European Road Safety Observatory

Road Safety Thematic Report

Consequences of crashes

This document is part of a series of 20 thematic reports on road safety. The purpose is to give road safety practitioners an overview of the most important research questions and results on the topic in question. The level of detail is intermediate, with more detailed papers or reports suggested for further reading. Each report has a 1-page summary.

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Contents

Summary

Consequences of crashes

The literature and crash statistics show that the consequences of road crashes can be considerable, even when injuries suffered by road users are considered as slight or moderate, especially because their repercussions on health can last for a long period of time. In the worst cases, crashes can be much more serious and lead to life-changing consequences or death. Road crashes can affect all aspects of human activity: functional aspects, mental and emotional aspects, as well as social and professional life. We identify three types of consequences: physical, psychological and socio-economic.

Physical consequences are concerned with injuries and medical consequences which relate to the impact of injuries on the functioning of the body, such as the ability to bend and stretch a knee, the functioning of the brain, and the functioning of blood circulation. These depend on crash characteristics but also on personal factors.

Road crashes can also result in psychological problems such as post-traumatic stress disorder (PTSD), depression, and anxiety disorder. Finally, road crashes may have socio-economic impacts for casualties such as the inability to return to work for a prolonged period or even indefinitely.

Crash consequences in relation to society can be expressed by means of different indicators such as Disability Adjusted Life Years (DALYs) or socio-economic crash costs. DALYs are the sum of life years lost due to premature mortality (YLLs) and the years lived with a disability (YLDs). Socio-economic costs express consequences in monetary units so that the impact of insufficient road safety can be compared to other societal problems. Socio-economic costs can also be used in cost-benefit analyses of road safety investments.

Countermeasures

Road safety measures are the main preventive means of reducing the overall burden of road traffic injuries for society. Road safety measures should aim at reducing health impacts in addition to reducing the number of casualties. In addition to enforcement and awareness campaigns and infrastructure developments to help reach this objective, there are also safety systems in two main categories: active safety systems (such as Advanced Driver-Assistance Systems and Automated Emergency Braking) that deploy before a crash occurs and can help prevent crashes; and passive safety systems (such as seat belts, airbags and helmets) which are designed to protect road users as much as possible when a crash occurs.

Post-impact measures such as emergency response, trauma care and rehabilitation are also important measures to reduce consequences for casualties. They improve the life of people who survive a crash.

1 Highlights

- Road crashes are known to have physical, psychological, and socio-economic consequences.
- Physical consequences include injuries as diverse as head injuries, injuries to the cervical spine, thorax, abdomen, and to the upper and lower extremities.
- The most frequent psychological consequences of road crashes reported in the EU are symptoms of post-traumatic stress disorder (PTSD), depression, and anxiety disorder.
- Road injuries constitute 1.36% of total Disability Adjusted Life Years (DALYs) in the European Union and are estimated to generate a total cost of about 280 billion EUR.

2 What are the consequences of crashes for the victims?

In 2020, there were an estimated 758,000 road crashes and 18,800 people were killed on the European Union roads (European Commission, 2022a). Although the COVID-19 restrictive measures on passenger transport are largely responsible for the drop in the number of road deaths compared with 2019 (-17%), the absolute number of fatalities in EU countries remains of concern. Additionally, more than 500,000 people were injured in road crashes during 2020.

Many studies show that the consequences of road crashes for (fatally or seriously) injured people are a major concern, both for individuals and for society. Road crashes have physical, psychological, and socio-economic consequences that contribute to the burden of injury[1] for society as a whole. In addition, it is important to note that the consequences are not limited to fatal or serious crashes, but also to less serious traffic crashes, i.e. those that cause injuries that are only treated in emergency departments without hospitalisation.

The consequences of road injuries are in many cases long-lasting - even permanent - and can affect all aspects of human activity (Meunier & Dupont, 2017): functional aspects (pain, fatigue, mobility, daily activities, etc.), mental health (post-traumatic stress disorder, depression, anxiety, etc.), social and emotional life, and professional life (absenteeism, reorientation, etc.). Road crashes also have economic and financial impacts (loss of income). The consequences for victims are generally of three kinds (Meunier et al., 2018, Weijermars et al., 2016):

- physical consequences
- psychological consequences

[1] The burden of injury (expressed in DALYs) integrates mortality, expressed in Years of Life Lost (YLL), and disability, expressed in Years Lived with Disability (YLD) associated with one type of injury or medical condition (Weijermars et al., 2016).

- socio-economic consequences.

2.1 Physical consequences

2.1.1 Injury patterns and severity

In the European Union, the number of seriously injured road users (MAIS3+)[2] has slightly decreased over the pre-COVID period 2010-2019 (ETSC, 2021) and the proportion of seriously injured among people injured has remained relatively stable over the years. Given that the number of fatalities in many countries has dropped during the last decades, the consequences of non-fatal injuries have come under scrutiny (Stigson et al., 2020). Injury patterns have been studied in several European countries.

For example, Amin et al. (2022) conducted a study to investigate the burden of pedestrian injuries compared to other transport-related injuries in Sweden, analyzing more than 360,000 fatalities and injuries reported by emergency hospitals during 2010-2019. The results show that, regardless of severity, the most common type of injury among pedestrians involved in crashes are superficial wounds (72%), followed by fractures of the hip, knee and leg (28%). Cyclists are more frequently affected by injuries to the upper extremity such as wrist, shoulder and elbow (35%) while car occupants are commonly affected by injuries to the cervical spine (45%) (see Table 1).

Table 1 Proportion of injuries by road user category and body part (2010-2019) in Sweden. A person can have injuries to several body parts.

	Pedestrian fall injuries	Pedestrian crash injuries	Cyclist injuries	Car occupant injuries
Head	6%	13%	10%	7%
Face	2%	4%	5%	2%
Thorax	1%	6%	4%	6%
Upper extremity	42%	14%	35%	6%
Cervical spine	1%	5%	2%	45%
Thoracic spine	0%	2%	1%	6%
Lumbar spine	1%	3%	1%	5%
Abdomen	0%	1%	1%	1%
Lower extremity and pelvis	24%	28%	12%	3%
External and thermal injuries	36%	72%	59%	48%

Source: Amin et al., 2022

In the same context, Bouwen et al. (2022) showed that, compared with other road users, powered two-wheeler riders (PTWs) have a more even distribution of injuries across different parts of the body. As with pedestrians and cyclists, legs are the first to be affected in a collision with a motorized vehicle. Severe injuries are therefore mostly to the lower limbs, particularly the thighs (29%), but also to the chest (34%). Compared with cyclists, serious head injuries are less frequent among PTW riders (24%), which may be attributed to the more frequent use of helmets by these road users (Bouwen et al., 2022).

[2] The MAIS (Maximum Abbreviated Injury Scale) is a standard measurement scale (accepted by the medical profession and adopted in most European countries) used to assess the severity of injuries.

Vulnerable road users[3] (VRUs) account for a large proportion of deaths and injuries on the roads of the European Union. For example, crashes involving motorized vehicles, especially those involving very large vehicles such as trucks, are likely to cause very severe injuries to this group. In this context, Malczyk & Bende (2019) conducted a study in Germany describing the circumstances and injury outcomes of severe crashes between heavy trucks and pedestrians and those between heavy trucks and cyclists. MAIS3+ cases accounted for around two-thirds of all victims in both groups. The highest proportion of AIS3+ injuries for pedestrians was found in the thorax region (31%) and for cyclists in the lower extremity region (40%). On the other hand, the study noted a high prevalence of old persons among VRUs.

2.1.2 Medical consequences

Some countries have extended the definition of serious injuries (MAIS3+) to include injuries leading to permanent medical impairment (PMI). The concept of PMI has been established by consensus amongst experts - medical, legal and from the insurance world - and reflects the rate of limitation of physical or mental functioning associated with an injury (Meunier & Dupont, 2017). The proportions of injuries leading to PMI were calculated by Amin K. et al. (2022) for the different road user categories and differ from the proportions presented in Table 1, especially as regards external and thermal lesions which are much less frequent since they are mostly temporary impairments.

As was stated in Weijermars et al. (2016) there is a correlation between injury severity and physical consequences: studies quite consistently show that the risks of mainly functional and socio-economic consequences increase as a function of injury severity. However, minor injuries, such as strain injuries to the spine, may also have grave long-term consequences. Parallel to this, Stigson et al. (2020) mention the fact that some injuries with low MAIS levels (MAIS 1-2) can lead to long-term consequences while some injuries with high MAIS scores (MAIS 3+) are low-risk in terms of long-term consequences.

Consequences differ from one casualty to the other, depending on the type and severity of injury, transport mode, and several personal and environmental factors such as age, gender, comorbidity, and socio-economic status (Weijermars et al., 2016). For example, Stigson et al. (2015), who conducted a study on long-term medical consequences for road casualties in Sweden, found that 12% of all car occupants injured in a car crash sustained permanent medical impairment. An impairment is considered permanent when no further improvement in physical and/or mental functioning is expected despite continued treatment (Malm et al., 2008).

Finally, higher proportions of severely injured casualties and of long-term health conditions are generally found among pedestrians and motorcycle riders. Cyclists, on the other hand, were found to suffer less severe injuries, to report better recovery, and to be less likely to report persistent functional limitations (Weijermars et al., 2016). It is worth noting, however, that the number of cycling fatalities and serious injuries has increased in the last decade while the overall number of fatalities has decreased significantly.

[3] Vulnerable road users refer to pedestrians, cyclists, riders of mopeds and motorcyclists.

2.2 Psychological consequences

Road crashes can also result in a variety of long-term psychological and psycho-social problems. For example, Meunier et al. (2018) conducted a survey across 20 EU Member States in order to examine the consequences of road crashes from different points of view, including medical, psychological, social, and economic consequences. A large proportion of respondents reported psychological difficulties, the most common of which related to symptoms of post-traumatic stress disorder (PTSD) (± 60% of the sample), depression (± 55%), and anxiety disorder (± 45%). It should be noted, however, that this study contains some bias because the casualties that experienced consequences were not a representative sample of all casualties.

In this same context, Weijermars et al. (2016) compiled results from other case studies in Europe. For example, a Spanish case study (EDAD[4]) found that 15% of the people with impairments due to road traffic crashes report having chronic depression or anxiety. A French case study (ESPARR[5]) found that 20% of the MAIS3+ casualties reported PTSD one year after the crash. Results from a German case study (GIDAS[6]) showed that 19% of the respondents involved in crashes reported anxiety. Finally, results from a case study conducted in the United Kingdom showed that mental impacts are greatest one month after the crash (Weijermars et al., 2016).

Psychological disorders are a major concern, especially because even relatively minor injuries can have profound psychological effects and because they have been found to be the most persistent consequences of involvement in road crashes (Weijermars et al., 2016). For example, symptoms of PTSD may last for several months after the event and, in some cases, casualties do not fully recover even years after the crash (Craig et al., 2016).

Kovacevic et al. (2020) have investigated the psychological consequences and associated factors in road crash survivors in Croatia, one month after experiencing the crash. They found that:

- Symptoms of depression were associated with below-average self-perceived economic status, irreligiousness, medication use, psychiatric medication use, and injury-related factors (such as hospitalization).
- PTSD symptoms were associated with female gender, below-average self-perceived economic status, previous psychiatric illness, medication use, psychiatric medication use, not being at fault in the road traffic crash, claiming compensation, and injury-related factors.
- Anxiety symptoms were associated with previous chronic or psychiatric illness, previous permanent pain, psychiatric medication use, and self-perceived threat to life.

In addition, the number of days of hospitalization and subjective trauma appraisals (such as traumatic fear and negative cognition about the self) were found to be significant predictors of PTSD symptoms (Măirean & Cimpoeșu, 2020).

[4] Spanish National Disability Survey 2008.
[5] Étude de Suivi d'une Population d'Accidentés de la Route dans le Rhône.
[6] German In Depth Accident Study.

Few differences have been identified in the psychological consequences of crashes according to the type of transport used by the victim. However, passengers appear to suffer greater consequences than other road users, especially regarding travel anxiety (Meunier & Dupont, 2017). They are particularly anxious about re-occupying a passenger seat in a car. Another study also suggests that motorcyclists are at lower risk of developing PTSD than occupants (passengers or drivers) of four-wheel vehicles (Chossegros et al., 2011). Clarifying why motorcyclists have higher psychological resilience after traffic injuries is a matter for future research (Sharwood et al., 2021).

2.3 Socio-economic consequences

The consequences of road crashes are not only likely to affect the physical and mental health of victims but can also have a major impact on their social, family and professional lives (Meunier & Dupont, 2017). One of the coping strategies often reported (in 16% of cases) is the reassignment of work within the family, with at least one family member having to re-arrange his or her usual activity to care for and support an injured person (Meunier et al., 2018).

Social impacts include consequences for the everyday life of the family, impact on leisure activities, and impacts on emotional life and (sexual) relationships (Weijermars et al., 2016). Social consequences usually depend on injury severity: the higher the injury severity, the higher the professional consequences. For example, the ESPARR study (cf. paragraph 2.2) shows that more than half of the severely injured participants (MAIS3+) reported that the accident had had an impact on the everyday life of their family. This was twice as many as in the mild-to-moderate injury group (MAIS1 or 2). Severely injured reported relational difficulties (20%), impaired sexual life (16%), and the rate of separation was significantly higher than in the mild-to-moderate injury group (Weijermars et al., 2016).

The economic impacts of a traffic crash include sick leave from work or study, impact on employment and employability, and financial problems (Weijermars et al., 2016). As for social consequences, these also generally depend on injury severity (Meunier et al., 2018). In the ESPARR study, the mean time off work was significantly longer in the severe injury group: 32% of the severe injury group who had stopped work had not returned one year later, compared to 5% of the mild-to-moderate injury group (Hours et al., 2013).

3 What are the consequences of crashes for society?

The magnitude of the road safety problem is usually assessed by means of indicators such as the number of road fatalities or injuries. These indicators do not take into account the long-term consequences of crashes. DALYs (Disability Adjusted Life Years) provide a more complete picture of the consequences of crashes for society. DALYs measure the burden of injury for society and include both mortality and morbidity. In addition, the impact of crashes can also be assessed in terms of socio-economic costs. These indicate the monetary value of the consequences of crashes for society.

Social costs are also included at the top of the pyramid of road safety indicators which was developed in the framework of the European SUNflower-project (Koornstra et al., 2002; Wegman et al., 2008) with the objective of comparing road safety performance between countries; this was further elaborated by Bliss & Greene (2009). Furthermore, socio-economic crash costs can be used to compare road safety policy with other policy areas to define policy priorities, as well as in cost-benefit analyses (Wegman et al., 2008).

3.1 DALYs

3.1.1 Approach

Disability-Adjusted Life Years (DALYs) is an indicator which originated in the health sector. DALYs express the health loss of a population in lost healthy life years and take into account the long-term consequences of road injuries. This indicator was developed by the World Health Organization (WHO) and the World Bank to calculate the 'global burden of disease'. The burden of disease is defined as the total loss of health at population levels through the impact of diseases and injuries on life expectancy and quality of life. One DALY is equivalent to one lost healthy life year, either due to premature death or to disability (Murray & Lopez, 1996).

DALYs combine the impacts of fatal and non-fatal road injuries (or diseases) and express them in one unit of measurement. They consist of two components:

- Years of Life Lost (YLL) are lost life years due to premature death. In the context of road safety these are the lost life years of fatal road victims.
- Years Lived with Disability (YLD) express the loss of quality of life due to non-fatal injuries and diseases. In the context of road safety YLDs quantify the health loss of (seriously) injured road victims.

YLL are calculated as the remaining life years of road fatalities, taking into account average life expectancy. YLD are calculated by multiplying the number of years road victims suffer from the consequences of their injuries with a disability weight that expresses the severity of the loss of quality of life. These disability weights vary between 0 (perfect health) and 1 (death).

Suppose that a road casualty suffers from an injury that results in a loss of quality 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 road fatalities, the disability weight is by definition one, implying that the quality of life loss is equal to the number of life years lost. The number of DALYs related to road casualties can be calculated by summing together the YLD and YLL for these casualties (Schoeters et al., 2017).

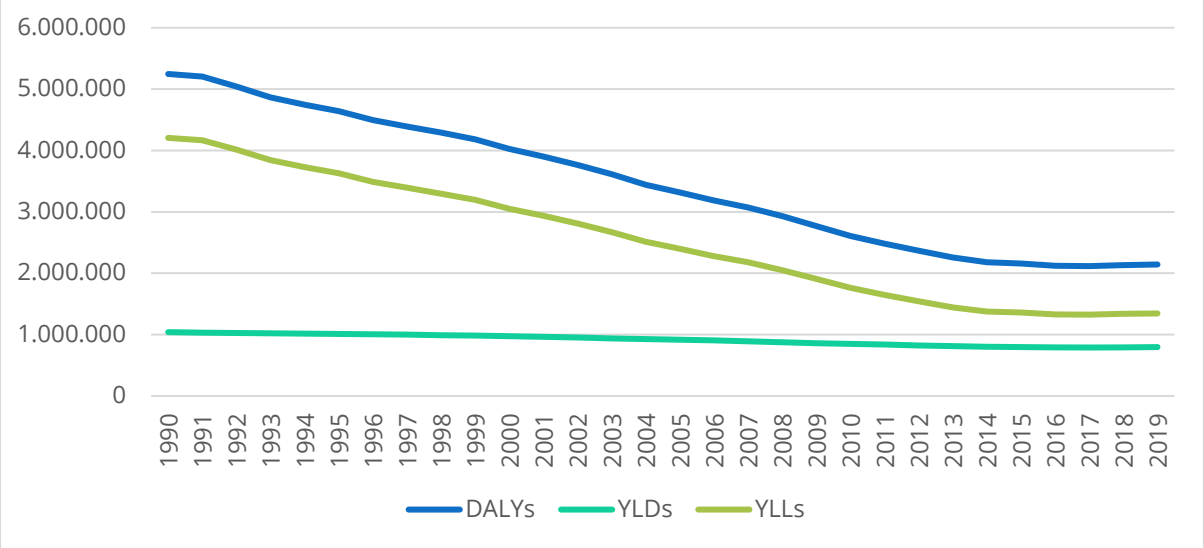
3.1.2 Applications

DALYs have been used mainly in the health sector, yet they are also suitable for calculating the burden of disease resulting from road crashes. In contrast to traditional indicators that merely reflect the number of road victims, DALYs indicate a total effect by taking into account both the effect of road crashes on mortality and on the quality of life (Wijnen, 2008). This last aspect especially can produce a better understanding of the severity and

duration of the consequences of road crashes. Furthermore, DALYs can be used to compare the burden of disease of road crashes with the burden of disease of other health problems.

The WHO included road injuries in their global burden of disease study (GBD, 2019). In this study it was estimated that road injuries constitute 1.36% of total DALYs in the European Union. The trend in the number of DALYs, and more specifically in the number of YLL and YLD, is presented in Figure 1. This figure shows that DALYs have been decreasing between 1990 and 2014 and remained stable over the past five years. The YLLs have declined more sharply (-68% between 1990 and 2018) than the YLDs (-24% between 1990 and 2018).

Figure 1 Trend in DALYS, YLDs and YLLs due to road injuries in the European Union (1990 - 2018).



Source: World Health Organization (2019)

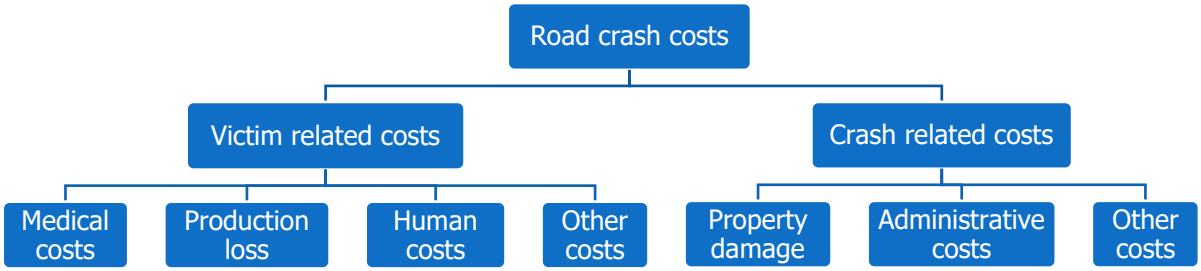
While the DALY approach is relatively new in road safety, there are several national studies that have been carried out to estimate the number of DALYs due to road injuries: e.g. in France (Lapostolle et al., 2009), Belgium (Dhondt, 2013), Sweden (Tainio et al., 2014), and the Netherlands (Weijermars et al., 2016a). In the European SafetyCube-project, YLDs have been calculated for six EU countries (Weijermars et al., 2016b).

3.2 Socio-economic costs

3.2.1 Approach

Another indicator that expresses the burden of road crashes on society are the costs of crashes. Several guidelines have been developed that describe how socio-economic crash costs should be estimated. In the European SafetyCube project, Wijnen et al. (2019) developed a framework for estimating these costs based on guidelines from the European studies COST313 (Alfaro et al., 1994) and HEATCO (Bickel et al., 2006). They recommend a classification of costs as set out in Figure 2. Six major cost components are identified related to the victim or to the crash, and within each component there are several smaller cost items.

Figure 2 Classification of road crash costs.



Source: Wijnen et al. (2019)

Three cost components are related to road victims:

- **Medical costs** include all costs related to the medical treatment of road victims, either at the crash location, in the hospital, or by other medical institutions such as rehabilitation centres.
- Costs related to **production loss** result from road casualties who temporarily or permanently are not able to work. Mostly market production only is taken into account, while some studies also estimate non-market production loss such as in households or volunteering.
- **Human costs** express the suffering that road crashes cause for those involved and their relatives. It is the pain and sorrow of the victim and their relatives, but also the loss of quality of life due to injuries and the loss of life years due to premature death. These are intangible costs: they have no market price and are therefore less easy to quantify than the other costs. Nevertheless, they are routinely included in the calculation of social costs since they represent a significant loss of social welfare.

Two cost components are related to road crashes:

- Costs related to **property damage** result from damage to both private and public property caused by road crashes. The largest share consists of damage to (passenger) vehicles, and a smaller part represents damage to road infrastructure and freight traffic loads.
- **Administrative costs** include the working hours of police and fire departments at the crash location, but also the services provided by insurance companies and the legal costs of prosecuting offenders.

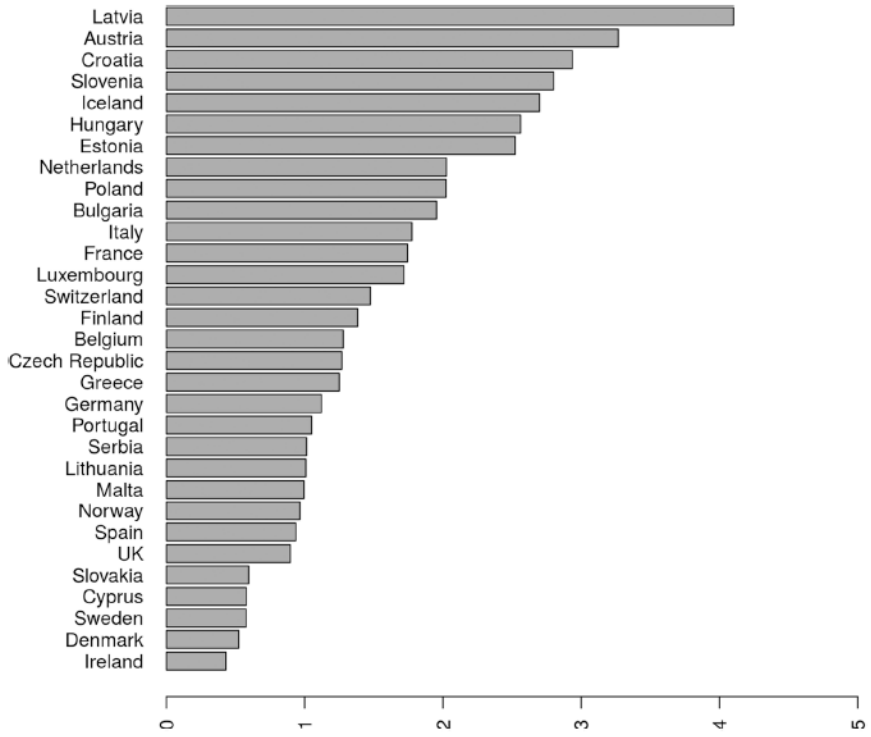
Furthermore, there are also several other cost items that relate either to the victim or the crash. These include funeral costs, congestion costs, costs related to vehicle unavailability, and costs of house adaptations for victims that suffer disabilities due to a road crash.

Most cost components are easily translated into a monetary value because they have a market price. For other components without a market price, this is not so obvious. Different valuation methods have been developed to accommodate this. Wijnen et al. (2019) provide an overview of the recommended methods for calculating each cost component.

3.3 Applications

The European SafetyCube project (Wijnen et al., 2019) collected official cost estimates from 31 European countries (EU28[7], Switzerland, Norway and Iceland). A comparison between unit costs per victim and total costs showed that there are large differences between countries. The total crash costs range from 0.4% of GDP in Ireland to 4.1% of GDP in Latvia (Figure 3). These differences are largely explained by the cost components included and the calculation methods used.

Figure 3 Total costs of road crashes as a percentage of GDP (2015).



Source: Wijnen et al. (2019)

The EU handbook on the external costs of transport (European Commisson, 2019) provides cost estimates for all EU countries. These estimates are based on the values calculated in the SafetyCube-project (Wijnen et al., 2017) and on the Value of a Statistical Life in OECD (2012). Based on these estimates, the total cost of road crashes in the European Union is estimated to be about 280 billion EUR.

4 Countermeasures to mitigate the consequences for victims

Road safety measures are the main preventive means for reducing the overall burden of road traffic injuries for society. Each EU country has its own regulations and implements its own strategies to improve road safety. Crash prevention and mitigation measures are

[7] Including United Kingdom

diverse and include the installation of speed cameras, higher traffic fines for the use of mobile phones, measures to promote the use of alcohol interlock devices, new fines for dangerous overtaking of cyclists, the creation of safe cycling infrastructures and safe school environments, the development of safe railway crossings, etc. (ETSC, 2021; ITF, 2021). These measures are essential to reduce the risk of being involved in a road crash. Recent safety measures for specifically protecting parts of the body include passive vehicle safety systems such as the use of airbags, seat belts, helmets or gloves (for motorcycle riders). The use of helmets for motorbike riders is of particular importance because injuries to the head and neck are among the main causes of death, severe injury and disability among PTW users (WHO, 2022). Moreover, fatality rates in countries with full helmet laws were shown to be lower on average than death rates in countries without full helmet laws (Branas & Knudson, 2001). Although helmet laws are already in effect in EU countries, helmet wearing controls remain essential to ensure compliance.

Protecting VRUs such as pedestrians and cyclists is also of great importance, especially in view of their vulnerability to motorized vehicles. In this context, the revised EU General Safety Regulation and Pedestrian Safety Regulation have recently been updated with improved passive and active safety requirements for all new vehicles sold in the EU. Many of those new vehicle safety requirements contribute to improve the safety of pedestrians and cyclists (ETSC, 2020), for example Automated Emergency Braking (AEB) with VRU detection, Intelligent Speed Assistance (ISA), enlarged head impact protection zones, direct vision requirements, and Blind Spot Detection Systems for trucks.

Beside crash prevention measures, post-impact measures are also crucial to reduce the consequences for victims. Post-impact care is defined as the chain of help provided to casualties following a road crash (European Commission, 2022b). It comprises measures and emergency systems such as:

- the eCall (Emergency Call) which is a system used in vehicles in the EU which automatically dials the European emergency number;
- the advanced mobile location (AML) which identifies the crash location from a Cell ID when making an emergency call from a mobile network;
- a first aid training for drivers that could be a mandatory prerequisite for obtaining a driver's license;
- emergency corridors that grant priority to emergency vehicles and allows them to reach the scene of a crash quickly and safely;
- rescue sheets which are documents provided by vehicle manufacturers containing information about the structure, design, and components of a vehicle to help fire and rescue services to extricate casualties as quickly and safely as possible from a crashed vehicle.

More information about post-impact measures can be found in the Road Safety Thematic Report on Post-impact care (European Commission, 2022b).

5 Further reading

European Commission (2022b) Road Safety Thematic Report – Post-impact care. European Road Safety Observatory. Brussels, European Commission, Directorate General for Transport.

Weijermars, W., Meunier, J.-C., Bos, N., Perez, C., Hours, M., Johannsen, H., Barnes, J., et al. (2016). Physical and psychological consequences of serious road traffic injuries, Deliverable 7.2 of the H2020 project SafetyCube.

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, Deliverable 3.2 of the H2020 project SafetyCube.

6 References

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.

Amin, K., Skyving, M., Bonander, C., Krafft, M. & Nilson, F. (2022). Fall- and collision-related injuries among pedestrians in road traffic environment – A Swedish national register-based study. Journal of Safety Research, Volume 81, 2022, Pages 153-165, ISSN 0022-4375, https://doi.org/10.1016/j.jsr.2022.02.007.

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.

Bliss, T. & Breene, J. (2009). Country guidelines for the conduct of road safety management capacity reviews and the specification of lead agency reforms, investment strategies and safe system projects. World Bank, Washington.

Bouwen, L., Nuyttens, N., & Martensen, H. (2022). Les blessés de la route hospitalisés – Analyse des données hospitalières belges de 2005 à 2020, Bruxelles : Institut Vias.

Branas & Knudson (2001). Helmet laws and motorcycle rider death rates. Accident Analysis & Prevention, Volume 33, Issue 5, 2001, Pages 641-648, ISSN 0001-4575, https://doi.org/10.1016/S0001-4575(00)00078-6.

Chossegros, L., Hours, M., Charnay, P., Bernard, M., Fort, E., Boisson, D., Sancho, P.-O., et al. (2011). Predictive factors of chronic post-traumatic stress disorder 6 months after a road traffic accident. Accident Analysis & Prevention, 43(1), 471–477.

Craig, A., Tran, Y., Guest, R., Gopinath, B., Jagnoor, J., Bryant, R.A., Collie, A., Tate, R., Kenardy, J., Middleton, J.W. & Cameron, I (2016). Psychological impact of injuries sustained in motor vehicle crashes: systematic review and meta-analysis. BMJ Open. 2016 Sep 8;6(9):e011993. doi: 10.1136/bmjopen-2016-011993. PMID: 27609849; PMCID: PMC5020848.

DaCoTA (2012). Post-Impact Care, Deliverable 4.8m of the EC FP7 project DaCoTA.

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(0), 659–666. Journal Article. http://doi.org/http://dx.doi.org/10.1016/j.aap.2012.06.019

ETSC (2003). Transport safety performance in the EU - a statistical overview, European Transport Safety Council, Brussels.

ETSC (2020). How safe is walking and cycling in Europe? PIN Flash Report 38.

ETSC (2021). Ranking EU progress on road safety, 15th Road Safety Performance Index Report, June 2021.

European Commission (2019). Handbook on the external costs of transport. Brussels, European Commission, Directorate Generale for Transport.

European Commission (2022a). Annual statistical report on road safety in the EU, 2021. European Road Safety Observatory. Brussels, European Commission, Directorate General for Transport.

European Commission (2022b) Road Safety Thematic Report – Post-impact care. European Road Safety Observatory. Brussels, European Commission, Directorate General for Transport.

Hours, M., Chossegros, L., Charnay, P., Tardy, H., Nhac-Vu, H.-T., Boisson, D., Luauté, J. & Laumon, B. (2013). Outcomes one year after a road accident: Results from the ESPARR cohort. Accident Analysis & Prevention, 50(0), 92–102. Journal Article. doi: 10.1016/j.aap.2012.03.037

ITF (2021). Road Safety Annual Report 2021: The Impact of Covid-19, OECD Publishing, Paris.

Koornstra, M., Lynam, D., Nilsson, G., Noordzij, P., Petterson, H.-E., Wegman, F., & Wouters, P. (2002). SUNflower: A comparative study of the development of road safety in Sweden, the United Kingdom, and the Netherlands. Leidschendam: SWOV.

Kovacevic, J., Miskulin, M., Degmecic, D., Vcev, A., Leovic, D., Sisljagic, V., Simic, I., Palenkic, H., Vcev, I. & Miskulin, I (2020). Predictors of Mental Health Outcomes in Road Traffic Accident Survivors. J Clin Med. 2020 Jan 22;9(2):309. doi: 10.3390/jcm9020309. PMID: 31979086; PMCID: PMC7074414.

Lapostolle, A., Gadegbeku, B., Ndiaye, A., Amoros, E., Chiron, M., Spira, A., & Laumon, B. (2009). The burden of road traffic accidents in a French Département: the description of the injuries and recent changes. BMC Public Health, 9(1), 1–10. http://doi.org/10.1186/1471- 2458-9-386

Măirean, C. & Cimpoeșu, D. (2020). The relations between trauma exposure, subjective trauma appraisals, and posttraumatic stress symptoms in a sample of road traffic accident victims. 36-40. DOI: 10.36315/2020inpact008

Malczyk, A., and Bende, J. (2019). Heavy truck crashes involving pedestrians in comparison to bicyclists. 26th International Technical Conference on the Enhanced Safety of Vehicles (ESV): Technology: Enabling a Safer Tomorrow National Highway Traffic Safety Administration. No. 19-0080. 2019.

Malm, S., Krafft, M., Kullgren, A., Ydenius, A., & Tingvall, C. (2008). Risk of permanent medical impairment (RPMI) in road traffic accidents. Annals of advances in automotive medicine (Vol. 52, pp. 93 – 100). Association for the Advancement of Automotive Medicine.

Mayou, R. & Bryant, B. (2003). Consequences of road traffic accidents for different types of road user. Injury, 34(3), 197–202.

Meunier J.-C. & Dupont E. (2017). Dossier thématique Sécurité routière no 10. Conséquences des accidents de la route pour les victimes. Bruxelles, Belgique: Institut Belge pour la Sécurité Routière - Centre de connaissance Sécurité routière.

Meunier, J.-C., Dupont, E., Mersch, J. & Van den Berghe, W. (2018). My Life After the Crash - MyLAC: An international study on medical, psycho-social and economic consequences of road injuries. Brussels, Belgium: Vias institute.

Murray, C. J. L., & Lopez, A. D. (1996). The Global burden of disease : a comprehensive assessment of mortality and disability from diseases, injuries, and risk factors in 1990 and projected to 2020, In Harvard School of Public Health. https://doi.org/10.1088/1742-6596/707/1/012025

OECD (2012). Mortality risk valuation in environment, health and transport policies. Paris, OECD.

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

Schoeters, A., Large, M., Koning, M., Carnis, L., Daniels, S., Mignot, D., Urmeew, R., Wijnen, W., Bijleveld, F. & van der Horst, M. (2022). Economic valuation of preventing fatal and serious road injuries. Results of a Willingness-To-Pay study in four European countries. Accident Analysis and Prevention, 173. https://doi.org/10.1016/j.aap.2022.106705

Sharwood, L., Kifley, A., Craig, A. Gopinath, B., Jagnoor, J. & Cameron, I. (2021). Comparison of physical and psychological health outcomes for motorcyclists and other road users after land transport crashes: an inception cohort study. April 6th, 2021, PREPRINT (Version 1). Research Square. https://doi.org/10.21203/rs.3.rs-347525/v1

Stigson, H., Gustafsson, M., Sunnevång, C., Krafft, M. & Kullgren, A. (2015) Differences in Long-term Medical Consequences Depending on Impact Direction Involving Passenger Cars, Traffic Injury Prevention, 16:sup1, S133-S139, DOI: 10.1080/15389588.2015.1014999

Stigson, H., Boström, M. & Kullgren, A (2020). Health status and quality of life among road users with permanent medical impairment several years after the crash. Traffic Inj Prev. 2020 Oct 12;21(sup1):S43-S48. doi: 10.1080/15389588.2020.1817416. Epub 2020 Oct 7. PMID: 33026889.

Tainio, M., Olkowicz, D., Teresiński, 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(1), 1.

Tournier, C., Charnay, P., Tardy, H., Chossegros, L., Carnis, L., & Hours, M. (2014). A few seconds to have an accident, a long time to recover: Consequences for road accident victims from the ESPARR cohort 2 years after the accident. Accident Analysis & Prevention, 72, 422–432.

Weijermars, W., Meunier, J.-C., Bos, N., Perez, C., Hours, M., Johannsen, H., Barnes, J., et al. (2016), Physical and psychological consequences of serious road traffic injuries, Deliverable 7.2 of the H2020 project SafetyCube.

Wegman, F., Commandeur, J., Doveh, E., Eksler, V., Gitelman, V., Hakkert, S., . . . Oppe, S. (2008). SUNflowerNext: Towards a composite road safety performance index. Leidschendam: SWOV.

WHO (2019). Global Burden of Disease study 2019. Retrieved on 15th of December 2022 on https://ghdx.healthdata.org/

WHO (2022). Powered two-and three-wheeler safety: a road safety manual for decision-makers and practitioners, second edition. ISBN 978-92-4-006056-2.

Wijnen, W. (2008). Bruikbaarheid van QALY's en DALY's voor de verkeersveiligheid. SWOV.

Wijnen, W., Weijermars, W., Schoeters, A., Van den Berghe, W., et al. (2019). An analysis of official road crash cost estimates in European countries. In: Safety Science, vol. 113, p. 318-327.

World Health Organisation (2022). Disability-adjusted life years (DALYs), accessed 12 December 2022, < https://www.who.int/data/gho/indicator-metadata-registry/imr-details/158>.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