 24 hours in hospital after crash
Latvia	> 24 hours in hospital after crash
Lithuania	-
Luxembourg	> 24 hours in hospital after crash
Malta	-
Netherlands	Hospital admission and injury severity MAIS2+
Norway	Two categories were collapsed to match standard categories. (1) Very serious injury: life-threatening or leading to permanent impairment (very serious); (2) Serious injury: specific injuries, mostly requiring in-patient hospital treatment.
Poland	-
Portugal	-
Romania	-
Serbia	Overnight hospital stay or specific injuries (eg. fractures, concussion, internal injuries, crushing)

Slovakia	Severe health impact (not specified)
Slovenia	Life threatening injury or permanently/temporary inability to work
Spain	-
Sweden	-
Switzerland	Three categories were collapsed to match the standard categories. (1) Serious injury: inability to work or carry out daily activities > 3 months; (2) Moderately injured: inability to work or carry out daily activities >1 and < 3 months; (3) Disabled: permanently physically disabled, resulting in a disability allowance from an insurance.
UK	Hospital admission or specific injury (eg. fracture, concussion, internal injuries, crushings)

Table C-1 Definition of a serious injury for 32 European countries

Appendix E Hospital costs in Belgium

	Study population			Hospital costs		
	N	%	Mean €	SD €	Median €	IQR €
Year accident						
2009	20,953	33	7,504	14,370	2,751	1,483 – 7,180
2010	22,658	35	7,597	13,957	2,829	1,499 – 7,399
2011	20,693	32	6,970	12,328	2,824	1,543 – 6,944
Gender						
Male	37,563	58	6,708	13,893	2,531	1,453 – 5,913
Female	26,741	42	8,287	13,117	3,331	1,623 – 9,089
Age category						
0-16 years	8,061	13	2,213	6,411	1,348	1,014 – 1,981
17-29 years	10,956	17	5,637	13,997	2,243	1,411 – 4,522
30-44 years	9,744	15	5,847	13,045	2,455	1,515 – 4,868
45-59 years	11,705	18	6,323	13,337	2,712	1,574 – 5,536
60-74 years	10,213	16	7,956	13,265	3,404	1,761 – 7,965
≥ 75 years	13,625	21	13,339	15,093	8,217	3,409 – 17,972
SES						
High	49,260	77	6,426	12,436	2,491	1,447 – 5,893
Low	15,044	23	10,439	16,480	4,654	1,884 – 12,052
Disabled						
Yes	748	1	10,586	18,746	4,530	1,842 – 10,613
No	63,556	99	7,327	13,524	2,789	1,506 – 7,130
Roadway user						
Cyclist	17,678	27	5,010	10,252	2,141	1,360 – 4,643
Pedestrian	25,609	40	8,795	13,298	3,447	1,622 – 9,963
Motorcyclist	7,314	11	7,209	15,792	3,079	1,693 – 6,267
Motor vehicle driver	9,965	16	8,058	16,662	2,883	1,538 – 6,675
Motor vehicle passenger	3,738	6	7,156	14,362	2,791	1,478 – 6,809
Nature of injury						
Fracture	41,725	65	8,189	12,929	3,713	1,926 – 8,650
Dislocation	1,821	3	4,812	10,867	1,802	1,265 – 3,535
Sprain or strain	2,450	4	3,920	6,831	1,825	1,297 – 3,235
Internal Injury	10,683	17	6,321	17,181	1,578	1,105 – 3,738
Open wound	3,391	5	4,706	10,383	1,647	1,196 – 3,348
Contusion/ Superficial Injury	3,231	5	4,659	8,388	1,594	1,104 – 3,910
Injury to blood vessels	111	0	35,893	40,823	15,970	5,056 – 60,9814
	N	%	Mean €	SD €	Median €	IQR €
Crush injury	337	1	23,166	28,041	13,463	4,879 – 32,610
Injury to nerves	19	0	6,640	16,247	2,061	1,394 – 4,690
Amputations	112	0	6,187	17,848	1,451	1,159 – 2,285
Unspecified injury	424	1	5,631	10,719	1,492	985 – 4,008

Injured body region						
TBI	11,480	18	5,389	14,278	1,649	1,124 – 3,891
Head, face, neck	5,871	9	5,014	10,183	2,080	1,260 – 4,444
Spine and back	9,703	15	10,829	17,995	4,605	2,090 – 11,324
Torso	5,828	9	8,729	15,449	4,227	2,197 – 9,382
Upper extremities	16,049	25	4,248	7,980	1,982	1,430 – 3,434
Lower extremities	14,491	23	10,112	12,938	5,273	2,510 – 11,666
Unspecified	882	1	13,189	23,220	2,948	1,346 – 14,379
Cancer						
Yes	1,429	2	18,763	21,957	11,621	4,879 - 25,633
No	62,875	98	7,106	13,234	2,735	1,496 – 6,873
Diabetes						
Yes	3,721	6	13,976	17,402	7,842	3,356 - 18,268
No	60,583	94	6,959	13,223	2,654	1,477 – 6,622
Diseases of the musculoskeletal system and connective tissue						
Yes	2,937	5	18,203	17,316	13,235	6,133 – 25,538
No	61,367	95	6,846	13,172	2,649	1,477 – 6,473
Diseases of the nervous system and sense organs						
Yes	1,060	2	16,144	28,326	5,838	2,278 – 18,423
No	63,244	98	7,218	13,162	2,774	1,504 – 7,063
Diseases of the circulatory system						
Yes	11,955	19	15,574	19,959	8,825	3,778 – 20,488
No	52,349	81	5,490	10,828	2,319	1,399 – 5,089
Dementia						
Yes	3,068	5	19,776	21,260	13,253	6,693 – 25,728
No	61,236	95	6,743	12,784	2,633	1,475 – 6,410
Diseases of the genitourinary system						
Yes	1,293	2	19,544	20,662	13,479	6,487 – 25,930
No	63,011	98	7,115	13,298	2,735	1,496 – 6,862
Anaemia						
Yes	4,581	7	25,842	27,335	17,763	9,221 – 32,536
No	59,723	93	5,948	10,658	2,531	1,454 – 5,831
Alcohol abuse						
Yes	9,173	4	10,199	17,934	4,115	1,888 – 10,063
No	55,131	96	6,893	12,673	2,630	1,469 – 5,436
Acute illness						
Yes	7,192	11	23,642	27,544	15,233	7,036 – 30,453
No	57,112	89	5,315	8,666	2,441	1,434 – 5,436
Weekend/holidays						
Yes	21,083	33	7,398	13,500	2,984	1,734 – 7,002
No	43,221	67	7,349	13,645	2,987	1,419 – 7,276
Died						
Yes	1,646	3	15,251	21,253	8,028	2,933 – 19,556
No	62,658	97	7,158	13,275	2,744	1,499 – 6,924
Total	**64,304**		**7,365**	**13,598**	**2,801**	**1,510 – 7,175**

Table D-1 Descriptive table of hospitalized traffic victims and their mean and median hospital costs (€2015); Source: Devos, 2017

Appendix F Patient characteristics in the REHABIL-AID study

	Greece n (%)	Germany n (%)	Italy n (%)	Total n (%)
Socio-demographic information				
Gender				
Men	36 (87.8)	27 (69.2)	30 (75.0)	93 (77.5)
Income (€)				
Up to 15.000	33 (86)	2 (5.1)	10 (30.3)	45 (40.9)
15.001-28.000	5 (13.2)	20 (51.3)	14 (42.4)	39 (35.5)
28.001-55.000	0 (0.0)	16 (41.0)	3 (9.1)	19 (17.3)
55.001-75.000	0 (0.0)	0 (0.0)	4 (12.1)	4 (3.6)
More than 75.000	0 (0.0)	1 (2.6)	2 (6.1)	3 (2.7)
Age[a]	35.9 (SD 15.9)	42.7 (SD 16.4)	47.0 (SD 16.4)	41.8 (SD 16.7)
Road incident information				
Type of road user				
Pedestrian	2 (4.9)	5 (12.8)	7 (17.5)	14 (11.7)
Cyclist	1 (2.4)	3 (7.7)	10 (25.0)	14 (11.7)
Motorcyclist	20 (48.8)	12 (30.8)	8 (20.0)	40 (33.3)
Driver four-wheel	14 (34.1)	16 (41.0)	10 (25.0)	40 (33.3)
Passenger four-wheel	4 (9.8)	3 (7.7)	5 (12.5)	12 (10.0)
Max. AIS score[b]	2 (4.9)	0 (0.0)	0 (0.0)	2 (1.7)
MAIS-1	11 (26.8)	6 (15.4)	17 (42.5)	34 (28.3)
MAIS-2	25 (61.0)	22 (56.4)	13 (32.5)	60 (50.0)
MAIS-3	2 (4.8)	11 (28.2)	10 (25.0)	23 (19.1)
MAIS≥4				
MAIS score and body region[c]				
Head	25 (61)	7 (18.0)	9 (22.5)	41 (34.2)
Face	1 (2.4)	3 (7.7)	2 (5.0)	6 (5.0)
Thorax	7 (17.1)	23 (59.0)	5 (12.5)	35 (29.2)
Abdomen	6 (14.6)	4 (10.3)	1 (2.5)	11 (9.2)
Spine	2 (4.9)	3 (7.7)	7 (17.5)	12 (10.0)
Lower extremities	10 (24.4)	15 (38.5)	19 (47.5)	44 (36.7)
Upper extremities	3 (7.3)	1 (2.6)	4 (10.0)	8 (6.7)

[a] mean, standard deviation

[b] AIS code was not possible for one subject

[c] Based on total of subject for each country and for entire sample

Table E-1 Characteristics of the initial patients of the REHABIL-AID study; Source: Papadakaki et al. 2016