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INSTITUTO SUPERIOR DE ECONOMIA E GESTÃO

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SOCIAL AND ECONOMIC IMPACT OF ROAD CRASHES **IN PORTUGAL**

Lisbon, October 2021

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EXECUTIVE SUMMARY

Road crashes result in annual significant human, economic and social costs to society. The quantification of this economic and social cost is fundamental in forming the debate on public policies of road safety in Portugal. The estimates of a victim's average cost - dead, seriously injured or slightly injured - or those of a road crash are essential inputs in the evaluation of the impact of safety policies, in cost-benefit policies destined to quantify the social return on investments in the improvement of infrastructure safety, in programs of road crash prevention and in improving both vehicle security and the assistance and support given to victims. The estimate can also be used to better prioritize action based on effectiveness and economic efficiency criteria, as well as to compare the return on road safety investments and those of other public policy domains.

The social and economic costs of road crashes can be broken down to property and moral damage, intangible or non-patrimonial. Property damage consists of the damage done to the belongings of the injured and of third parties, including both emerging and ceasing damage. The moral costs, intangible or non-patrimonial, include, among others, the value of shortened human lives or permanently affected by crashes on the road, the physical pain and psychic and emotional shock caused among victims and their respective families, the injuries and medical procedures crucial to recovery, loss of quality of life, damage to one's physical appearance, and temporary or permanent consequences in the victim's personal and social statement.

While material damage usually can be evaluated through market prices in the quantification of social and economic value to road crash damages, non-patrimonial damage evaluation demands estimation methods. Cost is partially internalized, for example, as vehicle insurance premiums, though significant negative external factors mustn't be overlooked.

The social and economic cost of road crashes can be decomposed into costs that are directly related to victims of a road crash (injury-related costs), and costs that are related to the road crash itself (road crash-related costs).

In this study, we present detailed estimates of the social and economic cost of road crashes in Portugal, with a particular focus on road crashes that result in human fatalities. Using internationally referenced methodologies, we will present estimates of the total cost of road crashes in absolute value and in percentage of GDP (considering 2019 as reference year). The estimates will be decomposed into primary cost components (human cost, loss of production, medical cost, material damage, administrative cost, 'other costs'), and estimates of average costs by type and road crash circumstances (types of vehicles involved, location, age of intervening vehicles, types of roads, nature of the road crash, time, day of the week and month of the year, etc.).

Additionally, we analyze the exposure to risk, the frequency of risk, and the severity of the risk of road crashes in Portugal, using statistical data made available by the National Authority of Road Safety (Autoridade Nacional de Segurança Rodoviária - ANSR) particularly the characterization elements recorded in Statistical Bulletins of Road Crashes, together with data collected from other sources.

Furthermore, we present a worldwide comparative synthesis, as well as one of only Europe, of official traffic crash cost estimates, as well as the methodological proceedings used to obtain them. The problem with road crashes is contextualized and some public policy recommendations are presented.

In 2019, road crashes in Portugal generated an estimate of 6 422.9 million euros in social and economic cost - a number which represents 3.03% of the wealth generated within the country that year (GDP). Of said cost, most of it (83.5%) refers to road crashes with victims, making up a total of 5 362.7 million euros (2.53% of GDP). The remaining 1 060.1 million (0.5% of GDP) concerns road crashes with no victims which generated only material damage.

Among road crashes with victims, the biggest component of its total cost, at 64.7%, has to do with human cost (HC), estimated at 3 471.1 million euros (1.635% of GDP). The second most expressive component (at 26.8%) has to do with production loss (PL), estimated at 1 438 million euros (0.677% of GDP) in 2019. All in all, human and production loss represent 91.5% of the total cost of road crashes in Portugal. Property damage in traffic crashes with victims is estimated at 263.9 million euros (0.124% of GDP). Cost in victims medical care are estimated to be 84.6 million euros (0.04% of the GDP), while administrative costs are estimated at 78.5 million euros (0.037% of GDP). The value of other costs represents 26.6 million euros (0.013% of GDP). If we take into consideration road crashes with material damage but no victims, property damages resulting from road crashes with and without victims are estimated at 1 324.1 million euros (0.62% of GDP).

Almost all age groups had more human cost in male victims (drivers, passengers, pedestrians) rather than female, with the biggest difference in age being in those of active life, which are registered to have had the greatest number of road crashes in Portugal in 2019. The human cost of underage victims is estimated at 157.7 million euros in 2019, corresponding to a total of 3,764 victims - out of which 20 were fatal, 136 severely injured and 3,608 slightly injured.

The production loss is bigger among male victims when compared to female, with the biggest difference in age being registered at the beginning of active life. In these ages, total life expectancy and reminiscent job market life expectancy are bigger, which is why the verification of traffic crashes, particularly those with serious consequences involved, has a large impact in potential contribute for victims to generate wealth.

In the past 25 years there has been a significant social and economic cost reduction in road crashes with victims in Portugal, having gone from an annual number that surpassed 7% of GDP to a number that stabilized towards 2.5% of GDP in current prices in 2019.

The main contribution to the annual reduction in the social and economic cost of road crashes was the significant reduction in the number of severely injured victims, of which we should outline a 70% reduction in the number of fatalities during this period, as well as an 80.7% decrease in the number of severely injured.

Between 1995 and 2019, the estimate in social and economic cost avoided with the reduction of road crashes in Portugal reached 174 810 million euros, representing about 82.3% of wealth generated in Portugal in 2019. The main reason behind this cost deduction to society was the decrease in serious traffic crashes.

Regardless of the significant cost associated with the loss of human victims, mainly non-patrimonial, the costs referring to slightly injured victims represent the largest portion of the social and economic cost in road crashes with victims registered in Portugal in 2019, at a total of 2 249.9 million euros (1.06% of GDP). This number is explained mainly through human cost, loss of productive potential and material damage. The second most important portion of the total cost of road crashes involving victims is associated with fatalities, which, in 2019, corresponded to a total of 1 912.7 million euros (0.90% of GDP). The social and economic cost related to the severely injured reached 1 200.2 million euros, corresponding to 0.57% of 2019's GDP at current price.

The average social and economic cost of a road crash fatality is estimated at 3 055,358 million euros per fatality, largely due to high moral, immaterial and non-patrimonial costs to victims' family and friends (2 269,837 million euros) and the number of gross production loss (estimated at 760,927 euros per victim). The average cost of a severely injured victim for society is estimated at 530,828 euros per victim. The average cost of a slightly injured victim for society is estimated to be 49,953 euros per victim, when all cost components are considered.

The average cost of a victim in 2019's estimate of traffic crash victims is estimated at 111,894 euros per victim. When decomposing this average cost by social and economic components, it is to be concluded that the biggest part of cost relates to human cost (94,854 euros per road crash), followed by the cost of loss of production (39,167 euros), property damage (7,096 euros) and medical cost (2,275 euros).

The biggest contributor to human cost in traffic crashes are the cases where victims are drivers (3 385.9 million euros), followed by road crashes that result in victimized passengers (1 070.9 million euros) and road crashes that result in victimized pedestrians (906.0 million euros).

The analysis of average cost by nature of the road crash (with pedestrians, collision of vehicles or single-vehicle crash) has allowed for the conclusion that crashes with pedestrians are the road crash with the highest social and economic cost across all categories, with an estimated cost of 161,737 euros per road crash.

The average cost estimates of road crashes per type of vehicle (light or heavy vehicle, moped, motorcycle, quad, agricultural vehicle, bicycle motorized or not, among others) indicate that road crashes involving agricultural vehicles are very clearly those with the highest cost to society, being estimated at 466,998 euros per road crash. Road crashes involving heavy vehicles, where victims are also involved, come second at an estimate of 261,906 euros per road crash, road crashes involving quad vehicles come third at an estimate of 239,513 euros, and, at last, road crashes with motorcycles over 125cc rack up an average cost of 235,393 euros per road crash.

The estimates of the average cost of road crashes according to the preservation condition of roads indicate that road crashes on badly preserved roads have the highest average social and economic cost to society, estimated at 186,477 euros per road crash with victims.

Sunday is the day of the week where the cost of road crash ranks the highest, at a number that exceeds 181,913 euros per road crash, the largest portion of which is attributed to the most seriously injured victims resulting from the road crash.

The month of August is the month of the year with the most expensive cost of road crashes to society, at an estimated 171,578 euros per road crash with victims, followed by September, at around 159,202 euros per road crash, and January, at an estimate of 155,806 euros per road crash.

In terms of territory, the results obtained in this study indicate that Beja as a district has by far the costliest road crashes with victims, at an estimated number of 379,098 euros per road crash with victims. The Alentejo district, in particular, feature a particularly negative record, with Portalegre (322,969 euros per road crash) and Évora (263,185 euros per road crash) as second and third worst registers to society as far as the cost of road traffic by each crash is concerned.

When breaking it down by types of traffic lanes on which road crashes take place, road crashes in forest roads are by far the costliest to society, at an estimate of 403,163 euros per road crash with victims. Road crashes on main itinerary roads represent equally a high cost, of 339,494 euros per road crash. In addition, road crashes on municipal roads have an estimated average cost of 214,302 euros per road crash with victims.

When breaking down the average cost of road crash per age of intervening vehicles, results show that road crashes involving vehicles over 20-year-old have the highest social and economic cost, estimated at 170,078 euros per road crash with victims.

The rate of road crash risk has gone down in the past two decades. The probability of a road crash with victims involving an insured vehicle taking place has stabilized at around 0.55% in the last five years.

The risk of there being a road crash with victims of greater severity has gone down in the last decade, from 0.061% in 2010 to 0.043% in 2019. In 2019, per every 1,636 insured vehicles in Portugal, there was one road crash involving fatalities and/or seriously injured. The risk of road crashes is not homogeneous through time, space and circumstances.

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1. Introduction

Road crashes generate every year significant human, economic and social costs to society. The quantification of these economic and social cost is fundamental in informing the debate on public policies of road safety in Portugal. The estimates of the average cost of a victim - fatality, seriously injured or slightly injured - or of a road crash, are essential inputs on evaluating the impact of safety policies, on cost-benefit analysis destined to quantify the social return on investment in improving the safety of infrastructure, programs of road crash prevention, improvement of vehicle safety and improvement on assistance and victim support. They can still be used to prioritize actions based on both efficiency and economic efficiency criteria, or to compare the return on investment on road safety with that in other public policies.

As a general rule of thumb, the approval and construction/remodel/improvement of a big road enterprise, or the definition and implementation of a prevention plan, requires a positive cost-benefit analysis, among other proceedings, to identify the nature of risk, quantify its social and economic importance and to propose and prioritize efficient mitigation measures on the main impacts. The projects' cost includes implementation costs (e.g., change of infrastructure, the imposing of traffic control equipment) and operational costs (infrastructure maintenance, for example). As far as benefits are concerned, a good portion refers to potential gains it may provide in terms of road safety in both the short and the long term, particularly in reducing the number of road crashes and victims and consequential social and economic impacts, patrimonial or not.

To quantify cash value of that safety increase in complimentary metrics, and ones that don't run out, in attributing statistical value to human life, several indicators are needed: detailed and objective indicators on circumstances, causes, frequency and severity of road crashes, broken down in multiple dimensions and typologies, all accurately contextualized. This definition requires clear conceptual models and specific methods of estimating road crash costs that are based on objective statistical information (as much as possible) and consider the true heterogeneous dimension and nature of the phenomenon.

The social and economic costs of road crashes can be, roughly speaking, broken down into two main components: (i) property damage and (ii) moral damage, immaterial or non-patrimonial. Property damage includes damage caused on assets belonging to those who sustained injuries and to third parties (e.g., cost of vehicle repair and damaged roads, expenses being supported by the claimant, medical assistance costs), including both the so-called emerging damages, in reference to damaged goods, and pre-existing rights the injured parties held before the injury ever took place — like ceasing profits, in reference to the income missed out on as a result of temporary or permanent unavailability to participate in productive processes.

Moral, immaterial and non-patrimonial costs include, among others, the cost of shortened human lives or permanently affected by traffic crashes, the physical pain and emotional and psychological damage caused in those involved, family involvements, medical care needed towards recovery, loss of quality of life, damage to one's physical appearance, and both temporary and permanent consequences in one's personal and social lifestyle.

If, in what concerns property damages, it is possible to use market prices to quantify the economic and social value to damage caused by traffic crashes, the same cannot be said for non-patrimonial damage, which fails to be as trivial and therefore demands estimation methods. The evolution of these costs to society should aim to identify and quantify the present and future value of all damage caused by the road crash, as long as they're predictable. A portion of the total costs of road crashes is internalized, for example, through insurance premiums that are paid, but an important portion refers reference to the negative externalities of road crashes that mustn't be overlooked when accounting for the total cost.

The social and economic cost of road crashes is generally decomposed into two main components. The first has to do with costs directly related to road crash victims (injury-related costs), which include human costs, the cost of production loss and medical bills, and others. The second has to do with costs directly related to the road crash itself (road crash-related costs), which include the cost of property damages and administrative costs.

In quantifying the social and economic costs of road crashes, one must first start with a detailed analysis of the exposure to risk of a road crash, of the probability of a road crash (risk frequency) and severity of consequences resulting from the road crash (risk severity), particularly in terms of the number of human victims and their injury level (fatalities, seriously injured, slightly injured). It demands, secondly, the adoption of internationally recognized methodologies and approaches, among which we included the human capital approach (HCA) used in quantifying loss of victims' ability to remain productive, for example, the Willingness-to-Pay/Accept approach, frequently used in determining the statistical value of human life, or the method of replacement costs used in assessing the cost of medical care, property damage or administrative costs, to name a few.

In this study, we present detailed estimates of the social and economic cost of road crashes in Portugal, with a particular focus on road crashes that result in human fatalities. Resorting to internationally referenced methodologies, we will present estimates of the total cost of road crashes in absolute value and as a percentage of GDP (using the year of 2019 for reference). The estimates will be decomposed into primary cost components (human cost, loss of production, medical cost, material damage, administrative cost, 'other costs'), and estimates of average costs by type and road crash circumstances (types of vehicles involved, location, age of intervening vehicles, types of roads, nature of the road crash, time, day of the week and month of the year, etc.).

Additionally, we put together an analysis of the exposure, frequency and severity of risk of road crashes in Portugal, using statistical data made available by the National Authority of Road Safety (Autoridade Nacional de Segurança Rodoviária - ANSR) concerning general characterization elements of road crashes, found in Statistical Bulletins of Road Crashes, and other entities. Furthermore, we also provide a comparative overview of Europe and the rest of the world on official estimates of road crash costs and methodological procedures used to obtain them. The dilemma with road crashes is contextualized and some public policy recommendations are presented on the matter.

This project was based on statistical information made available (or obtained through public sources) by ANSR, Autoridade de Supervisão de Seguros e Fundos de Pensões (ASF), Instituto de Mobilidade e dos Transportes (IMT), Instituto Nacional de Estatística (INE), APS - Associação Portuguesa de Seguradoras, Comissão, Polícia de Segurança Pública (PSP), Guarda Nacional Republicana (GNR), fire departments and other organisations of civil protection, Associação Automóvel de Portugal (ACAP). Different databases were consulted, among which the community database on road crashes in Europe (CARE - Community database on Accidents on the Roads in Europe).

The study is structured in 7 chapters. The first chapter includes an introduction and placement on the issue of road crashes. The second chapter includes an analysis of the main European and global trends in physical indicators of road crashes, as well as an international comparative synthesis of official social and economic cost estimates, as well as the methodological procedures used to obtain them. The third chapter includes a brief characterization of road crashes in Portugal, considering statistical information made available for the year 2019 as a reference point. In the attached report we present a more detailed characterization of exposure, frequency and severity of risk. The fourth chapter includes the methodology used in this study to estimate social and economic cost of road crashes. The fifth chapter includes social and economic cost estimates of road crashes with victims in Continental Portugal in the year 2019, disaggregated by components of cost and severity of injury in victims (fatalities, seriously injured, slightly injured) and by road crash characterization. The sixth chapter includes brief public policy recommendations in regards to safety on the road. The seventh and final chapter includes a summary on main conclusions.

1.1. Framing the problem of road crashes

Vehicle circulation is constant in everyday life, not to mention extremely useful in daily commutes to work, in developing economic activity, in times of leisure and holiday, or even in getting tasks of personal nature done. As SWOV (2018:5) mentions, *"mobility is an important human necessity"*.

The increase in resident citizens with a driving license, the exponential growth in the number of vehicles and habits of consumption, the open space economy operations, the challenges that come with business competitiveness and sustainability, the attractive natural resources for tourism, the increase in purchasing power and easier accessibility to credit, are all contributors to the increase of vehicles circulating daily through Portugal.

Consequently, in addition to motor vehicles, there has been a noticeable increase in the number of bicycles and, more recently, in urban centers, massive use of scooters, with an increasing confluence of road traffic modes and their proximity and interaction, especially in the most active areas of cities, with pedestrian areas. However, and as SWOV (2018) emphasizes, to meet these mobility needs, road traffic must be permanently safe.

In this context, according to the most recent data[1], the number of road crashes with casualties in Portugal has increased, although the number of fatalities has reduced, serious and slightly injured have increased (ANSR, 2019). Traffic injuries are estimated to be among the top ten causes of death worldwide, constituting the leading cause of death among young adults aged 15 to 29 years (Chen, et al., 2019: e390). Notwithstanding the improvement in indicators in recent decades, road traffic crashes remain a leading cause of death from road crashes at work and the leading cause of death for children and young people from the age of 5 years and up to the age of majority.

This means that the increase in traffic flows observed requires a constant analysis of the main variables of this phenomenon, given the effects on the levels of road fatalities and, consequently, the associated economic and social costs. In other words, if the circulation of people and goods is a necessity, road crashes are a problem and a challenge that must be faced.

1.2. Conceptual aspects in the field of road crashes

The definition of road crashes, road crashes with victims and the classification of victims are essential to assess the economic and social impact of road crashes and to analyze their evolution over time. In this regard, not all road crashes are usually accounted for by safety authorities as road crashes in official statistics and not all road crashes occur on public roads. In Portugal, the nomenclature and guidelines used in classifying traffic crashes is defined by the Portuguese Road Safety Authority (Autoridade Nacional de Segurança Rodoviária - ANSR), nomenclature that we will adopt in this study. In this sense, and for the sake of completeness of the report, the nomenclature at the level of definitions adopted by ANSR (2019: 4) is presented below:

- Road crash with victims (AcV) - An occurrence on or originating from a public road involving at least one vehicle in motion, known to the police forces (GNR and PSP) and resulting in at least one victim.
- Road crash with fatalities (AcVM) - A road crash that results in at least one fatality.

[1] Road fatality data recorded in 2019 compared to 2018.

- Road crash with seriously injured (AcFG) - A road crash resulting in at least one seriously injured, but no fatalities.
- Minor injury road crash (MVA) - A road crash resulting in at least one minor injured, in which no deaths or seriously injured occurred.
- Victim - A human being who as a result of a road crash suffers physical injury.
- Dead or fatality: (i) at 24h (VM) - Victim whose death occurs at the scene of the road crash or during the trip to the health care facility; (ii) at 30 days - Victim whose death occurs within 30 days after the road crash.
- Seriously injured at 30 days (FG) - Victim of a road crash whose physical injury requires hospitalization for more than 24 hours and who does not die within 30 days after the road crash.
- Slightly injured within 30 days (FL) - A road crash victim who is not considered seriously injured and who does not die within 30 days after the road crash.
- Driver - Person in command of a vehicle or animal on the road.
- Passenger - Person assigned to a vehicle on the public road and who is not a driver.
- Pedestrian - Persons on foot on public roads; children up to the age of 10 riding bicycles; persons riding at hand two-wheeled bicycles without a trailer, moto cultivators without a trailer, handcarts and children's or handicapped persons' cars; persons in wheelchairs with an electric motor, scooters, roller skates or other similar non-motorized means of transport.
- Within localities - (DL) Area delimited by the signs of the Traffic Signal Regulation that identify and fix the beginning and the end of the localities for the rules specially foreseen for traffic inside and outside of them start to take effect from the place where they are placed.
- Severity index - Number of deaths per 100 road crashes with victims.
- Severity indicator - GI = 100xM + 10xFG + 3xFL, where M is the number of fatalities, FG is the number of seriously injured and FL is the number of slightly injured.
- Black spot - A stretch of road with a maximum length of 200 meters in which there have been at least 5 road crashes with victims in the year under review and whose sum of severity indicators is greater than 20.

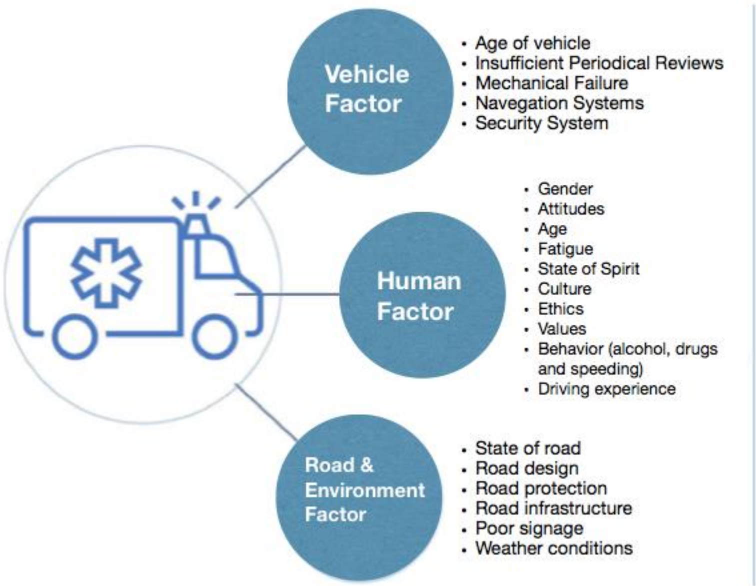
Following the development and implementation of the National Road Safety Strategy, the need to better understand the circumstances, causes and effects of road crashes, to properly quantify exposure to risk and the frequency and severity of traffic crashes, Portugal adopted, as of January 1, 2010, the international concept of 30-day injured, in line with the methodology used by most European Union countries, allowing international comparability of data on traffic crashes. In this sense, whenever no other classification is explicitly indicated, the reference to fatalities, seriously injured or slightly injured should be understood as respecting the respective 30-day definitions as explained above.

1.3. Groups and risk factors

Many studies on road fatalities consider drivers and the road environment itself as the main causes of the road crashes recorded. In this sense, the work of Cardoso (1996) reiterates this understanding also supported by the results of other studies conducted in the 80s. The National Plan for Road Safety (MAI, 2003:4) has also identified the main problems associated with fatalities in Portugal. To a large extent, some of them are directly related to drivers and to road environment. Namely, the lack of civic education and the existence of poor road infrastructures, but where the negative contribution of the vehicle factor to the high number of accidents is also noted, as a result, for example, of an old stock of vehicles, with insufficient maintenance, and the absence and/or inadequacy of safety and navigation systems. Likewise, in a work developed by CCDR Norte (2008:15), among a set of factors listed, the practice of inappropriate behavior and the failures of the road traffic system stand out as being at the root of the observed behavioral maladjustment.

Oliveira (2007:28-104) identifies four supra factors that underlie the occurrence of road crashes - human, vehicle, road, and environment. In Figure 1.1 we present the factors distributed by each of the groups (supra factors) adapted here, as elements to be considered when checking a road crash (Simões, M., 2014:19).

Figure 1.1. Motivational factors of road crashes



Source: Own elaboration based on Simões (2014)

A large part of the number of road crashes that occur can be explained by drivers' intrinsic errors, but many other factors also influence this area of road crashes, namely the condition of the roads, the weather conditions and the condition of the vehicle. As shown in Figure 1.1, there is a panoply of items that influence road crash levels.

Peden (2004:71) identifies risk in road crashes as a function of four main elements. The first are factors influencing exposure-to-risk. The second refers to the risk factors influencing road crash involvement, i.e., it is the underlying probability of a road crash, given a given exposure. The third are the risk factors influencing road crash severity, meaning they are associated with the probability of injury in case of a road crash. The fourth are the risk factors that influence the severity of post-crash injuries, embodying the outcome of the injury.

Also according to Peden (2004:71) risk arises, as illustrated in Figure 1.2, largely as a result of several factors, which include: (i) human error in the road system; (ii) the size and nature of the kinetic energy in the impact to which people in the system are exposed as a result of errors; (iii) the tolerance of the individual to this impact; and (iv) the quality and availability of emergency services and care for the most distressing conditions.

As an example, drivers in their routines, many due to daily stress and the attempt to meet goals and other challenges, tend to facilitate when it comes to compliance with safety rules, and a simple mistake can be fatal with irreversible consequences for the injured and their respective families and close friends.

So, behind human error, there may be particularities, namely physiological or intrinsic to the individual, such as the quality of vision at night and the timely perception of obstacles and their movement that, in association with age, can influence the risk of a road crash. But there are also external factors that can influence human error, such as road design, vehicle performance and traffic rules. With this in mind, it seems fundamental to us that risk analysis is based on an integrated perspective of elements - driver, vehicle and road environment - and not restricted to an isolated assessment of each of these elements, as Peden (2004:71-72) suggests.

Turning to a more particular look at the risk factors for road crashes mentioned above (Peden, 2004:71), we must consider factors that influence exposure to the risk of a road crash occurring: economic factors, including social deprivation, demographic factors, and the factors related to planning the route and duration of the trip or the choice of mode of travel, combining high-speed motor vehicle traffic with vulnerable road users and insufficient attention to the integration of road function with decisions on speed limits, road layout and design.

Figure 1.2. Main factors influencing road crash risk

Source: Own elaboration based in Peden (2004:71)

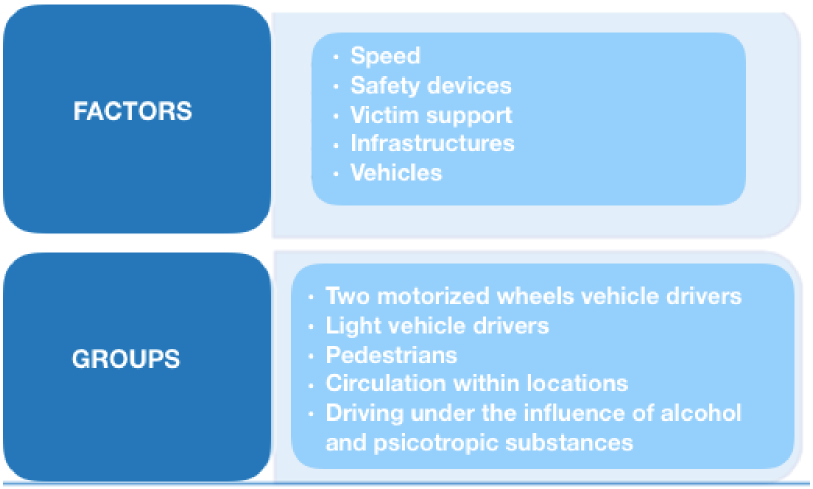
As for the risk factors influencing road crash involvement, Figure 1.3 presents some examples, inappropriate or excessive speed, the presence of alcohol, medicinal or recreational drugs, fatigue, being a young male, being a vulnerable road user in urban and residential areas, traveling in the dark, factors associated with the vehicle such as braking, handling and maintenance, defects in road design, layout and maintenance that can also lead to unsafe road user behavior, inadequate visibility due to environmental factors, making it difficult to detect vehicles and other road users, and poor driver vision.

Regarding risk factors influencing road crash severity, these include human tolerance factors, inappropriate or excessive speed, non-use of seat belts and child restraint systems, non-use of safety helmets by users of two-wheeled vehicles, insufficient protection against vehicle collisions for occupants and those hit by vehicles, and the presence of alcohol and other drugs (Peden et al., 2004: 71,88).

Finally, the following are considered risk factors that influence the severity of post-crash injuries: delay in road crash detection, presence of fire resulting from a collision, leakage of hazardous materials, presence of alcohol and other drugs, difficulty in rescuing and removing people from vehicles, difficulty in evacuating people from buses involved in a collision, lack of adequate pre-hospital care and lack of adequate care in hospital emergency rooms (Peden et al., 2004: 71).

In the particular case of Portugal and the framework of the National Road Safety Strategy 2008-2015, the work developed by Lopes et al. (n.d.: 6), illustrated in Figure 1.3, identifies a set of groups and risk factors to support the definition of the strategic objectives of the national initiative.

Figure 1.3. Main factors and groups at risk



Source: Own elaboration based on *Lopes et al.* (n.d: 6)

In this context, the following were considered as risk groups: (i) drivers of two-wheeled motor vehicles; (ii) light vehicle drivers; (iii) pedestrians; (iv) driving within localities; and (v) driving under the influence of alcohol and psychotropic substances. The following are considered risk factors: (i) speed; (ii) safety devices; (iii) victim rescue; (iv) infrastructure; and (v) vehicles.

Regarding drunk driving, in the period from 2016 to 2018, 6.1% of the total number of road crashes involving at least one driver with a BAC > 0.5g/l, resulting from this 20.9% of the total number of fatalities recorded and 14.6% of the total number of seriously injured in that period (ANSR, 2020b:16). In a more particular analysis, it was observed that the proportion of road crashes with victims, increased in 2018 after a reduction in 2017 compared to 2016, while, also in relative terms, in 2018, there was a reduction in the weight of the number of fatalities and an increase in seriously injured (ANSR, 2020b:16). Concerning the use of psychotropic substances, there was a reduction in the percentage of positive tests (10.3%) in the total number of fatalities in 2019 when compared to the values observed in 2018 (14.5%), except for drivers for which a trend reversal was observed, 13.3% in 2019 after 11.6% in 2018 (ANSR, 2020a:8).

1.4. Legal and institutional framework

The fight against road fatalities presupposes the definition of public policies appropriate to the characteristics of the population and the national road context supported by comprehensive and territorialized diagnoses and the development of impact assessment studies of current measures in their relationship with the main risk groups. It is with this purpose that, in the last three decades, the Integrated Road Safety Plan (PISER), from 1998 to 2000, the National Road Safety Plan (PNPR), from 2003 to 2010, and the National Road Safety Strategy (ENSR), for the years 2008 to 2015, were developed. In this context, the evolution of fatalities in Portugal showed remarkable improvements compared to the quantitative target set in the NRSS.[2]

Within this framework of promoting road safety for all, the National Road Safety Authority (ANSR) built the National Strategic Plan for Road Safety PENSE 2020, whose preparation was based on extensive participation of academia, public and private entities and civil society itself.[3] PENSE 2020 is directed towards the development of five strategic objectives *"improve road safety, make users safer, make infrastructures safer, promote greater vehicle safety, and improve support and assistance given to victims"*.

In this context, a set of structures were created with the mission of monitoring the development of the Plan and the evaluation of sectoral action programs. It was also intended with the delimitation in time of this plan to follow the time horizon of road safety policies of the European Union (EU) and the United Nations (UN). Moreover, in this field, it is worth mentioning the Portuguese endorsement of the recent UN General Assembly Resolution[4] on Improving Global Road Safety, proclaiming the period 2021-2030 as the Second Decade of Action for Road Safety, supported by the Declaration of Stockholm[5] with the goal of reducing road fatalities and injuries by at least 50% and urging Member States to continue to take action until 2030 on all Sustainable Development Goals with the need to promote an integrated approach to traffic safety as a Safe System approach and Vision Zero that promotes evidence-based action and objective data.

Requiring the Safe System approach a different understanding of the road fatality issue, requiring coordinated action from all sectors and for all road users with a strengthened governance structure, which presupposes setting clear targets and monitoring progress in preventing fatalities and seriously injured with the help of a set of key performance indicators (EC, 2018: 1), the European Commission, already in 2019, proposed within the European Union Road Safety Policy Framework for 2021-2030[6], a set of key performance indicators, which member states should produce, as a fundamental tool in the pursuit of the Safe System approach, being in line with the purpose of the United Nations Resolution in this field.

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[2] Council of Ministers Resolution No. 85/2017, of 19 June Preamble.

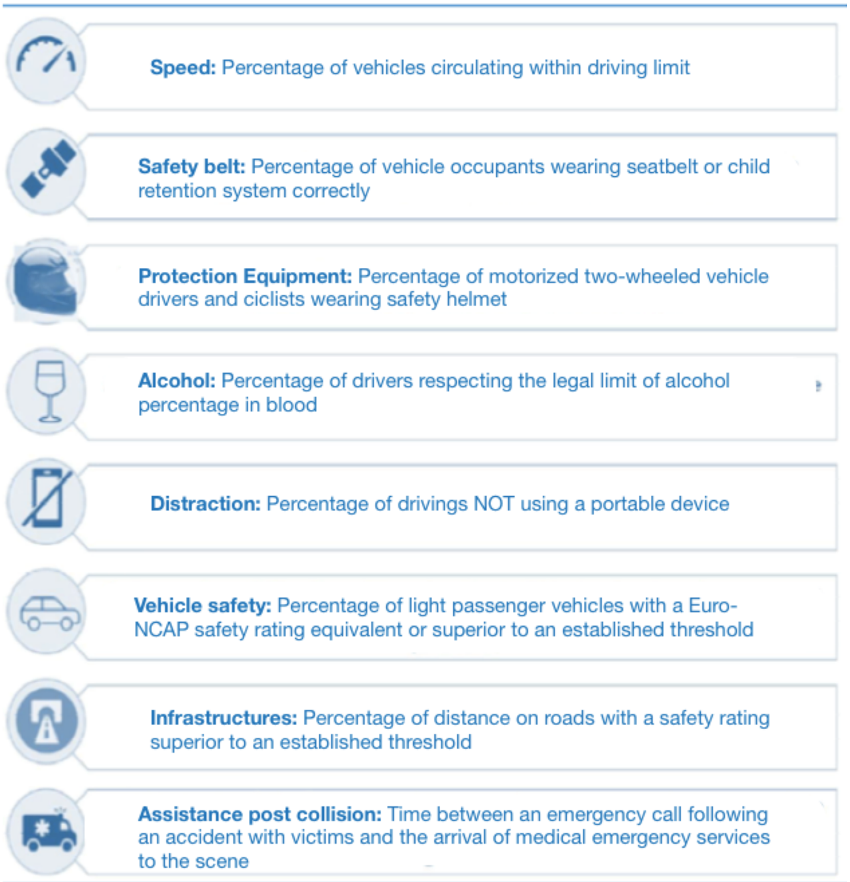
[3] Approved by the Resolution of the Council of Ministers No 85/2017, of 19 June.

[4] Resolution A / RES / 74/299 on Improving Global Road Safety adopted by the General Assembly of the United Nations on 31 August 2020.

[5] Agreed at the 3rd Global Ministerial Conference on Road Safety on 19-20 February 2020.

[6] Comissão Europeia, COMMISSION STAFF WORKING DOCUMENT - EU Road Safety Policy Framework 2021-2030 - Next steps towards "Vision Zero", SWD(2019) 283 final, Brussels.

Figure 1.4. Proposed Safe System key performance indicators



Source: ANSR (2019: 45) based on CE, SWD (2019) 283 final.

In the national context, ANSR's mission is to plan and coordinate support for the Government's road safety policy, as well as to enforce the law on road traffic offenses, namely by contributing to the definition of traffic and road safety policies, preparing and monitoring the national road safety plan, promoting the study of the causes and factors involved in road crashes and promoting and supporting civic initiatives and partnerships with public and private entities.[7]

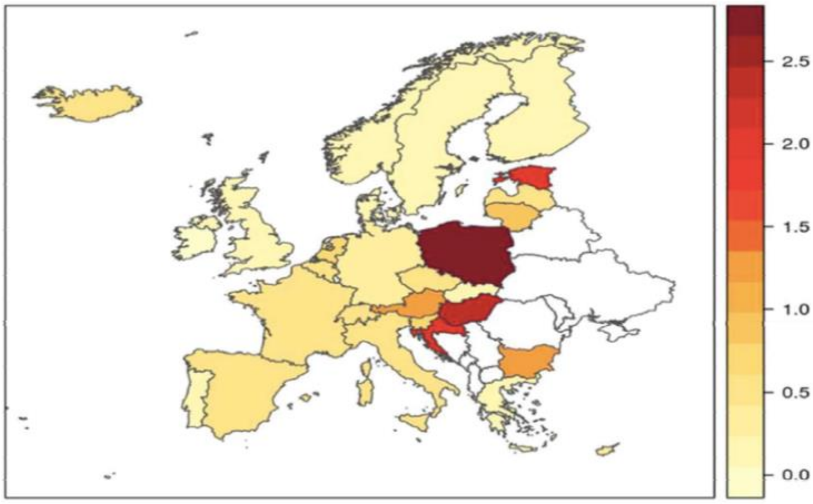
1.5. Economic and social dimension and negative externalities

The increase in the number of vehicles associated with the set of factors mentioned above is reflected in the behavior of fatalities worldwide, namely in Portugal. To get an overview of the economic dimension of the costs of road fatalities in the different EU countries, though only from the perspective of seriously injured, Figure 1.5 illustrates the total cost of seriously injured as a percentage (%) of GDP in each member-state. We can see that the total cost shows considerable variations. For example, while in Ireland and Portugal the economic costs of seriously injured recorded respectively 0.004% and 0.20% of GDP, Poland reached 2.7%. In some cases, the sharp differences between countries can be explained through methodological

[7] Decree-Law No 126-B/2011, of 29 December.

aspects that should be considered, used in each State to calculate the information (Schoeters et al., 2020).

Figure 1.5. Total cost in relation to seriously injured in GDP (%)



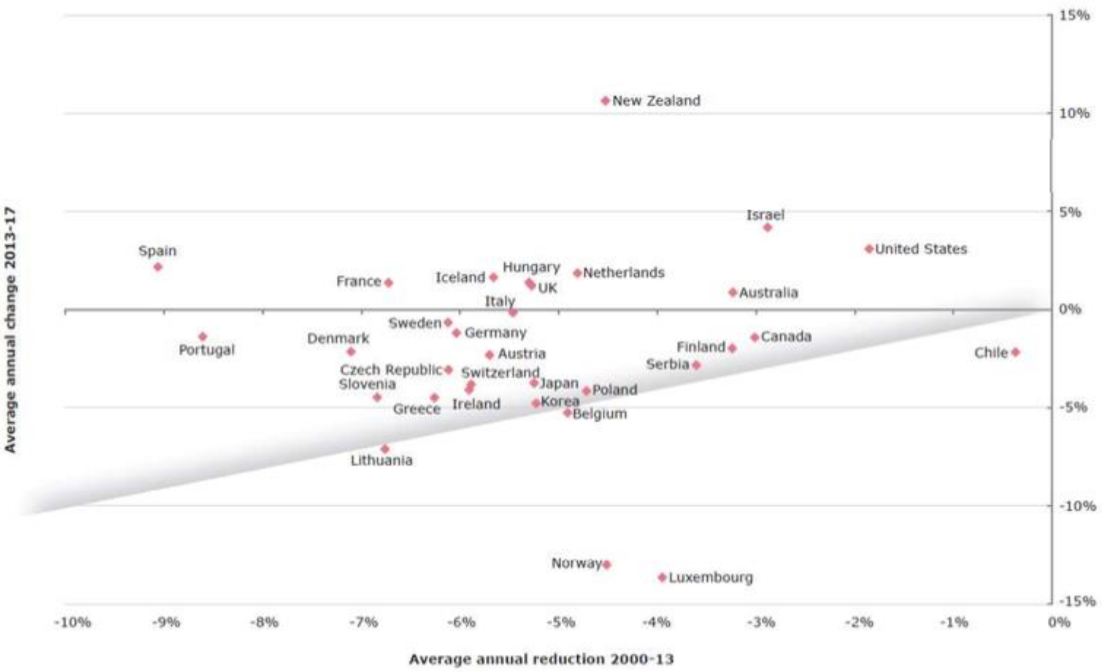
Source: Schoeters et al. (2020).

According to the work developed by Simões (2014:21), economic prosperity also tends to be linked to the increase in circulation of goods and products as a result of the growth in demand and the availability of supply, resulting in higher traffic volume. This means that there is a direct relationship between economic growth and an increase in road crashes due to the expansion of road traffic flows. Moreover, the (ITF, 2019a) in its 2019 Road Safety Annual Report notes that economic factors have an impact on road safety performance in that the economic recovery from 2013 onwards was accompanied by a significant increase in the number of traffic fatalities due to the increase in motorized traffic, as shown in Figure 1.6.

Also, according to Simões (2014: 21-22), in situations of economic recession, some grounds support two theses: according to the first one, the displacements by own car are embodied in shorter routes and at a reduced speed to save fuel, which leads to fewer road crashes. The second thesis points to the reduction in the purchasing power of young people due to job insecurity in the younger age groups and its reflection in the reduction of the purchase of a vehicle for one's use, as a fact that leads to a decrease in the levels of road traffic and, consequently, in the number of road crashes. In this line of reasoning is the national public position written in 2012 and contained in the Support Document for the Review of the National Strategy for Road Safety 2008-2015, stating *"bearing in mind the figures for the increase in unemployment, total and among young people, and especially its acceleration, and the decrease in the consumption of road fuels, we foresee a continued decrease in road fatalities with victims by the end of 2013"*.[8]

[8] Council of Ministers Resolution No. 85/2017, of 19 June.

Figure 1.6. Percentual variation in number of fatalities in traffic – 2000-13/2013-17



Source: OCDE, Road Safety Annual Report 2019.

Some investigators argue that in periods of economic recession there is an increase in the number of road fatalities due, among other things, to uncivil behavior of drivers as a result of possible emotional imbalances caused by states of need, the reduction of investment in the maintenance of the road system and in conducting studies and information campaigns and promotion of road safety actions, and also because drivers take less care with vehicle maintenance (Simões, 2014: 22) due to the resulting costs.

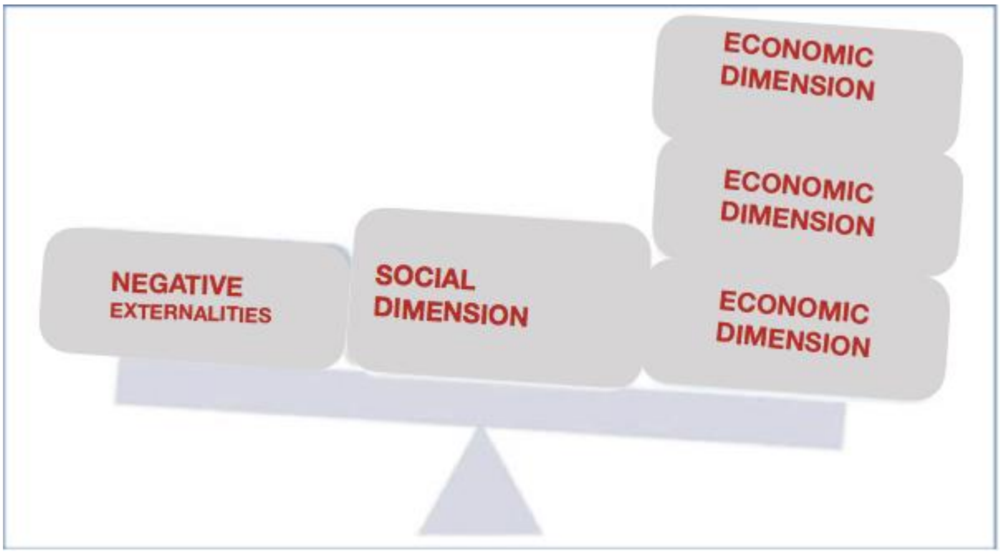
In addition to these perspectives on the interaction of the economy with road fatalities, one must also take into account (ANSR, 2014: 19) the impact of the loss of human lives and of situations in which those affected are unable to work on the budget of their own families due to the loss of income and on the economy of the country, namely by the reduction in government revenues resulting from the lower collection of taxes and contributions on labor income.

Regarding the income of injured people, Simões (2015:16) presents the results of the study Road Injuries and Long-Run Effects on Income and Employment according to which, based on a set of assumptions, the income of injured people who were injured in road crashes decreases relative to the income of those who were not injured, and this effect is more evident in men than in women. The same study also concluded that disposable income varies with the age of the injured person. For example, in a comparison by age groups it was found that six years after the road crash the youngest individuals have a disposable income similar to those who were not injured, contrary to the age groups of the oldest injured.

Therefore, there is a cause-and-effect relationship between the economic dimension and the social dimension. The latter in its objective and neutral sense, coinciding with the totality of social life. For, as we have observed, the behavior of the economy has determined the levels of wealth in society and the states of need of individuals and families, with natural reflections on their quality of life and well-being. Although these concepts also have a subjective nature, depending on how each person evaluates his or her quality of life, an aspect that is recognized by the World Health Organization when it states that *it is the individual's perception of his or her position life in the context of the culture and value system in which they live and in relation to their goals, expectations, standards and concerns* (Whoqol Group, 1998: 1569-1570), what's right is that the loss or reduction of income caused by traffic crashes may generate states of need. These situations translate into social and family dysfunctions that may lead to cases of marginalization and social exclusion with repercussions also at the level of public social protection systems in the fields of health care and cash benefits to replace income from work, to guarantee minimum subsistence or even to resort to social services and facilities.

In addition to the direct effect that road crashes may have on the daily lives of the injured, whether in terms of the loss of legitimate material goods such as income from work or, in some circumstances, the loss of autonomy in different bodily functions, they may also have repercussions at the psychological level of the individual, namely due to states of incapacity and/or dependence that make it impossible/interrupt a life project with dignity and individual freedom, access to education and employment, personal and professional progress and fulfillment, the constitution of a family life, accompanying children, leisure activities, and several achievements of inestimable value that are difficult to quantify. Besides the direct victims, as mentioned (Pires et al., 2004: 589), road crashes may also cause acute stress disorders and post-traumatic stress disorders to professional teams, particularly to those who are in states of greater vulnerability as a result of frequent exposure to events that show some danger, as is the case of firemen, doctors, paramedics, first-aiders, among others.

Figure 1.7. Levels of road traffic impact



Source: Own elaboration.

The approach to the social dimension of road crashes would be incomplete if we did not include the damage caused to the family and close friends. The situations of disability and dependence require the family to provide the necessary support to meet basic, health and legal needs, which condition the daily life and freedom of its members, and may lead to physical and psychological stress with repercussions on their quality of life, caused by the routines, the limitations and impediments to a life with dignity and even by the isolation it may cause. Grief, pain and sadness are also states caused by the loss of family members and friends with irreparable moral and social damage that is difficult to quantify, but which cannot be dissociated from the impact and costs of road crashes.

In this context, the following also have a particular effect on income, safety, quality of life and the health of all, caused and enhanced by road crashes: material damage to the vehicles themselves and to equipment and infrastructure, administrative and medical costs, the spillage of fuel and other toxic products with consequences for air, soil and water pollution, and, in the event of a fire outbreak, the devastation of nature and landscape and even the loss of crops and resulting losses (Becker, 2012: 10-15). These side effects of road crashes caused by car crashes constitute negative externalities, which need to be considered.

2. International trends in road crashes

2.1. General considerations

Road traffic crashes are causing an increasing number of fatalities worldwide. The most recent reports from the World Health Organization (WHO, 2018) [i], worryingly indicate that in the face of a lack of safety measures in poor countries, road crashes are already today the leading cause of death among children and young people. In the 2018 Report, the WHO explains that in recent years, the total number of deaths in road crashes worldwide has steadily increased, with 1.35 million deaths recorded, up from more than 1.2 million in the report published in 2009. "These deaths represent an unacceptable price for mobility," commented WHO Director-General Dr. Tedros Adhanom Ghebreyesus.

In addition to the fatalities, 20 to 50 million people were injured, many of whom will remain disabled for the rest of their lives as a result of their injuries. Traffic crashes are the leading cause of death for young people in the age group 5 to 29, the third leading cause of death up to the age of 40, and the eighth leading cause of death for all ages. Estimates from international studies indicate that road crashes represent, in most countries, an economic and social cost corresponding to about 3% of their gross domestic product.

Almost half of those killed on the roads are "vulnerable users" (pedestrians, cyclists and motorcyclists). About 93% of road deaths occur in countries with low or middle-income levels, but which have about 54% of the world's vehicle fleet on the road. International organizations highlight the importance of improving infrastructure safety in reducing fatalities, for example the creation of dedicated lanes for cyclists and motorcyclists, as well as improving vehicle safety standards (e.g. the widespread inclusion of electronic stability control devices and advanced braking systems).

While safety indicators and road crashes in more developed countries have improved significantly in recent decades, the situation is quite different in underdeveloped countries, where the number of serious road crash victims continues to worsen, mainly due to the lack of investment in prevention and infrastructure improvement. The risk of death from traffic crashes is still three times higher in underdeveloped countries when compared to developed countries, with the rates of death in underdeveloped countries being as high as in developed countries. Mortality rates are highest in Africa (26.6 deaths per 100,000 inhabitants), while the lowest rates are found in Europe (9.3 deaths per 100,000 inhabitants).

For this reason, the United Nations 2030 Agenda for Sustainable Development includes in its goals an ambitious road safety target, aiming to halve the total number of road fatalities by 2030.

2.2. Evolution of road crashes in Europe

According to the European Accident Database CARE[ii], between 2000 and 2018 the number of road crash fatalities in the European Union (EU28) decreased by 61%, the number of seriously injured decreased by about 42% and the number of slightly injured decreased by about 31%. The 2019 data shows that approximately one million road crashes were recorded in the EU27, resulting in 22.7 thousand fatalities, about 180 thousand seriously injured and more than 900 thousand slightly injured (tables 2.1 and 2.2).

Table 2.1. Evolution in no. of fatalities in the European Union (2010-2019)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
EU-27	29 600	28 700	26 500	24 200	24 100	24 400	23 800	23 400	23 300	22 700
Belgium	850	884	827	764	745	762	670	609	604	646
Bulgaria	776	656	601	601	660	708	708	682	610	628
Czech Republic	802	772	742	655	688	734	611	577	656	618
Denmark	255	220	167	191	182	178	211	175	171	199
Germany	3 648	4 009	3 600	3 339	3 377	3 459	3 206	3 180	3 275	3 046
Estonia	79	101	87	81	78	67	71	48	67	52
Ireland	212	186	163	188	192	162	182	155	139	140
Greece	1 258	1 141	988	879	795	793	824	731	700	696
Spain	2 479	2 060	1 902	1 680	1 688	1 689	1 810	1 830	1 806	1 755
France	3 992	3 963	3 653	3 268	3 384	3 461	3 471	3 444	3 246	3 244
Croatia	426	418	390	368	308	348	307	331	317	297
Italy	4 114	3 860	3 753	3 401	3 381	3 428	3 283	3 378	3 334	3 173
Cyprus	60	71	51	44	45	57	46	53	49	52
Latvia	218	179	177	179	212	188	158	136	148	132
Lithuania	299	296	302	256	267	242	192	191	173	184
Luxembourg	32	33	34	45	35	36	32	25	36	22
Hungary	740	638	606	591	626	644	607	625	633	602
Malta	13	16	9	17	10	11	23	19	18	16
Netherlands	537	546	562	476	477	531	533	535	598	586
Austria	552	523	531	455	430	479	432	414	409	416
Poland	3 908	4 189	3 571	3 357	3 202	2 938	3 026	2 831	2 862	2 909
Portugal	937	891	718	637	638	593	563	602	700	647
Romania	2 377	2 018	2 042	1 861	1 818	1 893	1 915	1 951	1 867	1 864
Slovenia	138	141	130	125	108	120	130	104	91	102
Slovakia	371	325	352	251	295	310	275	276	260	270
Finland	272	292	255	258	229	270	258	238	239	211
Sweden	266	319	285	260	270	259	270	253	324	221
Unit. Kingdom	1 905	1 960	1 802	1 770	1 854	1 804	1 860	1 856	1 839	1 808
Switzerland	328	320	339	269	243	253	216	230	233	187
Norway	208	168	148	187	147	123	135	106	108	108
Iceland	8	12	9	15	4	16	18	16	18	6
Liechtenstein	0	2	1	2	3	2	0	2	0	0

Source: CARE (Community Road Accident) database. Numbers reported by police entities. **Notes**: (1) Ireland – provisory numbers for 2018 and 2019; (2) Netherlands – number of reported victims is underestimated and is only about 85% of total victims reported annually); (3) Portugal – numbers of 2018 include data on Azores and Madeira, which correspond to about 4% of the total.

Table 2.2. Evolution in no. of fatalities per 1 million inhabitants of the EU 2010-2019

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
EU-27	67	66	60	55	55	55	54	53	53	51
Belgium	78	80	75	69	67	68	59	54	53	56
Bulgaria	105	89	82	83	91	98	99	96	87	90
Czech Republic	77	74	71	62	65	70	58	55	62	58
Denmark	46	40	30	34	32	31	37	30	30	34
Germany	45	50	45	41	42	43	39	39	40	37
Estonia	59	76	66	61	59	51	54	36	51	39
Ireland	47	41	36	41	41	35	39	32	29	29
Greece	113	103	89	80	73	73	76	68	65	65
Spain	53	44	41	36	36	36	39	39	39	37
France	64	63	58	51	53	54	54	53	50	50
Croatia	99	97	91	86	73	82	73	80	77	73
Italy	70	65	63	57	56	56	54	56	55	53
Cyprus	73	85	59	51	52	67	54	62	57	59
Latvia	103	86	87	88	106	95	80	70	77	69
Lithuania	95	97	101	86	91	83	66	67	62	66
Luxembourg	64	64	65	84	64	64	56	42	60	36
Hungary	74	64	61	60	63	65	62	64	65	62
Malta	31	39	22	40	23	25	51	41	38	32
Netherlands	32	33	34	28	28	31	31	31	35	34
Austria	66	62	63	54	51	56	50	47	46	47
Poland	103	110	94	88	84	77	80	75	75	77
Portugal	80	84	68	61	61	57	54	58	68	63
Romania	117	100	102	93	91	95	97	99	96	96
Slovenia	67	69	63	61	52	58	63	50	44	49
Slovakia	69	60	65	46	54	57	51	51	48	50
Finland	51	54	47	48	42	49	47	43	43	38
Sweden	28	34	30	27	28	27	27	25	32	22
Unit. Kingdom	30	31	28	28	29	28	28	28	28	27
Switzerland	42	41	43	33	30	31	26	27	27	22
Norway	43	34	30	37	29	24	26	20	20	20
Iceland	25	38	28	47	12	49	54	47	52	17
Liechtenstein	0	55	27	54	81	54	0	53	0	0

Source: CARE (Community Road Accident) database. Numbers reported by police entities. **Notes**: (1) Ireland – provisory numbers for 2018 and 2019; (2) Netherlands – number of reported victims is underestimated and is only about 85% of total victims reported annually); (3) Portugal – numbers of 2018 include data on Azores and Madeira, which correspond to about 4% of the total.

As shown in Table 2.1, the countries in which there were the most fatalities in 2019 are France (3,244), Italy (3,173), Germany (3,046), Poland (2,909), Romania (1,864), the United Kingdom (1,808) and Spain (1,755). Six countries (Portugal, Greece, Czech Republic, Hungary, Bulgaria and Belgium) recorded between 600 and 700 road fatalities. For all other EU countries, the number of fatalities is below 600.

Absolute numbers of fatalities do not allow a comparison of fatality indicators between countries with very different resident populations, and one must therefore use metrics that consider the number of inhabitants of a country or the distance traveled.

Table 2.2 summarizes the evolution of the number of fatalities per million inhabitants in Europe for the period between 2010 and 2019. The number of fatalities in the EU27 reduced between 2010 and 2019 by 24.2% to a value of 51 deaths per million inhabitants. The largest reductions were recorded in Luxembourg (-43.8%), Greece (-42.6%), Ireland (-38.7%) and Estonia (-33.8%). Conversely, in countries like Malta (+3.2%) and the Netherlands (+4.7%) the mortality per million inhabitants increased in the last decade. The reduction registered in Portugal in this same period was 21.2%. Outside the EU27 area, significant progress was recorded in Switzerland, Norway and Iceland, with reductions of -48.0%, -52.7% and -33.3% in the number of victims per million inhabitants.

2.3. Global trends in road crashes

International or intra-regional comparisons must be made considering structural differences (e.g., size of the country, density and quality of the road network, the population in particular) and socioeconomic differences (e.g., the composition of the vehicle fleet, presence of international and tourist traffic, user behavior). For this purpose, the number of deaths or injuries is not sufficient, so other indicative metrics have been developed. The number of fatalities can thus be reduced to the population figure (per 100,000 inhabitants or per million), the number of passengers and/or the number of kilometers traveled (when it is possible to estimate this figure), or the number of vehicles registered or driving licenses. Traditionally, in Europe the fatality rate refers more to population, and in the United States to kilometers traveled.

Different international institutions regularly publish indicators on road fatalities, among which we highlight the World Health Organization, the World Bank, the European Commission, the OECD in partnership with the International Traffic Safety Data and Analysis Group (IRTAD). The WHO World Road Safety Report 2018 for 2016 concludes that the number of road traffic deaths continues to rise, reaching 1.35 million in 2016, while death rates relative to the size of the world's population have stabilized in recent years. The progress made by several countries in stabilizing the overall risk of death in road crashes has not, however, been fast enough to compensate for the population growth and rapid expansion of transportation experienced in many parts of the world.

According to the WHO, the target of halving fatalities by 2020 will not be met. However, the institution states, in relation to the main risk factors, that there has been progress in strengthening key road safety laws, improving the safety of infrastructure, and adopting best practices in the response to victims of road crashes. The institution also states that part of the differences in mortality rates observed between regions and countries corresponds to differences in the types of road users most affected by road crashes, with the most vulnerable road users - pedestrians, cyclists and motorcyclists - accounting for more than half of the deaths recorded worldwide. According to the WHO, road crashes are responsible for the loss of more lives than HIV, tuberculosis or diarrheal diseases.

The Annual Road Safety Report published by the OECD and IRTAD notes in its 2019 edition that the years 2017 and 2018 were encouraging in terms of road safety in most countries. The average annual reduction was much greater between 2010 and 2013 than in the period 2013-2017, despite encouraging results in 2017 and 2018. In 2018 the number of deaths decreased in most countries, according to preliminary data. Among the 26 countries for which provisional or final data are available this year, the number of road deaths decreased or stabilized in 16 countries and increased in 10 countries. In particular, the number of road deaths increased by 28% in Sweden, 14% in the Czech Republic, and 11% in the Netherlands. On average, the number of deaths decreased by 1.7% in IRTAD member countries in 2018 compared to 2017.

Road safety was also found to have improved in most countries in 2017. The number of deaths fell in 27 of the 33 countries with validated data. Overall, the number of road deaths decreased by 2.6%, from 81,669 road deaths in 2016 to 79,554 road deaths in 2017 in 33 countries. Information from countries with unconfirmed data suggests a similar downward trend. Since systematic record-keeping began, 15 countries recorded the lowest number of road crash-related deaths in 2017. These countries are Austria, Belgium, Canada, Czech Republic, Germany, Greece, Ireland, Japan, South Korea, Lithuania, Luxembourg, Norway, Poland, Slovenia and Sweden. The countries that saw the largest reduction in 2017 were Luxembourg, Norway and Slovenia with a reduction of over 20%. However, the number of deaths increased in six countries (Spain, Hungary, Italy, Portugal, Switzerland and New Zealand). This is the fourth consecutive year that New Zealand and Spain have recorded increases. Road fatality rates decreased by 5.7% between 2010 and 2017.[9]

Progress in reducing fatalities has been slow since 2013. From 2010-2013, the overall average annual reduction in the number of road fatalities in IRTAD countries was 2.6%. The 2013-2017 period, on the other hand, saw an annual increase of 0.5%. New Zealand, for example, saw an average annual reduction of 12.3% in the number of road crash fatalities during the 2010-2013 period, but saw an average increase of 10.6% during the 2013-2017 period. The

[9] It is important to acknowledge the impact of the United States, as the most populous member of IRTAD, on the evolution of data at the global level. If the United States is included, the average reduction in traffic fatalities is 17.4%.

large disparities in road safety development between countries partly explain the average figures.

When compared to 2010 data, a decrease in the number of traffic deaths was recorded in 29 of the 33 IRTAD member countries in 2017. The largest reductions are achieved by Norway and Greece.[10] An additional group of three countries (Portugal, Lithuania, and Denmark) recorded a reduction in the number of deaths by more than 30%. Four countries recorded an increase in the number of road fatalities during the period 2010-2017: United States (+12.5%), Argentina (+4%) and New Zealand (+1.1%).

Based on the progress made over the period 2000-2013, the IRTAD report highlights three groups of countries. Six countries recorded an average annual reduction in the number of deaths of 6.5% or more: France, Lithuania, Slovenia, Denmark, Portugal and Spain. Seven countries registered an average annual reduction in the number of deaths to 4%: Chile, the United States, Israel, Canada, Australia, Finland, and Serbia. All other countries registered an average annual reduction in the number of deaths between 4% and 6.5%. A comparison between the second periods 2000-2013 and 2013-2017 shows that only five countries performed better after 2013: Lithuania, Belgium and Chile improved slightly, Norway and Luxembourg made significant progress. Ten countries experienced an increase in the number of road crash deaths in 2013-2017. Some of them recorded sharp reductions in the previous period.

The long-term trend is positive, but insufficient to meet international road safety targets. The target of a 50% reduction in fatalities by 2020, set by the international community as part of the United Nations Decade of Action for Road Safety and the United Nations Sustainable Development Goals (SDGs) remains out of reach according to current trends. To achieve a 50% reduction between 2010 and 2020, a reduction of at least 38% by 2017 (i.e., an average annual reduction of 6.7%) would have been required. Only two countries, Norway and Greece, have achieved this.

A few factors help contextualize recent trends in road safety performance internationally:

a) Excessive speeding and drunk driving are the leading cause of fatal road crashes.[11]

b) Economic factors impact road safety.[12]

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[10] Norway reduced the number of road deaths from 208 to 107 during the period 2010-2017. Greece reduced the number of traffic deaths from 1,258 to 731, a drop of 42%. Norway's success is particularly notable, as the country's roads are already among the safest in the world.

[11] There is no standardized methodology for assessing the role of alcohol or speeding in the likelihood of road traffic crashes. However, all countries report that speed contributes between 15% and 35% of fatal road accidents. Similarly, driving under the influence of alcohol contributes between 10% and 30% to fatal crashes in most countries.

[12] For example, the aftermath of the 2008 financial crisis was associated with a decrease in the number of fatalities. On the other hand, the economic recovery from 2013 onwards was accompanied by a significant increase in the number of fatalities following the resumption of motorized travel.

c) The popularity of cycling is increasing. Countries collecting data on cycling have recorded a marked increase in the number of kilometers ridden over the past 20 years. A sharp increase in the use of electric bicycles has also been noted. This development is associated with a significantly higher number of fatal road crashes involving bicycles in several countries.[13]

d) Enforcement of police laws has been toned down. Several countries report less intense enforcement intensity. In some cases, this is a change in the priorities of the police force.[14]

e) There is an encouraging reduction in the number of young people killed on the roads. All countries with validated data observed a reduction in fatalities among young people between the ages of 18 and 24.[15]

Analyzing the indicators by type of user, the IRTAD report concludes that vehicle occupants (driver and passengers) continue to benefit from improvements in road safety. With the exception of the United States and Iceland, the number of vehicle occupants killed in road crashes has decreased in all countries since 2010.[16] The number of pedestrians killed increased by 2.7% between 2010 and 2017. However, this increase is largely attributable to the increase in the number of pedestrians killed in the United States (+38.9%), where walking trips increased between 1990 and 2017, according to the National Household Travel Survey.[17]

The number of motorcyclists killed in traffic increased in 2017 compared to 2016. Of the 30 countries for which data is available, 17 experienced an increase in fatalities among passengers of two-wheeled motor vehicles. The safety of cyclists shows a worrying trend in several countries. The number of cyclists killed increased in 13 countries between 2010 and 2017, out of the 30 countries with available information. The most significant increases were observed in Ireland (from 5 cyclists killed in 2010 to 14 in 2017), Norway (from 5 to 9) New Zealand (from 10 to 18), the Netherlands (from 162 to 206) and the United States (623 to 783). The total number of cyclists killed, however, fell by 5.9% over the same period.

In the analysis by age groups, young adults and adolescents have benefited the most from the advances in road safety since 2010 (Figure 2.1). Eight countries have succeeded in reducing

[13] Data is also provided on the impact of new forms of mobility, e.g. electric scooters, on road safety.

[14] Less restrictive enforcement of traffic laws will likely encourage less prudent behavior by road users, including speeding and drink driving, causing more traffic accidents and fatalities.

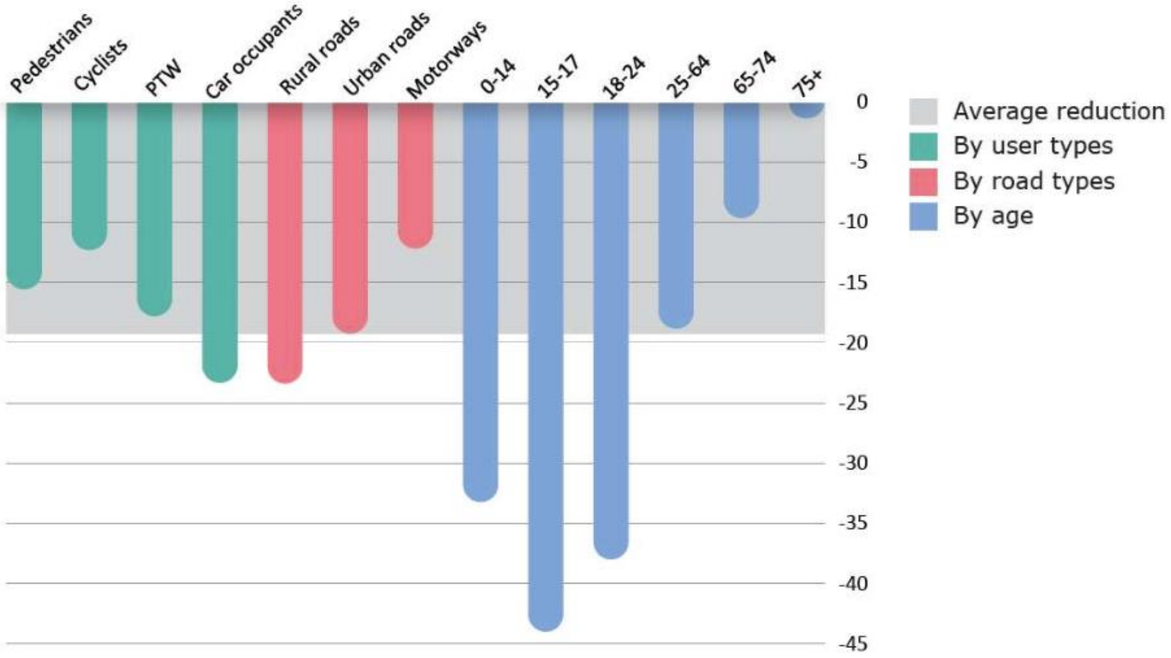
[15] This can be explained by several factors: the success of road safety education and training policies, the trend observed in some countries to delay obtaining driving licenses, and the increasing use of public transport and safer modes of travel.

[16] On average, the number of car occupants killed in traffic accidents decreased by 10.8% between 2010 and 2017, compared to a 5.7% drop in the total number of traffic fatalities. The most significant reductions occurred in Luxembourg (-52%) and Norway (-49%). Safer roads as well as the increase in the fleet of safer vehicles equipped with collision avoidance technologies (such as electronic stability control) or impact mitigation devices (such as airbags) contributed to this improvement.

[17] In 24 of the 30 countries for which data are available, fewer pedestrian fatalities were recorded. The most marked improvements occurred in Slovenia (-62%) and Denmark (-55%). The number of pedestrian fatalities increased in Germany (+1.5%), New Zealand (+11%), the United Kingdom (+17%) and Sweden (+19%).

the number of young people killed in traffic by more than half.[18] Despite this progress, road fatalities of young people remain higher than those of the general population.

Figure 2.1. Evolution of fatalities on the road by age groups, road types and user types



Source: Own preparation based on OECD-IRTAD (2019). **Notes**: PTW: Motorized two-wheeled vehicles.

The number of children killed in traffic has decreased dramatically over the past three decades. In IRTAD countries, the number of road deaths among children aged 0 to 14 has decreased by 19% on average since 2010. The elderly ones are particularly exposed to traffic. Traffic-related deaths among people aged 65 and older increased by 5% between 2010 and 2017, while the total number of road deaths decreased by 5.7%. This is partly due to the increasing weight of the elderly in the population.[19] The analysis of road deaths by age group should be interpreted in light of demographic trends, in particular the aging of the population and the relative decrease in the proportion of young people. The improvement in traffic safety among the younger population is not, however, due solely to demographic changes. Although their relative share in the population is declining in most countries, their share in the total number of traffic deaths has declined at a faster rate.

In the countries analyzed by the IRTAD report, road death rates vary considerably. For example, the risk of dying in a traffic crash is six times higher in Argentina than in Norway.

[18] Norway reduced the number of road deaths among 18 to 24 year olds by 74%, Lithuania by 62% and Ireland and Luxembourg by 60%.

[19] A more active lifestyle in old age and therefore greater participation of older people in traffic can also play an important role. Fourteen of the 29 IRTAD countries for which data are available recorded an increase in the number of road deaths among their citizens aged 65 and over. The largest increases were recorded in Australia (39%), the United Kingdom (27%) and Israel (26%). In 14 countries, citizens aged 75+ have the highest traffic fatality rate of all age groups. In Japan, this age group recorded 9.4 traffic deaths per 100,000 population, compared to 3.5, for example, for the national average.

The mortality rate among the 33 countries with validated data ranged from 2 to 12 deaths per 100,000 inhabitants in 2017. Five countries recorded a fatality rate of 3 deaths per 100,000 population or less: Norway (2), Sweden (2.5), Switzerland (2.7), the United Kingdom (2.8), and Denmark (3). The average road death rate worldwide is 18.3 traffic deaths per 100,000 population, according to the WHO Report published in 2018. Globally, there are large disparities between regions. The death rate in Africa is 26.6 deaths per 100,000 population, and 20.7 per 100,000 population in Southeast Asia. The risk of road fatalities measured as a function of distance traveled has decreased in all IRTAD countries since 2010, except in the United States.

Road fatalities do not show all the human, economic and social consequences of road fatalities. According to the WHO, the 1.35 million annual road deaths should be seen in the context of the approximately 20 to 50 million seriously injured recorded annually as a result of road crashes worldwide.

Injury information is usually compiled from police road crash records. They tend to under-report injuries and so do official road crash statistics. In most cases, this makes the information from police reports insufficient to analyze the nature and consequences of serious injury road crashes. Hospital records are more accurate and should be used to supplement police data. This is standard practice in only a few countries, for example, Israel, the Netherlands, Spain, and Sweden.[20] The number of seriously injured people resulting from road crashes is declining at a much slower rate than the number of deaths. Many survivors of serious road crashes do not fully recover and often face a marked reduction in their quality of life. Road crashes also reduce productivity and ultimately the economic performance of a country. The socio-economic costs of road crashes to the European Union are estimated at well over €500 billion or 3% of EU GDP. Most of these costs are related to fatal and seriously injured.

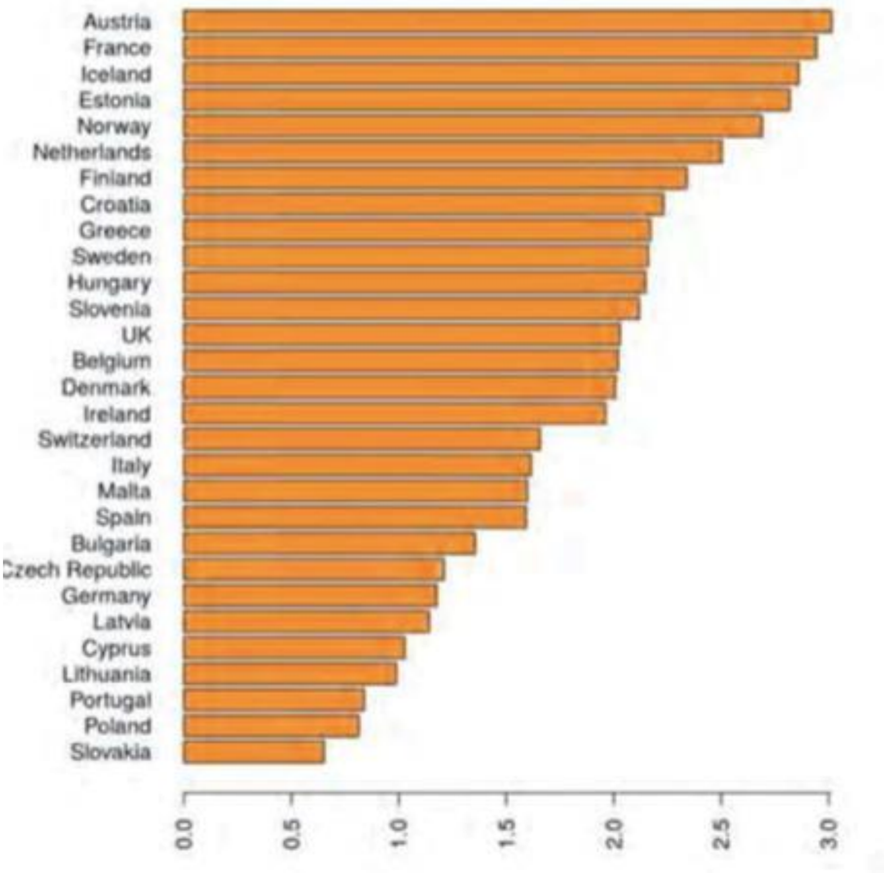
2.4. International comparative analysis of official cost estimates of road crashes

Figures 2.2 and 2.3 present the estimates of the economic and social cost of a fatality resulting from a road crash obtained in Wijnen et al. (2017) for a set of European countries. The results show that the official cost estimates per fatality vary from €0.7 million in Slovakia to €3.0 million in Austria (figure 2.2). It is generally found that the cost of a fatality is higher in northwestern European Union countries than in southern and eastern Europe (Figure 2.3). The significant differences between countries are explained by the adoption of different definitions of fatality, by differences in the components of total cost included, and by methodological differences. Regarding the definition of a road fatality, most countries apply

[20] Hospital data generally lack information on the circumstances of the crash, the environment and the category of road user. As the definition of what constitutes a serious injury, as well as the methodologies for considering it, vary widely between countries, international comparisons of serious injury crashes are less reliable. The creation of a common definition of serious injury is therefore crucial.

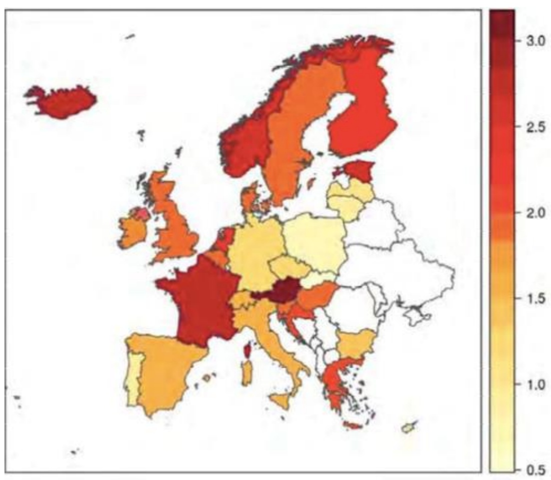
the same definition based on the criterion of fatalities at 30 days after the road crash, the exception is Slovakia that uses the 24-hour criterion.

Figure 2.2. Social and economic cost estimates of a fatality in a road crash



Source: Wijnen et al. (2017). Note: numbers at 2015 prices in millions of EUR adjusted in PPP.

Figure 2.3. Pattern of geographical distribution of social and economic cost estimates of a fatality in a road crash



Source: Wijnen et al. (2017). Note: numbers at 2015 prices in millions of EUR adjusted in PPP.

Regarding the total cost components, most countries have included medical costs, production losses, and human costs in the total cost calculation for both fatalities and injuries. The authors conclude, however, that road crash-related costs (property damage, administrative costs, and other costs) are not always included. Regarding the differences in calculation methods, the method used for estimating human costs largely explains the differences in total cost, and the conclusion is that countries that adopt an approach based on determining the statistical value of human life when calculating human costs (the approach recommended in the international guidelines) tend to have higher estimates for the cost of a road fatality.

The most recent European-level estimates of the economic and social costs of serious road traffic injuries, based on collecting nationally obtained values from 32 countries and calibrating them to allow for a comparative analysis of the results, again found significant differences in the values found between countries (Schoeters et al., 2020). Table 2.3 demonstrates the cost per serious injury and total serious injury costs as a percentage of GDP. It can be seen that the cost per serious injury ranges from €28,205 in Latvia to €975,074 in Poland, while the percentage of total serious injury costs to GDP is lowest in Ireland (0.04%) and highest in Poland (2.65%). In Portugal, in the same period, the cost per serious road crash is estimated to be only €136,365 and the total cost of seriously injured as a percentage of GDP evaluated at 0.20%.

Still with regard to the cost per serious injury, looking at the geographical location of the countries in the European Continent with the highest values, we can say that the highest records are observed in two Northern European countries (Norway and Finland) and three Eastern European countries (Poland, Estonia and Hungary).

Given the significant disparity between the data obtained in each country, the authors point out several factors as possible explanations for the differences observed in the estimates of the different countries, namely regarding the unit and total costs of seriously injured, a fact that should be taken into account when comparing the costs presented, namely differences regarding the understanding of serious injury, the cost components considered, different methodologies used in the determination of the value and differences in the value of GDP *per capita*.

Table 2.3. Average cost per serious injury and total cost in relation to the severely injured in GDP %

Country	Cost per serious injury (EUR)	Total Costs with serious injuries in GDP%
Austria	381 285	1,18
Belgium	307 364	0,45
Bulgaria	220 390	1,33
Croatia	290 042	2,11
Cyprus	135 535	0,29
Czech Republic	295 199	0,48
Denmark	344 536	0,23
Estonia	959 011	2,21
Finland	671 383	0,17
France	368 029	0,45
Germany	119 480	0,27
Greece	252 277	0,12
Hungary	501 194	2,59
Iceland	364 914	0,43
Ireland	225 511	0,04
Italy	211 860	0,55
Latvia	28 205	0,51
Lithuania	89 804	0,94
Luxembourg	NA	NA
Malta	203 913	0,70
Netherlands	269 149	0,74
France	368 029	0,45
Norway	845 812	0,19
Poland	975 074	2,65
Portugal	136 365	0,20
Romania	NA	NA
Serbia	NA	NA
Slovakia	141 504	0,20
Slovenia	247 550	0,75
Spain	254 777	0,46
Sweden	399 728	0,21
Switzerland	214 023	0,49
United Kingdom	227 979	0,20
Norway	845 812	0,19
Poland	975 074	2,65
Portugal	136 365	0,20
Romania	NA	NA

Source: Schoeters et al. (2020). Note: EUR 2015, numbers adjusted *on par* with purchasing power (PPP).

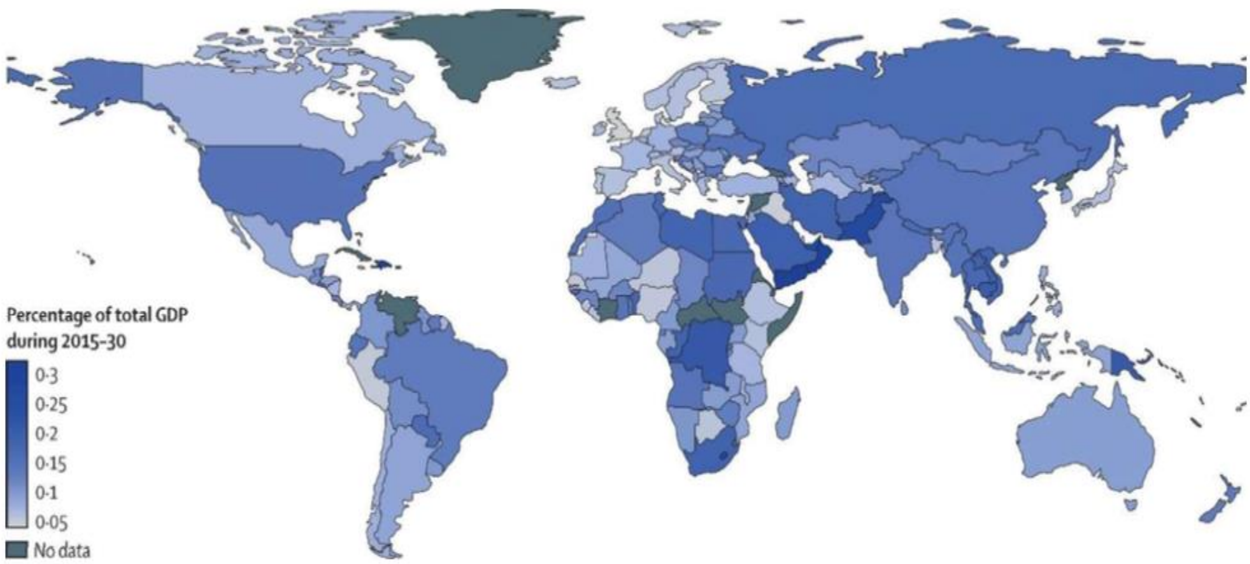
In a recent paper developed by Chen et al. (2019), estimates and projections on the global macroeconomic burden of traffic crashes and their distribution by countries and regions for the period 2015-2030 are derived using data from the World Bank. The authors calculated human capital according to the Mincer (1974) equation and that the experience-related human capital component from the corresponding estimates of Heckman et al. (2006). The physical capital data were taken from the Penn World Table Projections, with the value for the output elasticity of physical capital (the percentage change in output for a 1% change in the physical capital stock) following standard economic estimates. In the particular case of the U.S.A., the total cost of treating motor vehicle crashes is obtained from the Cost of Injury Reports from the Centers for Disease Control and Prevention.

The authors estimate that the overall macroeconomic loss from road crashes amounts to US $1 797 billion over the period 2015-2030 (Table 2.4). At constant 2010 values, the figure is US $1 460 billion using a 2% discount rate or US $1 317 billion using a 3% discount rate. The results imply that the cost of road crashes is equivalent to an annual tax of 0.12% on global output, with an average *per capita* burden of US $231.

Table 2.4 presents more detailed information on the economic cost attributable to traffic crashes in the period 2015-2030 in millions of US Dollars (USD), as a percentage of GDP in the period 2015-2030 and *per capita*, for a selected set of mostly European countries. Figure 2.4 complements the information for the 166 countries considered in the study. The highest values of *per capita* cost are obtained for Luxembourg, the United States and Norway.

By World Bank region, the macroeconomic aggregate of global road crash losses is highest in East Asia and the Pacific with total economic losses of US $560 billion. North America has the second highest total economic loss of US $515 billion, with the highest *per capita* loss of US $1 444. This loss corresponds to an annual rate of 0.15% over the region. The economic cost of traffic crashes increases as the income level increases: higher-income countries have the highest cost with an overall loss of US $963 billion and a *per capita* loss of US $779.

Figure 2.4. Macro-economic impact of road crashes victims



Source: Chen et al. (2019).

Table 2.4. Economic cost attributed to road crashes between 2015-2030

Country	Economical Cost (in Millions USD 2010)	Cost in GDP% (2015-2030)	Cost per capita (2010 USD)
Austria	5359 (4648–6188)	0·069% (0·060–0·080)	608 (527–702)
Belgium	7219 (6141–8486)	0·079% (0·067–0·093)	618 (526–726)
Denmark	4180 (3540–4941)	0·066% (0·056–0·078)	715 (606–846)
Estonia	444 (352–565)	0·091% (0·072–0·116)	349 (276–443)
Finland	2818 (2358–3372)	0·061% (0·051–0·073)	503 (421–602)
France	37 847 (32 157–44 671)	0·075% (0·064–0·089)	554 (471–654)
Germany	54 069 (45 530–64 565)	0·079% (0·067–0·095)	657 (553–784)
Greece	3164 (2697–3705)	0·072% (0·062–0·085)	288 (245–337)
Hungary	2869 (2459–3413)	0·098% (0·084–0·117)	302 (259–359)
Ireland	5356 (4711–6175)	0·074% (0·065–0·085)	1081 (951–1246)
Italy	23 554 (20 353–27 259)	0·066% (0·057–0·076)	400 (346–463)
Latvia	602 (469–771)	0·102% (0·080–0·131)	327 (254–418)
Lithuania	978 (840–1145)	0·109% (0·094–0·128)	349 (299–408)
Luxembourg	892 (726–1090)	0·072% (0·058–0·088)	1465 (1192–1791)
Netherlands	9791 (8503–11290)	0·058% (0·051–0·067)	567 (492–654)
Norway	5854 (5596–6140)	0·068% (0·065–0·071)	1052 (1005–1103)
Ireland	5356 (4711–6175)	0·074% (0·065–0·085)	1081 (951–1246)
Italy	23 554 (20 353–27 259)	0·066% (0·057–0·076)	400 (346–463)
Poland	15 674 (13 556–18 231)	0·134% (0·116–0·156)	417 (361–485)
Portugal	2505 (2071–3030)	0·059% (0·049–0·072)	247 (205–299)
Romania	4539 (3907–5252)	0·106% (0·091–0·122)	237 (204–274)
Russia	50 547 (48 746–54 386)	0·172% (0·166–0·185)	354 (341–381)
Slovakia	2557 (2112–3123)	0·119% (0·099–0·146)	472 (390–576)
Slovenia	1207 (1017–1453)	0·117% (0·099–0·141)	585 (493–704)
Spain	18 200 (15 919–20 832)	0·067% (0·058–0·076)	393 (344–450)
Sweden	6988 (6222–7931)	0·068% (0·060–0·077)	682 (607–774)
Switzerland	8530 (7438–9914)	0·074% (0·064–0·086)	971 (847–1129)
UK	24 048 (23 002–25 103)	0·049% (0·047–0·051)	353 (338–368)
Canada	27 573 (22 790–33 318)	0·082% (0·067–0·099)	719 (594–869)
USA	48 7147 (45 3399–51 3884)	0·157% (0·146–0·165)	1444 (1344–1523)

Source: Chen et al. (2019). **Note**: the numbers in brackets correspond to inferior and superior limits of a confidence interval in projection.

3. Frequency and severity of the risk of road crashes in Portugal

In this chapter, we briefly characterize the road crash risk in Portugal, considering as reference point the statistical information available for the year 2019. The analysis of road crash risk considers risk exposure metrics, which assess the extent to which road users may be involved in a traffic crash, risk frequency indicators, which assess the probability of occurrence of a traffic crash, and risk severity metrics, i.e., which quantify the expected human, economic and social cost arising from traffic crashes. For this purpose, we consider variables such as the distance traveled (whenever available), the number of vehicles in circulation and their age, the day of the week, the time of day, lighting conditions, the location of the road crash in the territory, the type of traffic lanes where the road crash took place, the age and gender of the users (driver, passenger, pedestrian) involved, the speed at which the vehicles were traveling (or the maximum speed allowed on the road), the type of road surface or road layout, the nature of the road crash, among other factors.

Once the risk exposure, the frequency of the risk and the severity of the risk are known, it is possible to take a quantitative approach in calculating the expected losses over a given period (e.g., one year), usually expressed in terms of fatalities, serious or slightly injured, or property damage. In formal terms, the road safety problem can be expressed as follows:

$$V = ETR \times \frac{A}{ETR} \times \frac{V}{A},$$

where V denotes the number of road crash victims, ETR denotes exposure to road crash risk, A denotes the number of road crashes with victims, the ratio $\frac{A}{ETR}$ denotes the probability of a road crash occurring and $\frac{V}{A'}$ denotes the probability of suffering harm (human material) in a road crash (e.g., the average number of victims per road crash). The risk exposure of the different types of road users is usually expressed as a quantity related to the number of trips in the different modes of transport (by car, motorcycle, bicycle, pedestrian, etc.) and/or the distance and journeys traveled, whereby the speed at which these trips and distances are traveled affects the risk.

Based on this definition, it is clear that measures to improve road safety can come from any of the three axes of action, i.e., we can consider measures to reduce exposure to risk, measures that reduce the probability of a road crash occurring (e.g., speed limitation), and measures that reduce the risk of injuries caused (e.g., restraint devices). In the field of road safety, this quantitative approach is generally preferred over more qualitative approaches.

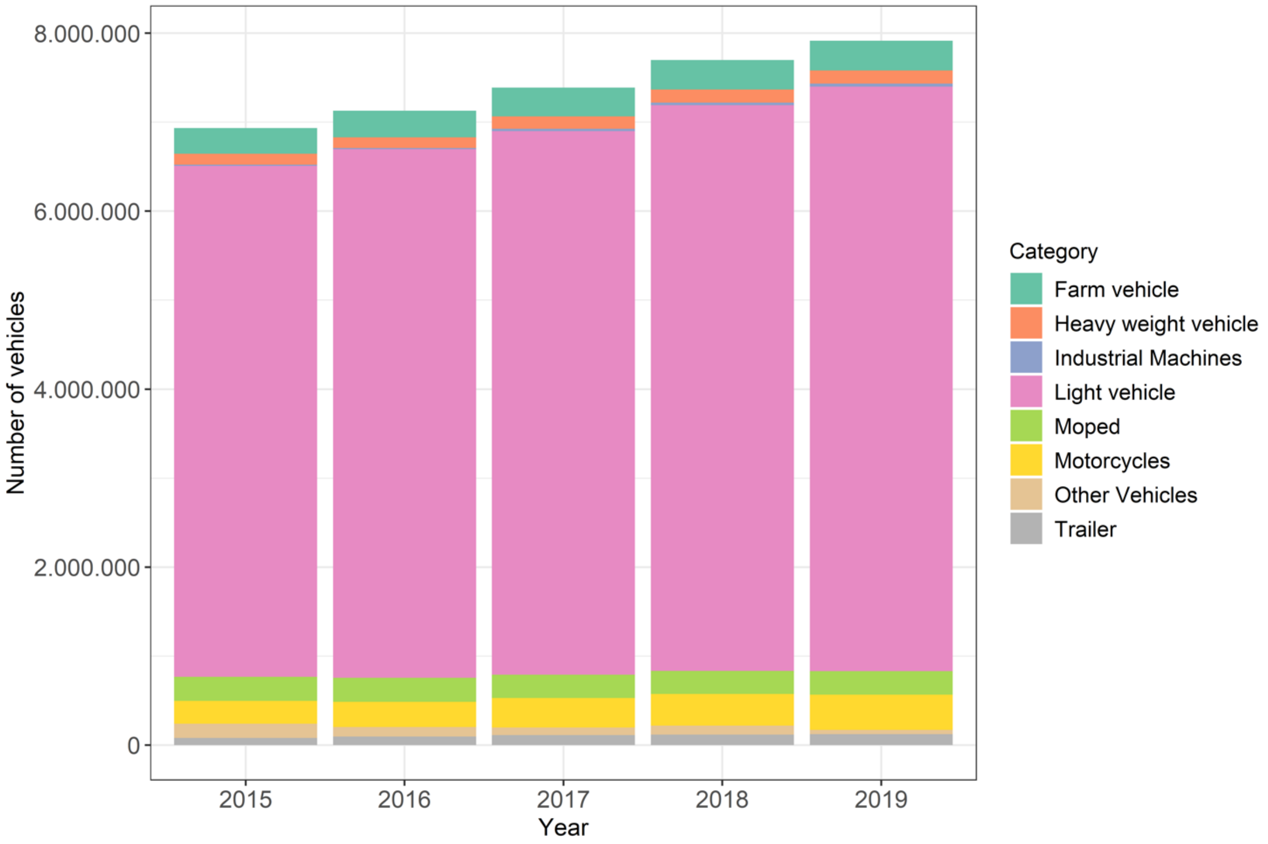
The road crash risk analysis carried out in this study focuses mainly on road crashes with victims in Mainland Portugal, i.e., road crashes known to the enforcement authorities (GNR and PSP) and resulting in victims (fatal, seriously injured or slightly injured).

In this work we used, among others, the statistical information made available by ANSR - Autoridade Nacional de Segurança Rodoviária (National Road Safety Authority) concerning the general characterization of fatalities in the Statistical Bulletins on Road Crashes (BEAV) and in the Annual Road Crash Reports, by the Autoridade de Supervisão de Seguros e Fundos de Pensões (ASF), Instituto da Mobilidade e dos Transportes (IMT), the Instituto Nacional de Estatística (INE) with regard to the number of vehicles, the APS - Associação Portuguesa de Seguradoras (Portuguese Association of Insurers) with regard to the number of claims and associated average costs per claim, the European Commission with regard to information on the evolution of road fatalities in the Member States, and the Associação Automóvel de Portugal (ACAP). Different databases were also consulted, including the Community database on Crashes on the Roads in Europe (CARE). Official reports on this matter were also analyzed, for example, the National Internal Safety Report (RASI), the Integrated Road Safety Plan (PISER), the National Plan for Road Prevention (PNPR), the National Road Safety Strategy (ENSR).

3.1. Exposure to risk of road crash

In international comparisons and trend studies at the national level, the number of inhabitants or the number of vehicles in circulation are often considered as available proxies to gauge risk exposure in aggregate terms. If we define risk as the number of fatalities (or victims) per number of vehicles, the number of vehicles in circulation (a much easier variable to obtain than the distance traveled) can be considered a proxy for risk exposure. Figure 3.1 represents the evolution of the insured vehicle fleet in Portugal between 2015 and 2019. In this period, the number of insured vehicles increased significantly (14.2%) from 6 932,920 million in 2015 to 7 914,475 million in 2019. The insured vehicle pool has been increasing consistently since 2008. Light vehicles continue to represent the vast majority of the insured parking lot (83% of the total in 2019), noting the growth in the number of motorcycles (5.02% of the total in 2019, an increase of 55.1% compared to 2015), heavy vehicles (+20.4% in 2019 compared to 2015). The only reduction recorded in this period was in the number of insured motorcycles (-2.83%). According to data published by ACAP for 2018, the motorization rate in Portugal stood at 470 light vehicles per 1,000 inhabitants, a figure that places the country below the European average by about 7%.

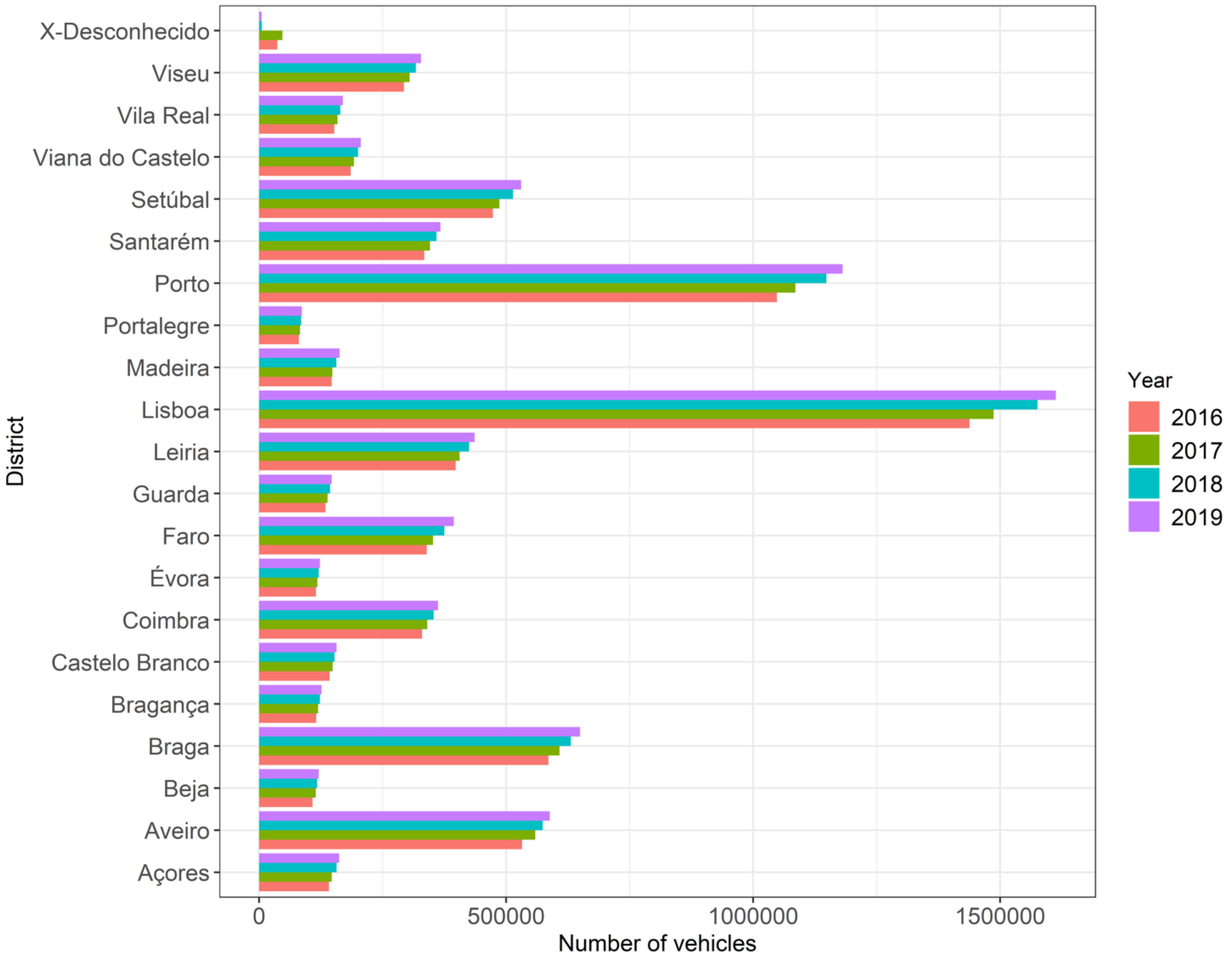
Figure 3.1. Evolution of insured car park in Portugal



Source: Own elaboration based in statistical data from Autoridade de Supervisão de Seguros e Fundos de Pensões (ASF).

The number of vehicles on the road is on the rise in all the mainland's districts, which may indicate an improvement in the living conditions of their owners and/or users and, or the inability of public transport to meet the citizens' growing mobility needs (Figure 3.2). According to the available information, the districts of Lisbon and Porto are where the greatest growth in the number of safe vehicles is recorded. In the year 2019, the district of Lisbon reached a number of insured vehicles exceeding 1.61 million, observing in the district of Porto in 2019 close to 1.18 million insured vehicles. Braga, Aveiro and Setúbal are districts that have more than 500 thousand insured vehicles in 2019.

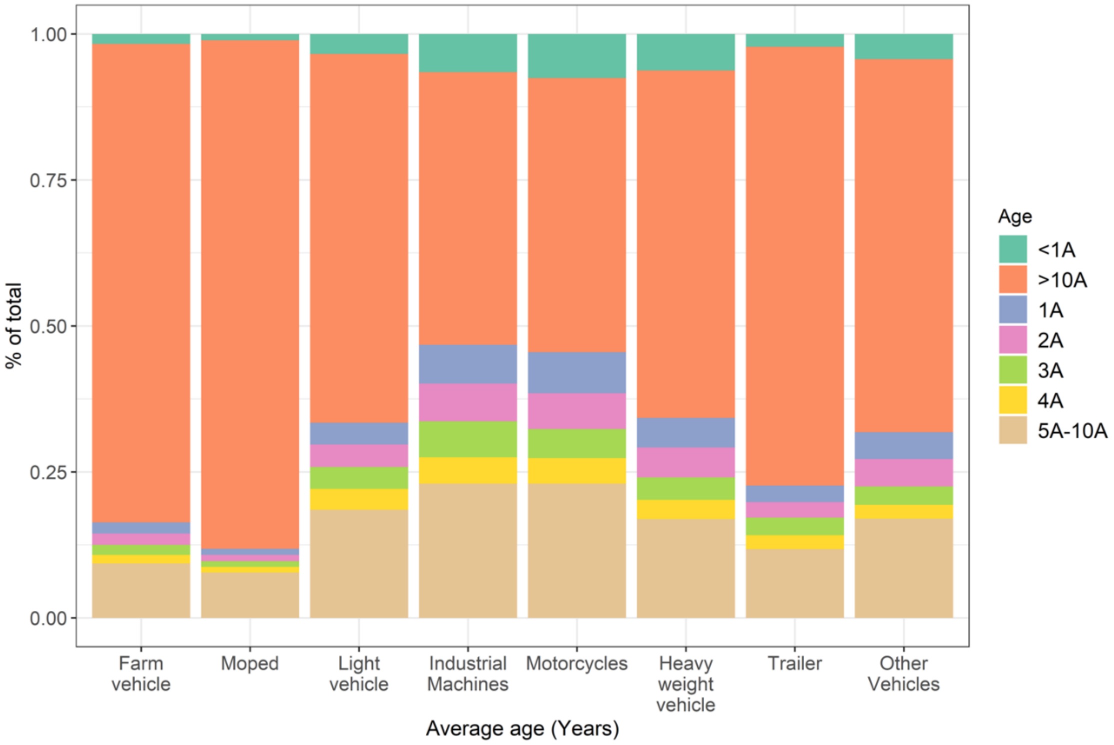
Figure 3.2. Insured car park per district



Source: Own preparation based on statistical data from the Insurance and Pension Funds Supervisory Authority (ASF).

Figure 3.3 shows the average age of insured vehicles in 2019. In all categories, there is a preponderance of vehicles older than 10 years, especially mopeds, agricultural vehicles and trailers. On the other hand, the vehicles with the lowest age (<1 year) are motorcycles, industrial machinery, and heavy machinery. It is also worth noting that light vehicles with an average age between 5 and 10 years are the second group with the greatest weight in the set of these vehicles.

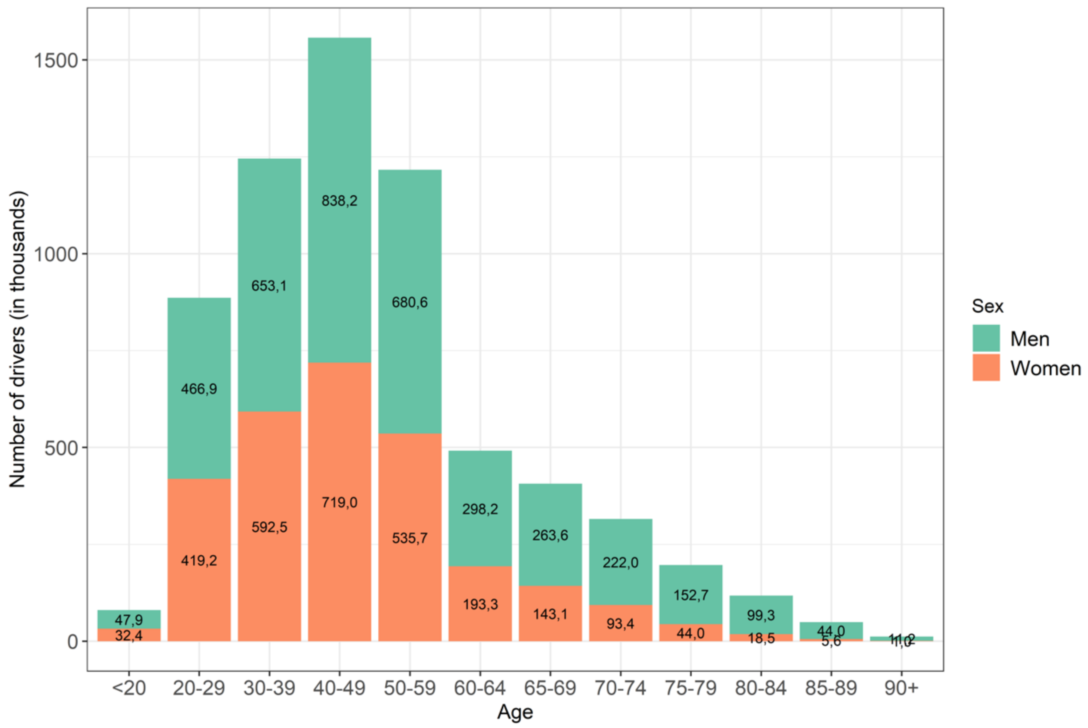
Figure 3.3. Average age of safe vehicles by category



Source: Own elaboration based on statistical data from Autoridade de Supervisão de Seguros e Fundos de Pensões (ASF).

As for drivers with a driver's license (Figure 3.4), the majority are between 30 and 59 years old. The age group between 40 and 49 years old has the largest number of drivers (23.7% of the total), followed by the group from 30 to 39 years old (18.9% of the total) and immediately after the drivers from 50 to 59 years old (18.5% of the total).

Figure 3.4. Number of drivers with a driving license in 2019 by age and gender

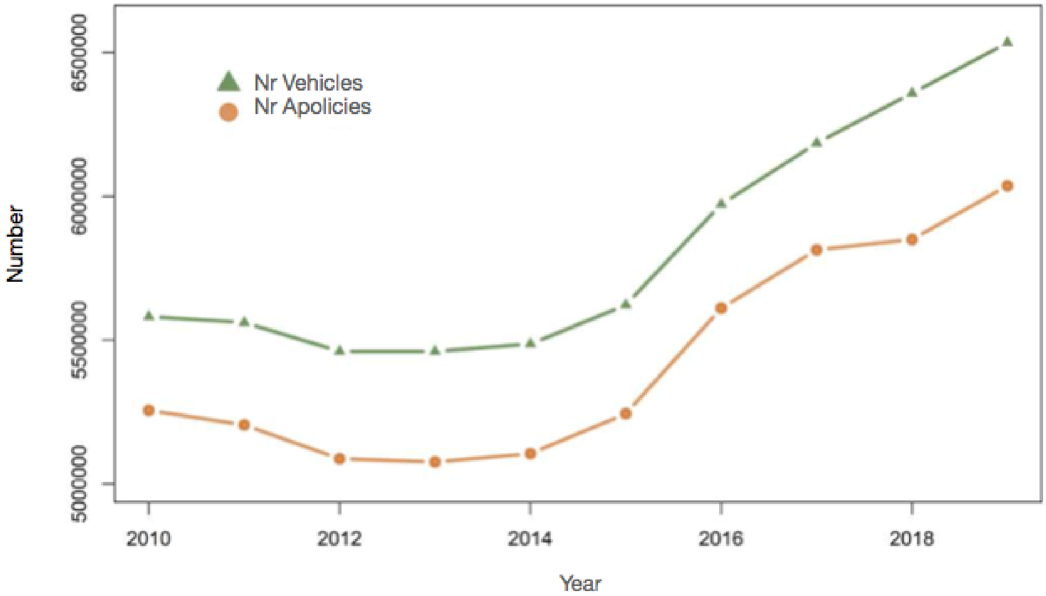


Source: Own elaboration based on statistical data from ASF.

Young people between 20 and 29 years of age are in fourth place, representing 13.5% of all drivers with a driver's license. In a breakdown by gender, men are in the majority in all the age groups presented, representing 57.45% of the total number of licensed drivers. In the younger age groups, there is an increasing parity between men and women.

Figure 3.5 represents the evolution of the number of insurance policies and the number of insured vehicles between 2010 and 2019. After the period, corresponding to the Economic and Financial Adjustment Program agreed with the Troika, there is significant growth in the number of policies and vehicles insured, and a slight increase in the number of vehicles insured per policy in more recent years.

Figure 3.5. Number of drivers with a driving license in 2019 by age and gender

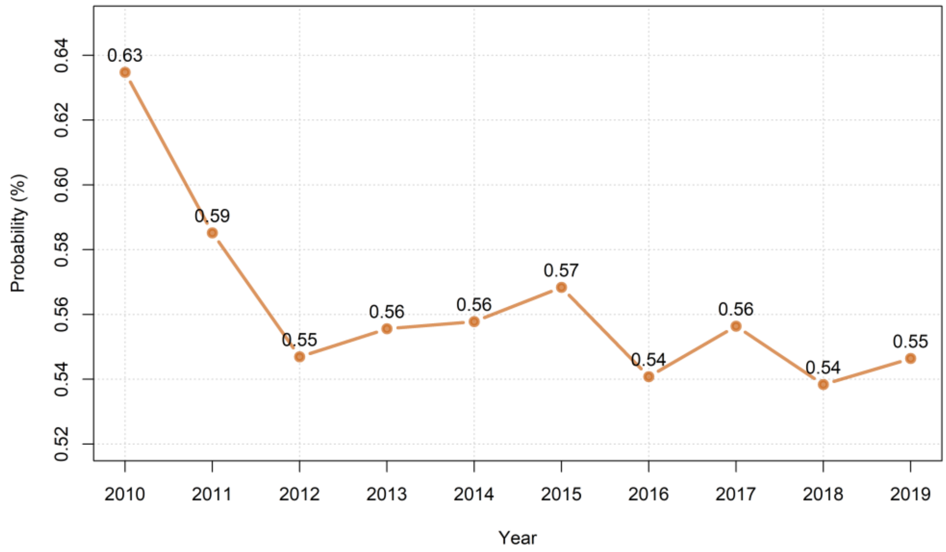


Source: Own elaboration based on statistical data from Portuguese Insurance Association (APS).

3.1. Frequency of road crash risk

Figure 3.6 shows the evolution in Portugal of the probability of occurrence of a road crash with victims between 2010 and 2019, calculated based on the ratio between the observed number of road crashes with victims and the number of insured vehicles. In 2010, the probability of occurrence of a road crash with victims was approximately 0.63%, i.e. for every 157 safe vehicles in Portugal one of them would be involved in a traffic crash. The frequency of road crash risk has been decreasing, stabilizing in the last five years at around 0.55%.

Figure 3.6. Evolution of the probability of a road crash with victims

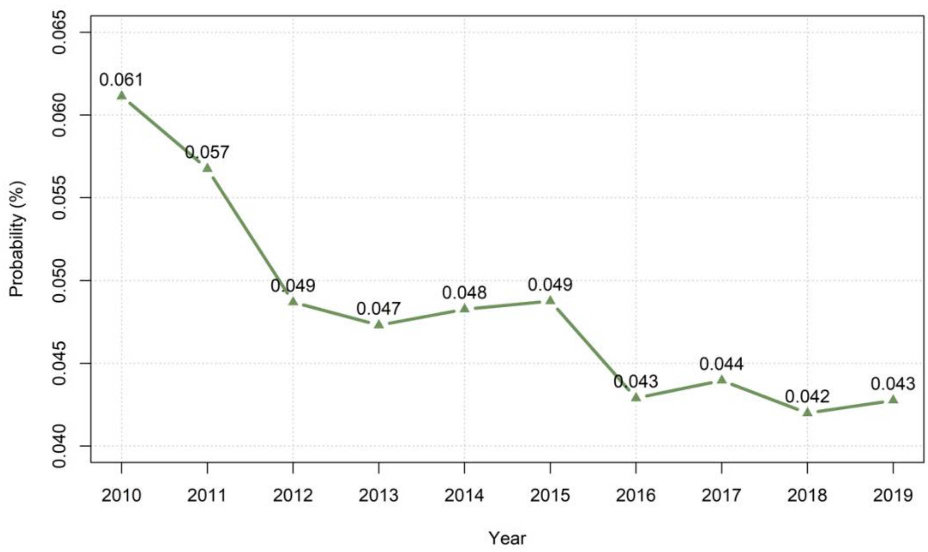


Source: Own elaboration.

In Figure 3.7, we show the evolution in Portugal of the probability of occurrence of fatalities and/or seriously injured, using as a metric the number of accidents with fatalities and/or serious injuries per million accidents.

The risk of road crashes generating victims with a higher degree of severity has been reducing over the last decade, from a value of 611.3 accidents with victims per million accidents in 2010, to 427.6 accidents in 2019. In 2019, for every 1,636 vehicles insured in Portugal there was one road crash with fatalities and/or seriously injured.

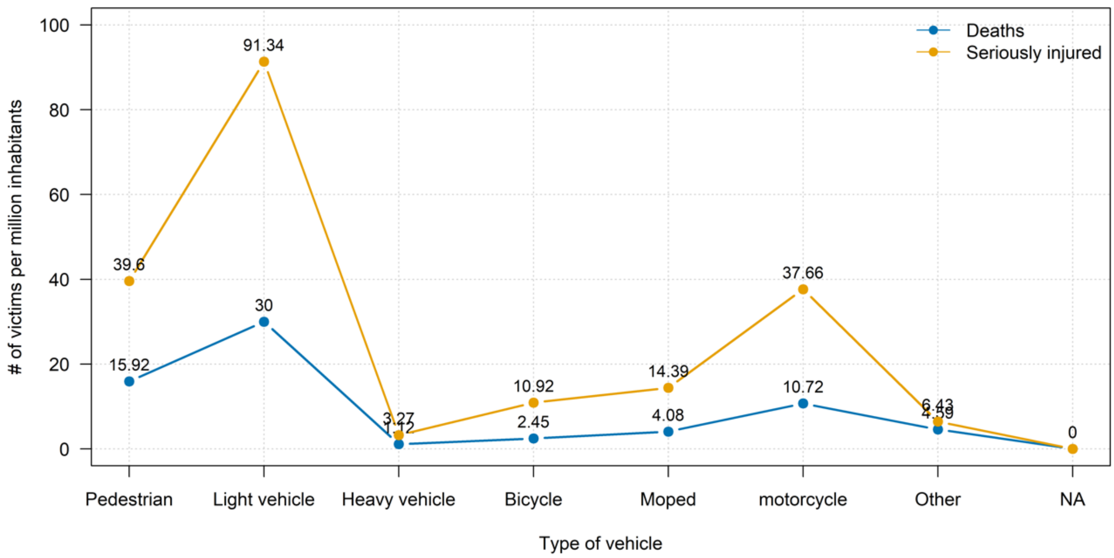
Figure 3.7. Evolution of the probability of occurrence of a road crash with fatalities and/or seriously injured



Source: Own elaboration.

Figure 3.8 represents the number of road crash victims per million inhabitants and vehicle category, an indicator of the frequency of road crash risk-weighted by the resident population.

Figure 3.8. Number of victims per million inhabitants and vehicle category, 2019

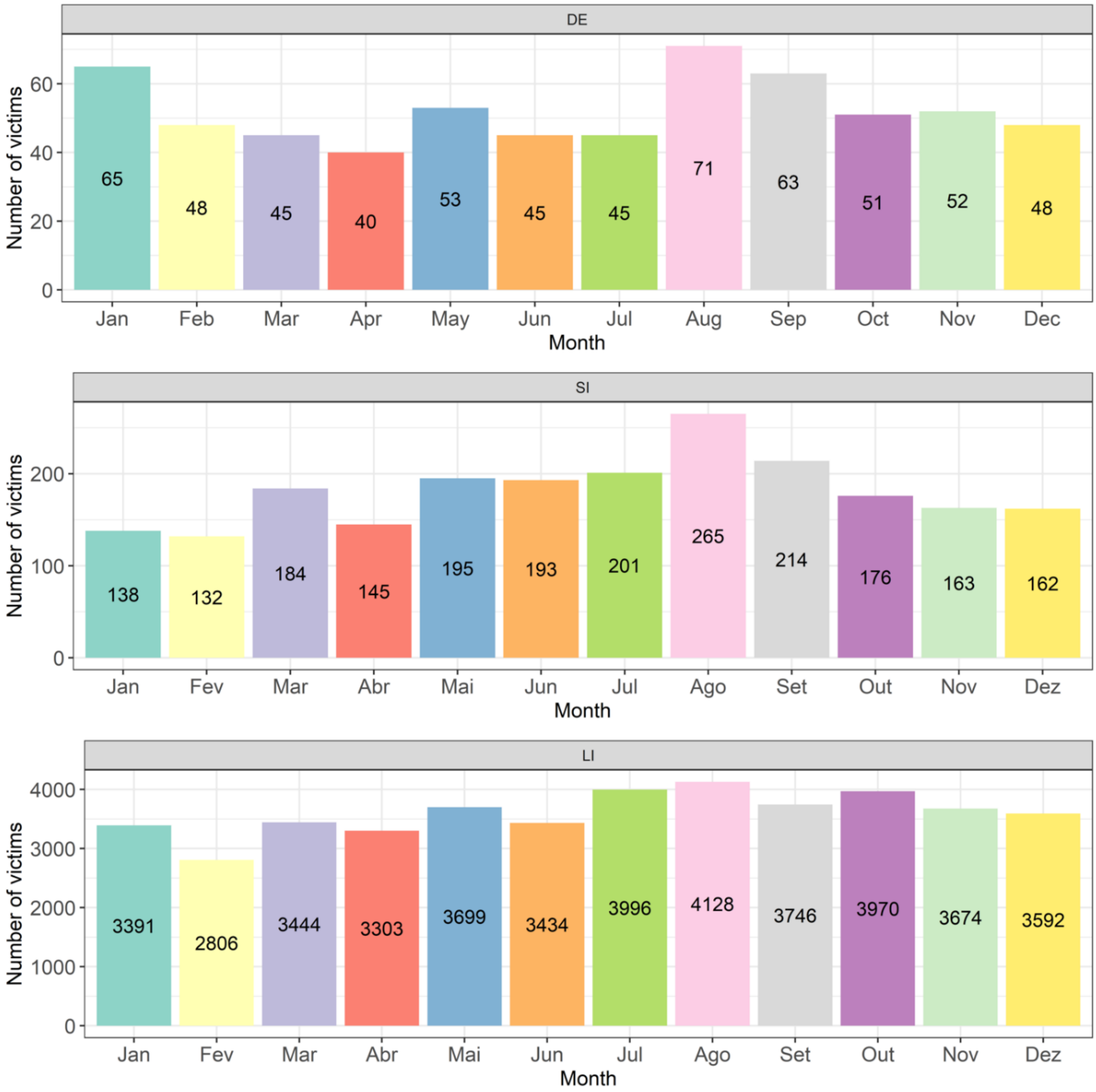


Source: Own elaboration.

As can be seen, it is in light vehicles (mainly passenger vehicles) that the highest number of fatalities *per capita* (30 deaths per million inhabitants) and seriously injured (91.34 injuries per million inhabitants) were recorded in 2019. The frequency of road crashes involving pedestrians (15.92 fatalities and 39.06 seriously injured per million inhabitants) and motorcycles (10.72 fatalities and 37.66 seriously injured per million inhabitants) is also noteworthy.

The risk of road fatalities is not homogeneous in time, space and circumstances, presenting a heterogeneous behavior in multiple dimensions among which are the day of the week, the time of day, and the month of the year or the location of the continental territory. Figure 3.9 represents the distribution of the number of traffic crash victims by month in 2019.

Figure 3.9. Distribution of road crash victims per month, 2019



Source: Own elaboration based on statistical data from ANSR.

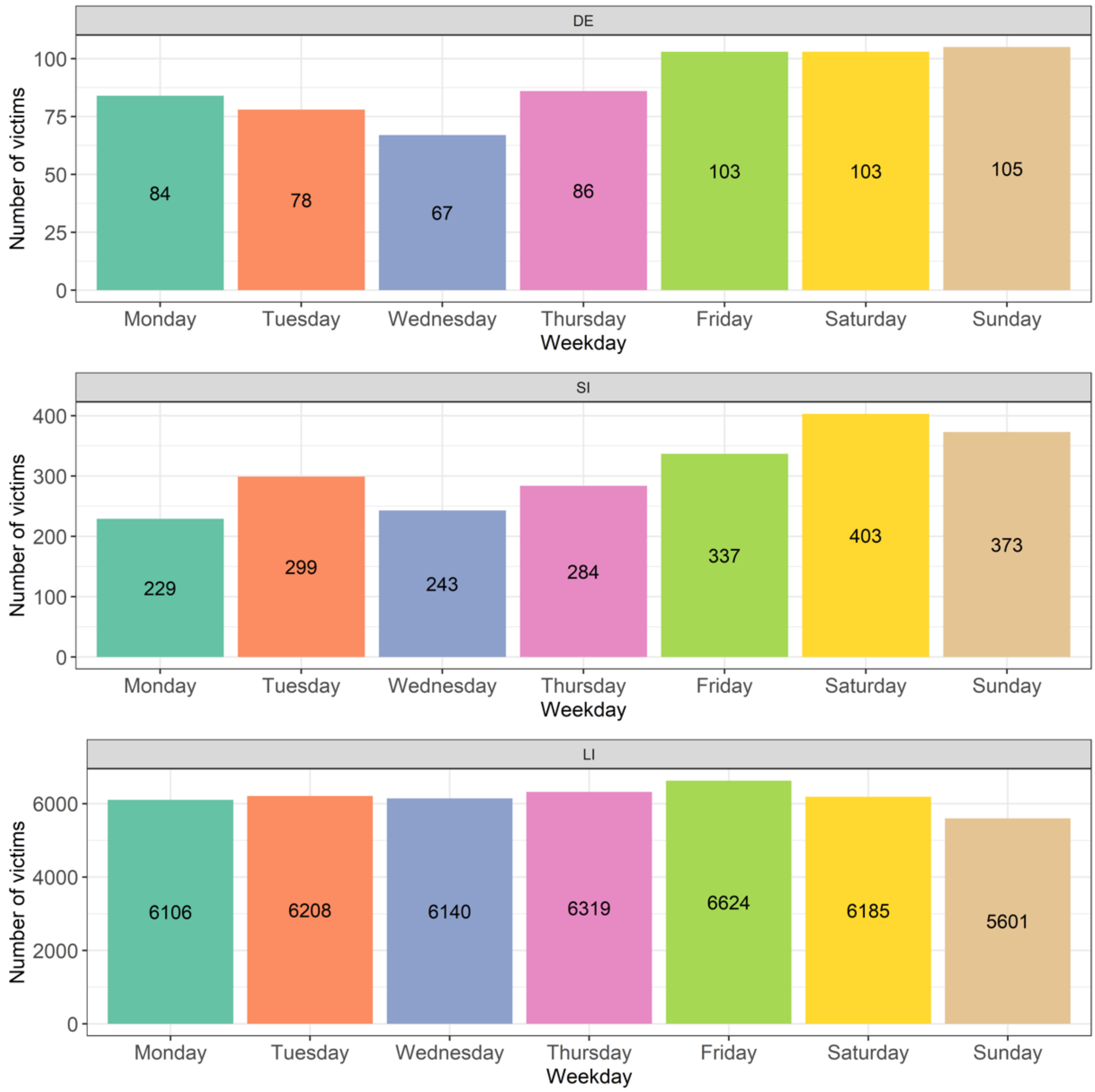
It verifies that the road crash risk shows seasonality patterns associated with the mobility patterns of citizens in the territory according to seasons (festive and non-festive) and to international migration flows.

Overall, the months July to August stand out as those with the highest number of road crashes and victims in 2019. The second half of the year shows higher road crash rate indicators compared to the first half of the year. In contrast, February was the month with the lowest number of road crashes, partly due to the lower number of days in the month compared to the others. In terms of fatal consequences, August (71 victims), January (65) and September (63) stand out as the months with the most fatalities for the year as a whole. This same seasonality pattern can be observed when we analyze the severity index of fatalities by month in the next section.

Road fatalities show seasonal patterns throughout the year and within each weekly cycle, associated with commuting for work and leisure and, at some times of the year, with festive seasons or significant dates (e.g., national and municipal holidays). Analyzing the distribution of the victims of road crashes by day of the week (Figure 3.10) we observe that Fridays and weekends (Saturdays and Sundays) are the days with the highest incidence of fatalities and seriously injured, with greater severity on Sundays in the case of fatalities and Saturdays in terms of seriously injured.

In Figure 3.11, we analyze the intra-day seasonality patterns of the fatalities recorded in 2019 in mainland Portugal. From the calculation of road crashes and victims according to the time of day, we conclude that the period between 6 and 8 pm is the one in where more road crashes are recorded (about a quarter of the daily total) and where there are also more victims. The most serious road crashes happen, however, at dawn and, in many cases, on weekends involving younger drivers.

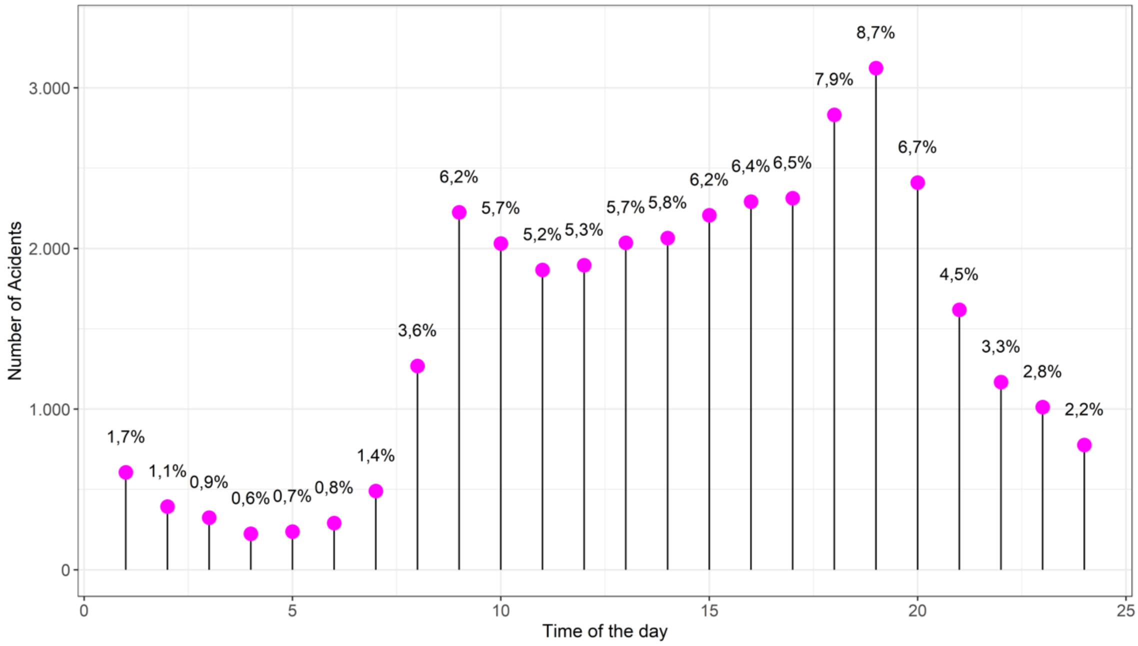
Figure 3.10. Distribution of road crash victims per day of the week, 2019



Source: Own elaboration based on statistical data from ANSR.

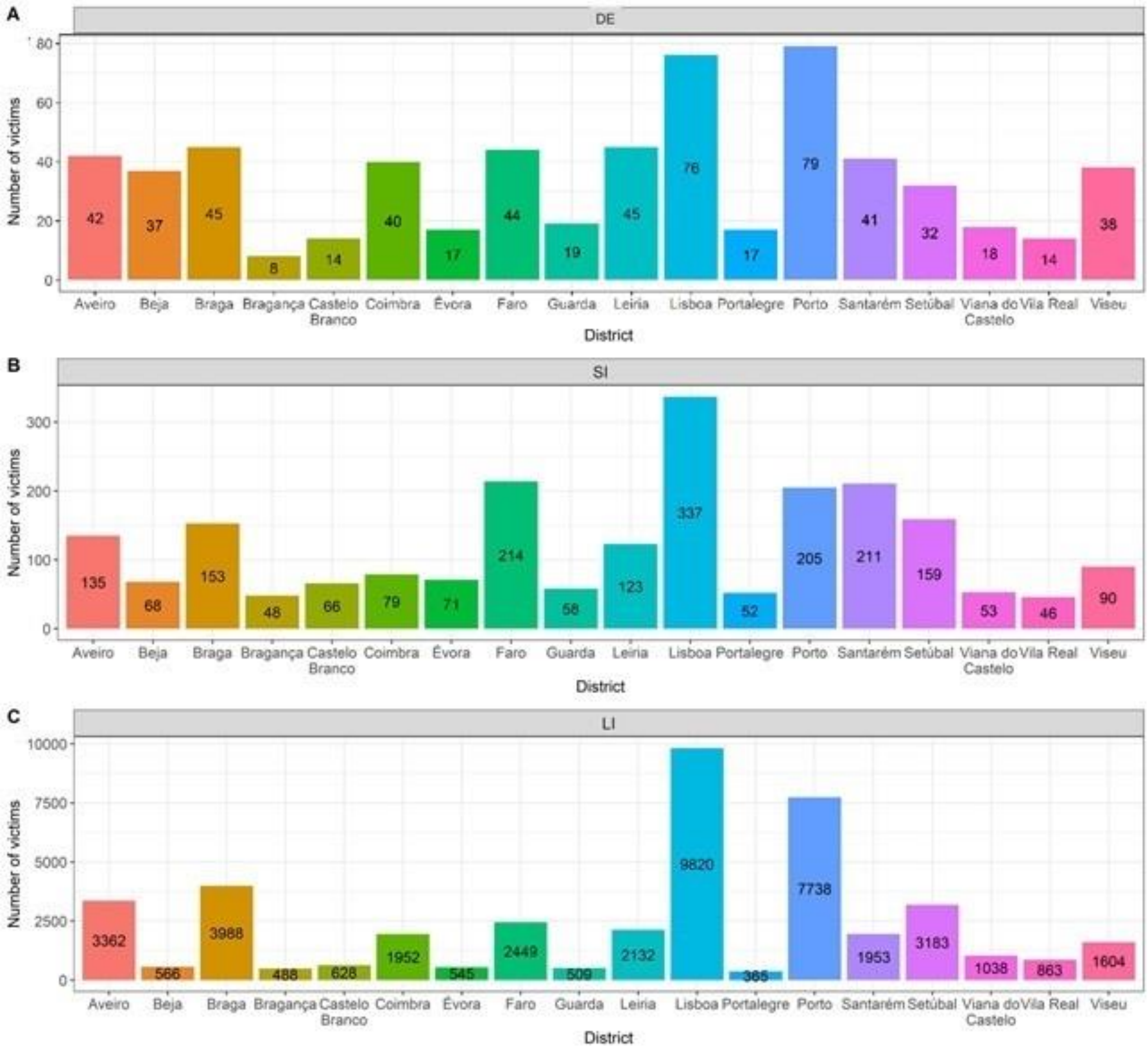
For a more territorialized perspective of road fatalities in Portugal, Figure 3.12 represents the number of road crashes with victims per district in absolute numbers. The graph shows that the districts of Porto (79) and Lisbon (76), followed by Leiria and Braga, both with 45 recorded fatalities, are those with the most road fatalities with victims in 2019, the least significant being Bragança with 8 victims. Concerning seriously injured, Lisbon (337), Faro (214), Santarém (211) and Porto (205) are the districts with the highest number of occurrences. The districts of Lisbon (9,820), Porto (7,738), Braga (3,988) and Aveiro (3,362) have the highest number of slightly injured people.

Figure 3.11. Number of road crashes with victims according to period of day, 2019



Source: Own elaboration based on statistical data from ANSR.

Figure 3.12. Number of victims of road crashes per district, 2019

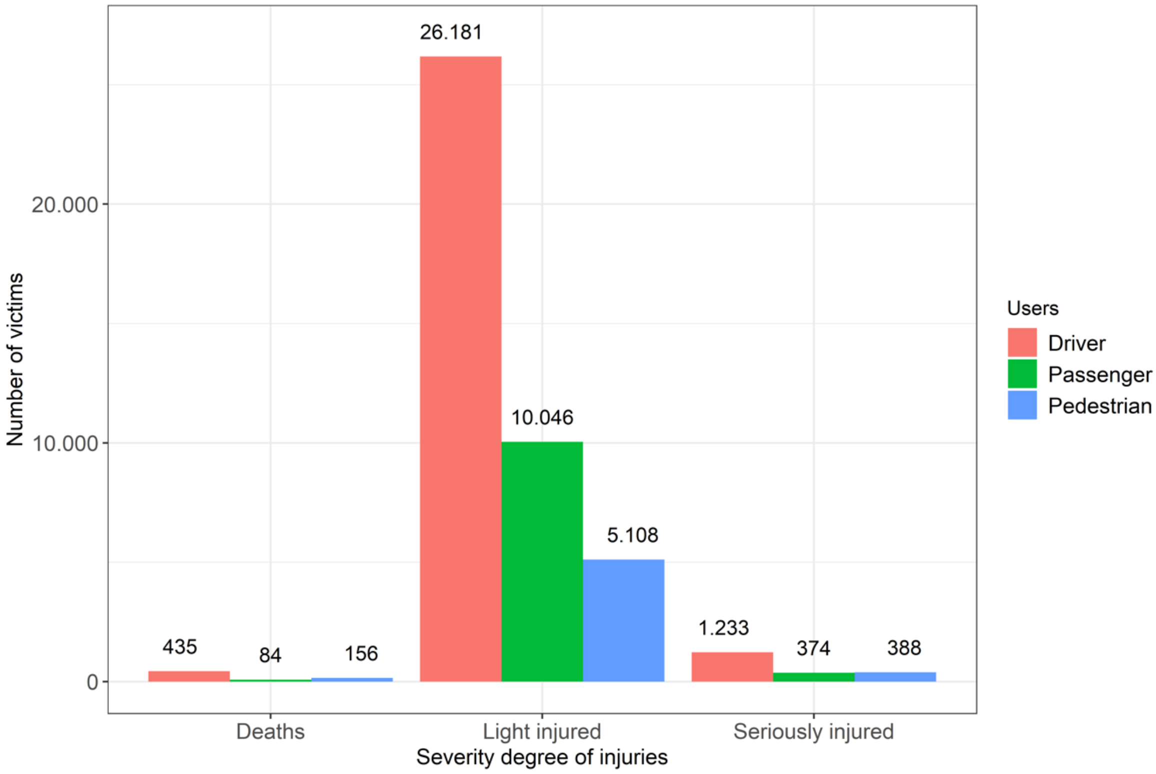


Source: Own elaboration based on statistical data from ANSR.

3.2. Severity of the risk of a traffic crash

The severity of the risk of a road crash may be gauged by the number of victims and the respective degree of severity of the injuries caused and by indicators that relate the number of victims per road crash, considering a set of explanatory covariates of road crash risk. In this section, we present a synthesis of the road crash risk severity indicators in Portugal referring to the year 2019. Figure 3.13 represents the number and typology of road crash victims by category of road users.

Figure 3.13. Number of victims according to user type and severity of the injury, 2019

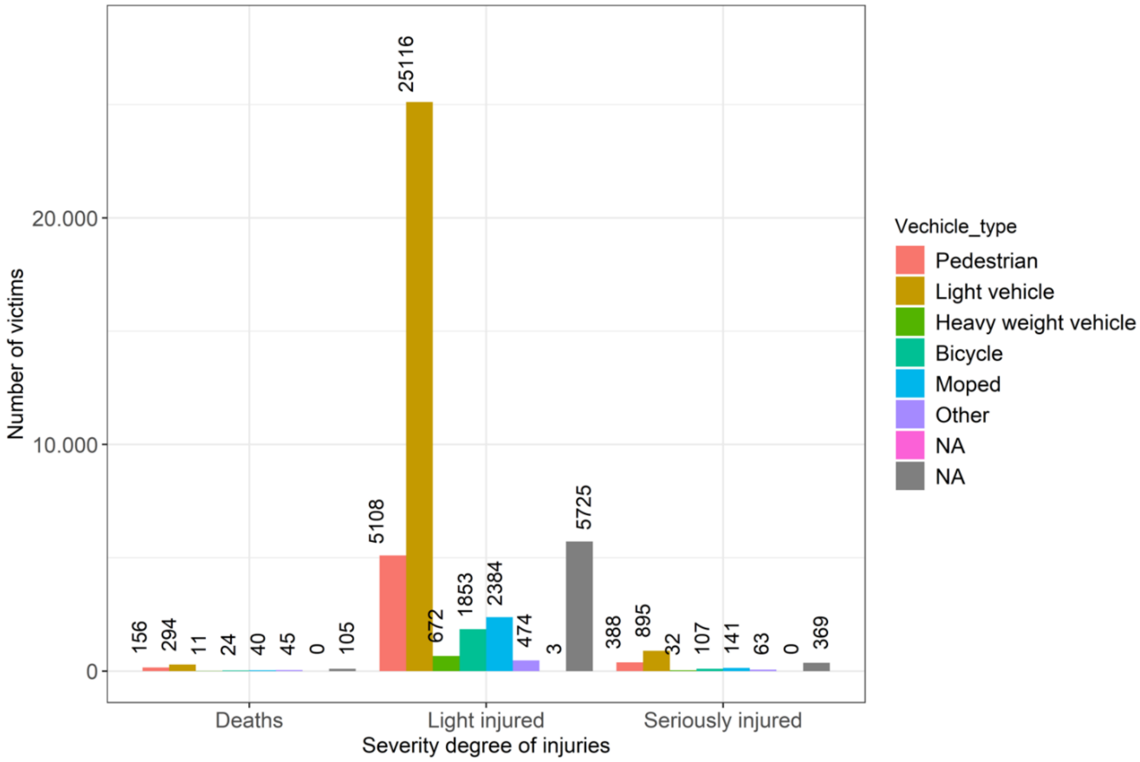


Source: Own elaboration based on statistical data from ANSR.

The highest number of victims are drivers, followed by passengers and pedestrians, all with minor injuries. Concerning seriously injured and fatalities, it is among drivers that we observe the highest number of occurrences. It should also be noted that pedestrians record a higher number of seriously injured and fatalities than passengers, indicating the usually more severe consequences of road crashes involving pedestrians.

The analysis of the number of victims according to the vehicle category and the degree of severity of the injuries caused (Figure 3.14) leads us to conclude that the highest number of slightly injured people occur in light vehicles, followed by motorcycles.

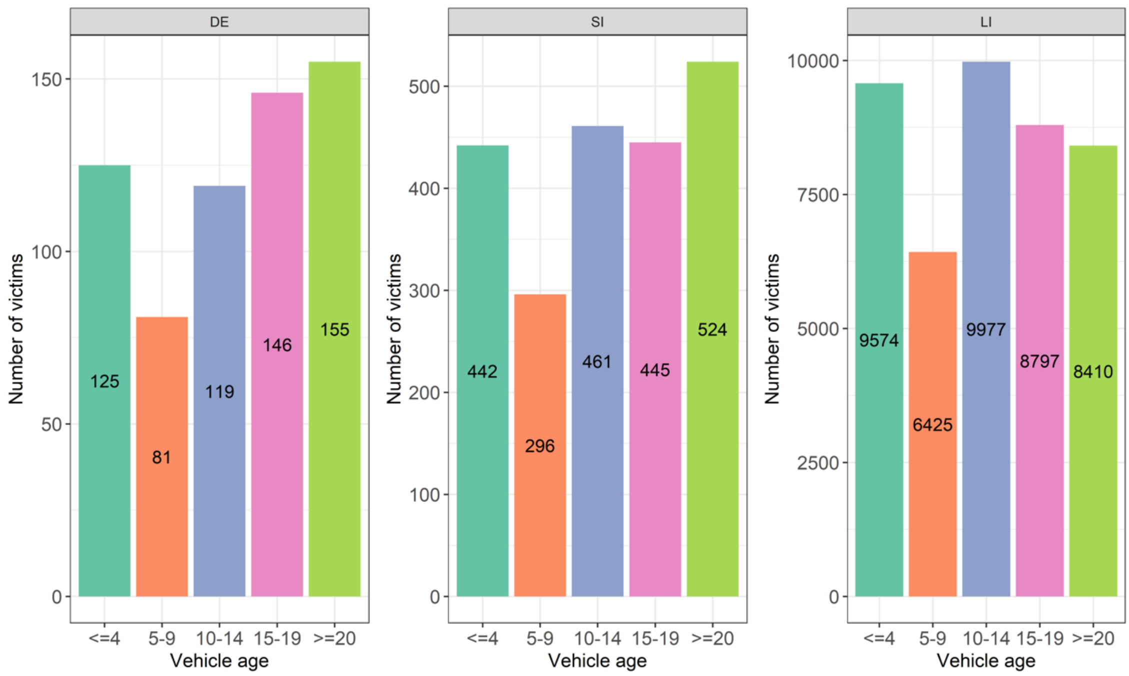
Figure 3.14. Number of victims by vehicle category and severity of injuries



Source: Own elaboration based on statistical data from ANSR.

In another perspective of correlation of the severity of victims with the age of the injured vehicles, we can see (Figure 3.15) that the highest severity of victims (fatalities) results from road crashes with vehicles 20 years old or more, while the number of slightly injured people is higher in vehicles between 10 and 14 years old (Figure 3.15).

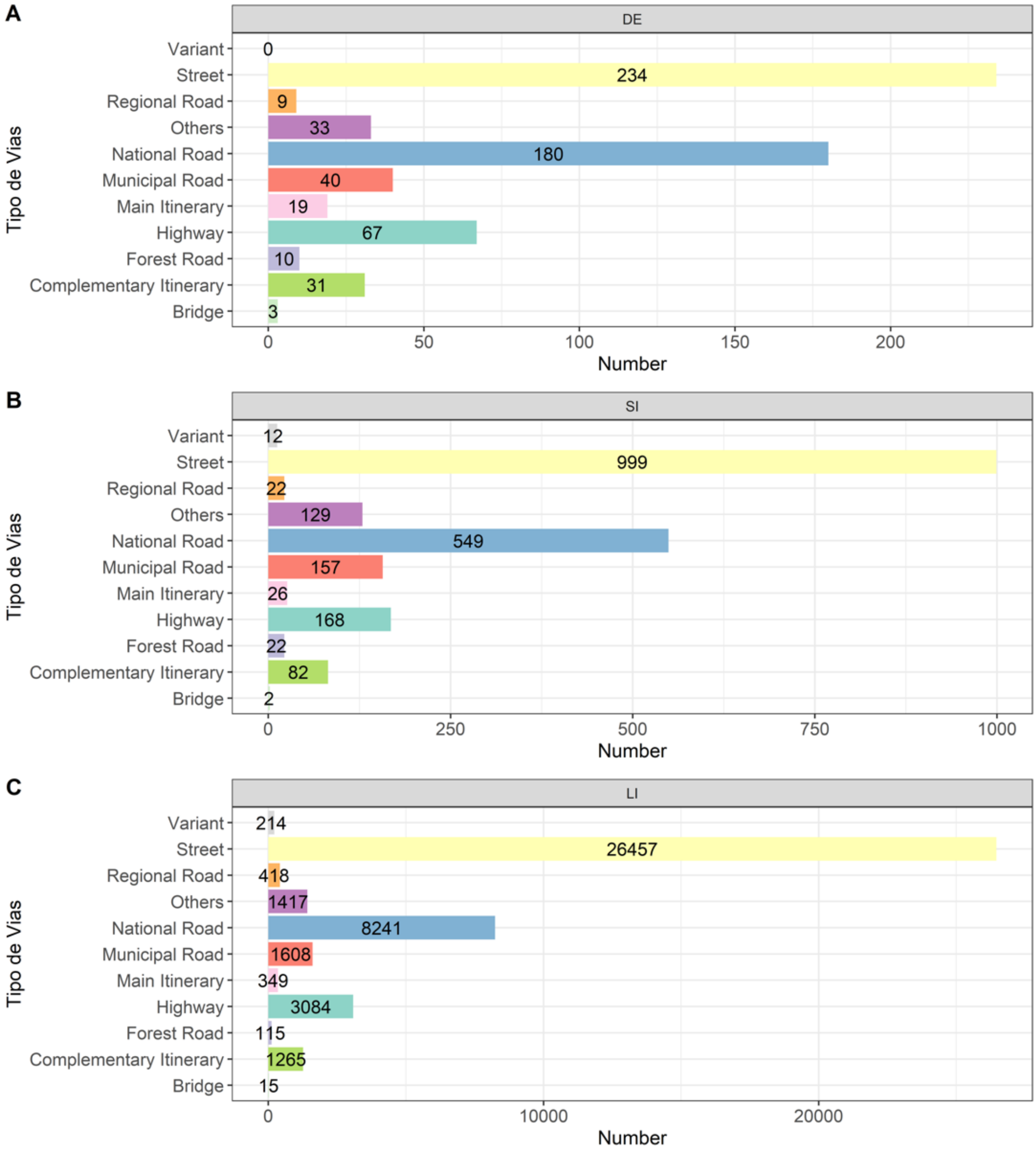
Figure 3.15. Distribution of victims per vehicle age



Source: Own elaboration based on statistical data from ANSR.

In terms of the type of roads with the highest number of victims (Figure 3.16), the highest number of fatalities (234), seriously injured (999) and slightly injured (26,457) were observed on roads. Immediately following were 180 fatalities, 549 seriously injured and 8,241 minor injuries on national roads.

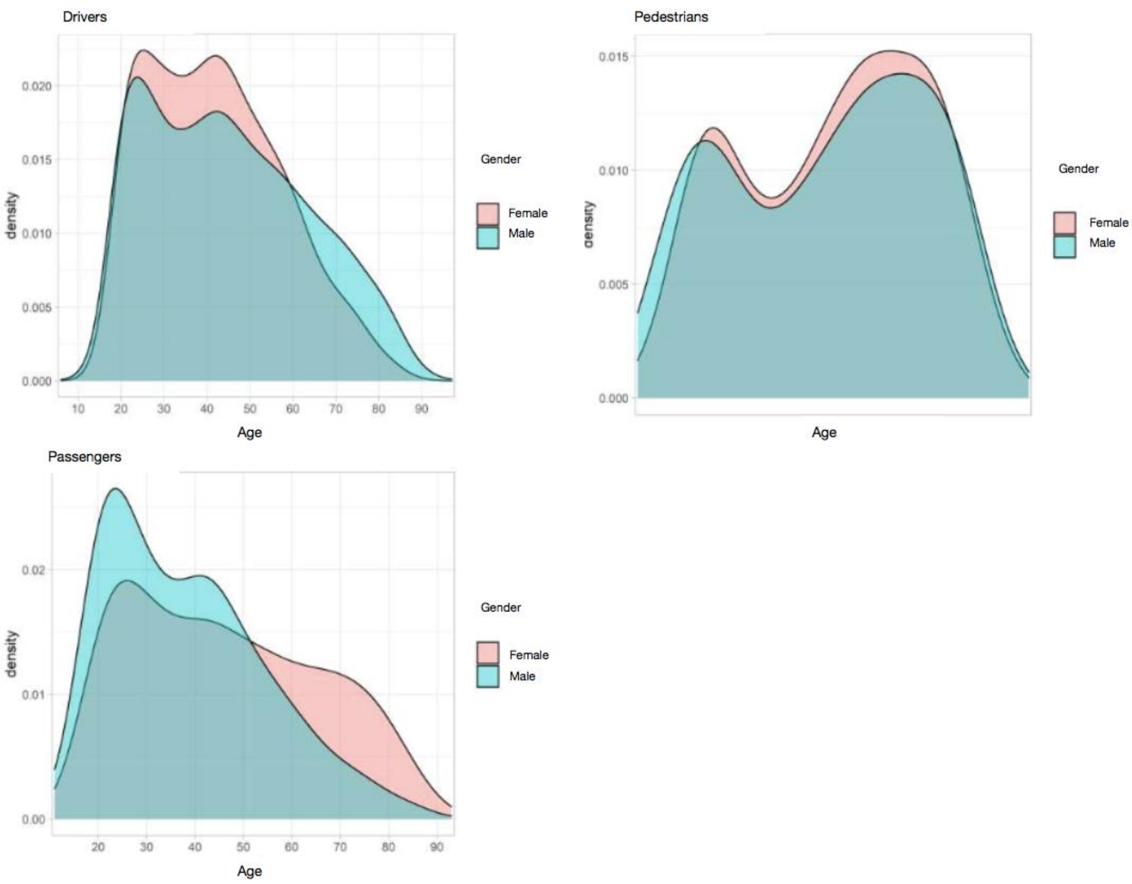
Figure 3.16. Number of victims per road type



Source: Own elaboration based on statistical data from ANSR.

A more specific breakdown of road traffic victims by age and gender (Figure 3.17) shows that male drivers are more aged than female drivers are.

Figure 3.17. Distribution of road crash victims by age and gender, 2019



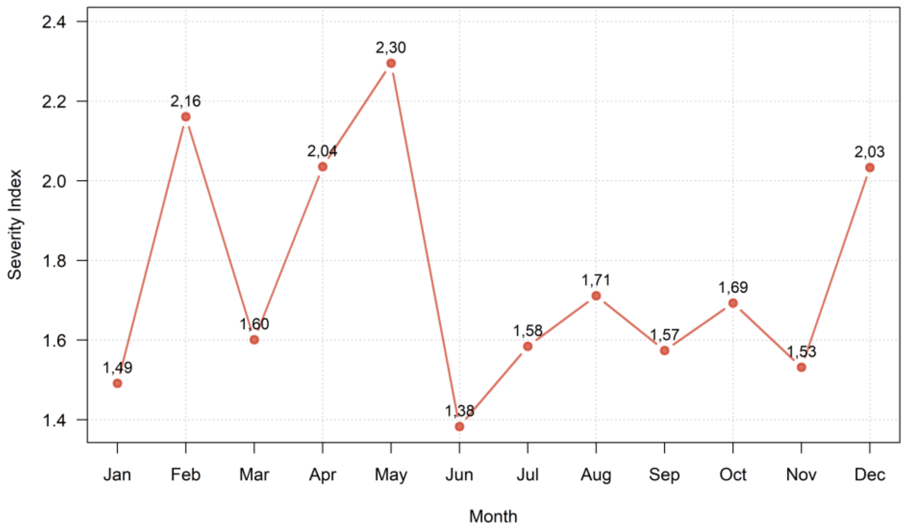
Source: Own elaboration based on statistical data from ANSR.

The age of driver victims is concentrated between 20 and 60 years old, with a higher incidence in female victims, although, in a longitudinal analysis, male drivers show a larger temporal distribution. Regarding passenger victims, there is a higher concentration of male individuals aged between 20 and 55 years old, with a higher incidence between 20 and 30 years old. The severity of road crashes involving pedestrians is also noteworthy, especially in the 55 to 75 age group, with the highest incidence in female pedestrians aged 20 to 75 years.

One way to gauge the severity of road crash risk is to construct composite indicators by aggregating partial indicators summarizing the human, economic and social consequences of road crashes. In this regard, the severity index is one of the indicators most commonly used by safety authorities in Portugal to measure risk severity. Among the other composite indicators are the severity indicator and the road crash Rate Index (RTI).

Figures 3.18 to 3.22 show the value of the road crash severity index calculated in different dimensions. Figure 3.18 illustrates the behavior of the road crash severity index in each of the months of the year, with May showing the highest expression of this indicator with 2.3 fatalities per 100 road crashes, followed in descending order by February (2.16) and April (2.04). The month of June has the lowest index with 1.38 fatalities.

Figure 3.18. Severity rate by month, 2019

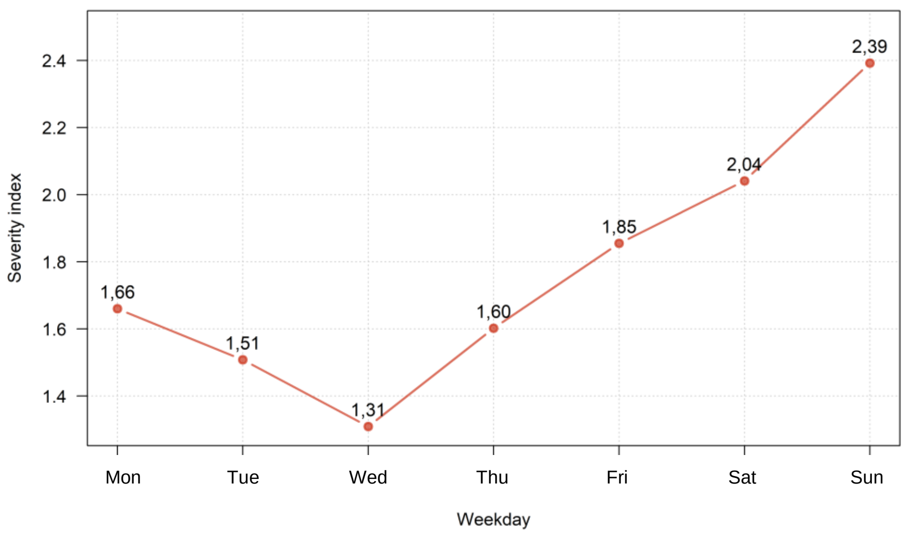


Source: Own elaboration based on statistical data from ANSR.

Figure 3.19 illustrates the behavior of the severity rate on each of the days of the week, with a peak on Sundays with 2.39 fatalities per 100 road crashes, while on Saturdays and Fridays it reached 2.04 and 1.85 respectively.

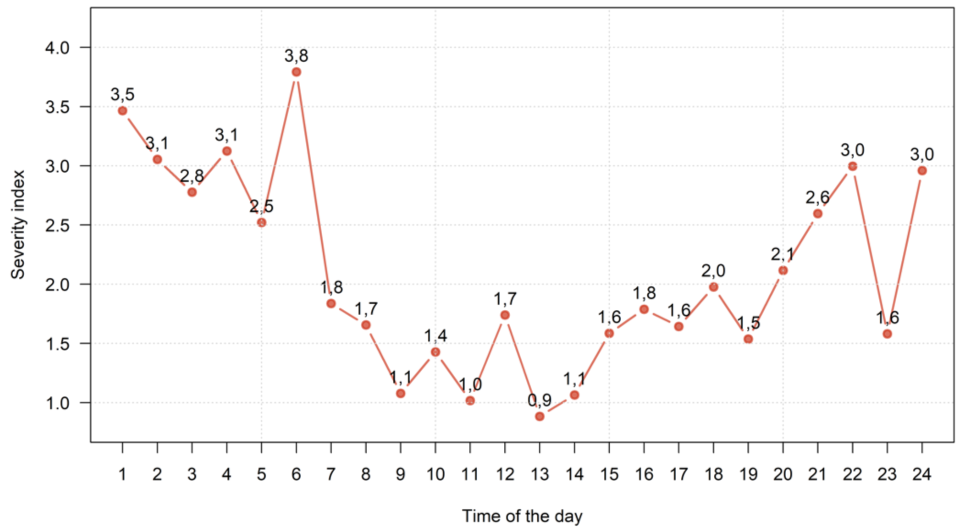
At a more particular level, based on the analysis of the road crash rate according to the time of day (Figure 3.20), it is during the night that the highest values are recorded, namely from 8 pm (2.1) to 6 am, reaching at this time the highest value, 3.8 fatalities, with the exception of the rate observed at 11 pm (1.6) lower than that reached at 7 am (1.8) and at 8 am and 12 noon (1.7).

Figure 3.19. Severity index by day of the week, 2019



Source: Own elaboration based on statistical data from ANSR.

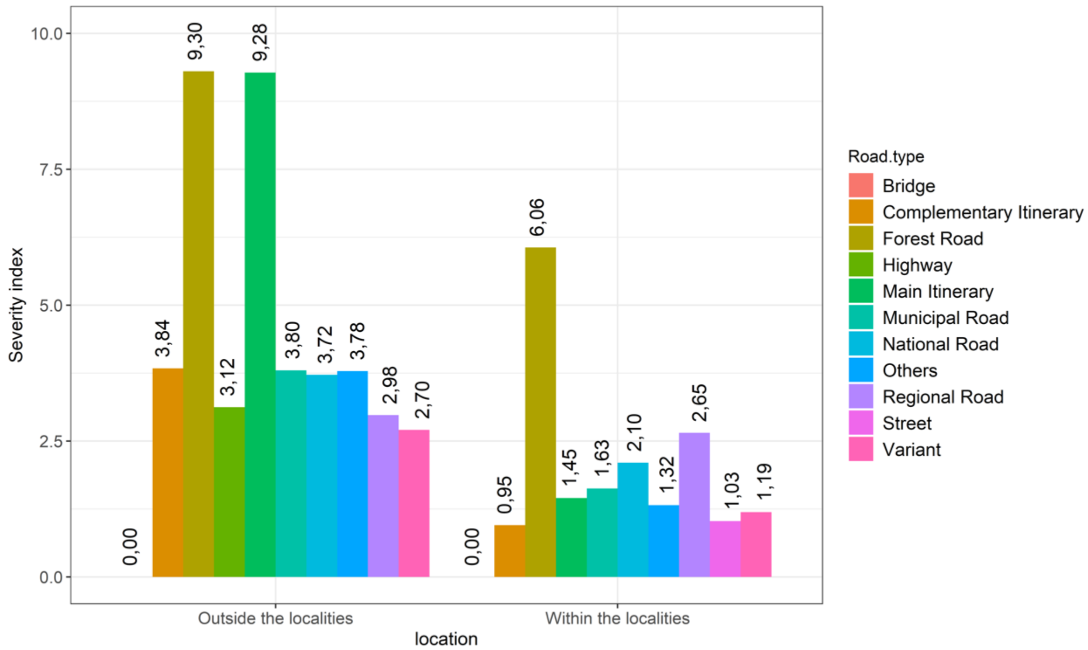
Figure 3.20. Severity index by time period, 2019



Source: Own elaboration based on statistical data from ANSR.

Turning now to an analysis of the severity rate according to location and road type, as can be seen in Figure 3.21, the severity rate shows considerably higher values outside localities than within localities.

Figure 3.21. Severity rate according to location and type of road, 2019

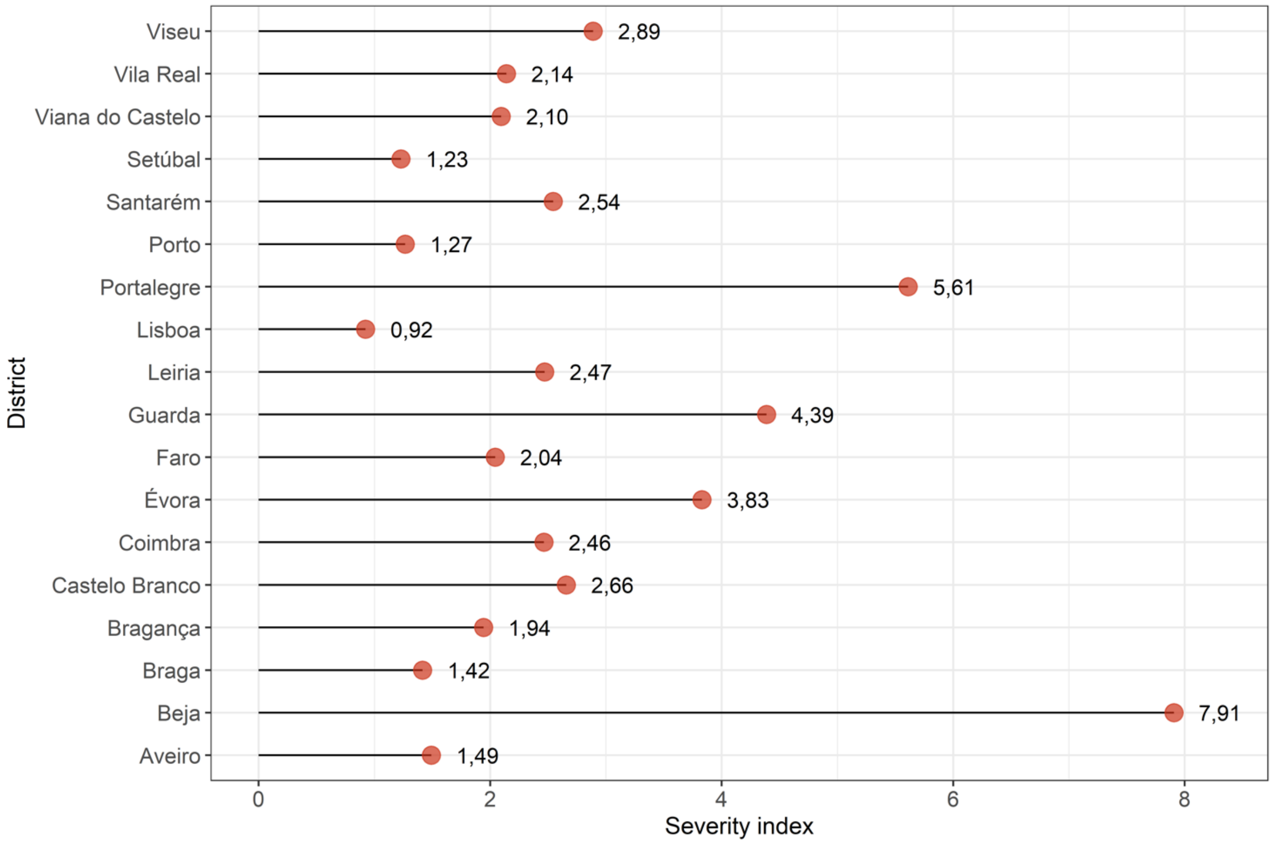


Source: Own elaboration based on statistical data from ANSR.

Outside localities, the values reach 9.28 victims on main routes and 9.3 victims on forest roads. Within localities, the highest value is observed in occurrences on forest roads (6.06) and on regional roads (2.65).

Finally, Figure 3.22 represents the value in 2019 of the severity index calculated by district in mainland Portugal. It should be noted that in 2019 the most serious road crashes took place in the Alentejo districts of Portalegre and Évora, with 7.91 and 5.61 fatalities respectively, per 100 road crashes. The Lisbon district has the lowest rate, with 0.9 fatalities. It should also be noted that the highest number of fatalities per 100 road crashes occurs in most of the country's inland districts.

Figure 3.22. Severity index by district, 2019



Source: Own elaboration based on statistical data from ANSR.

4. Methodology for estimating the economic and social costs of road fatalities

The economic and social costs of road crashes can be roughly broken down into two main components: (i) Damages of a patrimonial nature and (ii) Moral, immaterial or non-patrimonial damages.

Property damage comprises the damage caused to the injured parties' and third parties' property (e.g. the cost of repairing the vehicle and the affected roads, expenses incurred by the injured party, loss of profits, medical assistance, medication and treatment costs, vehicle and home adaptation costs, administrative costs, compensation for personal belongings damaged or destroyed as a result of the road crash). This component includes a set of costs that, due to their nature, may be subject to indemnity or reparation, either through replacement with the same or an equivalent item or payment of cash compensation, or through the restoration of the situation prior to the road crash. The costs of a patrimonial nature include the so-called emergent damages, referring to the damage caused to assets or rights already in the possession of the injured party at the date of the injury (Article 564 of the Civil Code) and the so-called lost profits, understood as the income lost by the company as a result of the temporary or permanent unavailability of the victims to participate in the production process, as well as other patrimonial income that the injured party ceased to obtain as a result of the injuries caused by the road crashes.

Moral, immaterial or non-patrimonial costs include, among others, the value of human lives shortened or permanently affected by traffic crashes, the physical pain the psychological and emotional shock caused to the injured and their families as a result not only of the injuries but also of the medical treatment required, the anguish and suffering triggered by the circumstances inherent to the road crash and subsequent moments, the removal from family, social and professional life, the perception and internalization of the risk of extemporaneous loss of life, the loss of quality of life, the damage caused to physical appearance, the temporary or permanent consequences in the victims' capacity for personal and social affirmation, for example, in their participation in sporting, recreational or leisure activities.

In the case of material costs, it is generally possible to use market prices to quantify the economic and social value of the damage caused by traffic crashes. In the case of moral, immaterial or non-patrimonial costs, it is easy to see that it is not trivial to translate into money the value of human life or the monetary value of the physical, psychic and emotional impacts caused by a traffic crash, and there are no market prices to quantify them. For this reason, it becomes necessary to resort to estimation methods to quantify the value of non-economic damages generated by road crashes.

It is not possible to determine the precise value of future property damage and personal injury in the strict, mathematical sense of the term. While it is true that in terms of judicial compensation, most countries have defined criteria and minimum and maximum amounts to quantify the compensation due to injured parties for damages suffered as a result of road crashes, the truth is that such compensation represents a small part of the economic and social impact of road crashes and always presupposes the use of estimation methods. The assessment of this cost to society should seek to identify and quantify the present and future value of all property and non-property damages caused by road crashes, provided they are foreseeable. A part of the total road crash costs is internalized, for example through the insurance premiums paid and/or through advance accounting of the possible impact of risks (provisioning). There is, however, an important part that refers to negative externalities that are also relevant and should be included in the total cost.

In this section, we present the methodological proposal for calculating the economic and social impact of road fatalities in Portugal.

4.1. International guidelines and review of the reference literature

The estimation of the economic and social costs of road crashes is a topic that has been addressed in the last decades by researchers, national and international bodies linked to the transport sector and road mobility and supra-governmental entities. There is, therefore, a vast scientific literature and international guidelines as to the best practices to be adopted to estimate these costs. In this section we briefly review the scientific literature and the main international guidelines to be adopted in the estimation of road crash costs, based on which we identify and detail in the following sections the components of the total cost and the methodologies used for their quantification. Table 4.1 summarizes the main conclusions of these studies.

The document with the most detailed guidelines as to the cost components to be included and the evaluation methods to be followed remains that of the COST313 project (1994), where results from 14 European countries are reviewed and systematized. The project recommends breaking down the total cost into six major components, namely human costs, medical costs, loss of production, property damage, administrative costs, and a residual category referring to other costs. The project recommends the use of three different methods to assess the total cost components, namely, the Human Capital Approach (HCA) methodology, the Willingness-to-Pay (WTP) or Willingness-to-Accept (WTA) methodology, and the Restitution cost Approach (RC) method. The project involved a quantitative analysis of costs by victim type, considering the factors that could explain these differences, for example, differences in the cost of living (GDP *per capita*), the variables that determine output loss (GDP growth rate, discount rate, age and wage structure of the working population), and methodological differences. Different methods were qualitatively and quantitatively evaluated using a multi-criteria analysis and recommendations were made for estimating the costs of traffic crashes. Other international reference documents with general guidance on this issue include the Handbook on the external costs of transport (EC, 2019), the OECD (2012) study on mortality and health risks of transport policies, studies by the Asian Development Bank (ADB, 2003), the British Government (TRL, 1995; BRS&TRL, 2003), the U.S.

Department of Transport. (Blincoe et al., 2015), the Australian Government (BITRE, 2009) and the UNITE project (Nellthorp et al., 2001), World Bank (2005).

Several EU projects have been developed to identify and estimate all the external costs of road fatalities (costs not covered, for example, by car insurance policies), aiming at developing general guidelines for the implementation of effective strategies, measures and approaches to reduce road fatalities and to minimize the costs of road crash prevention measures, some of them focusing on vulnerable users (see, for example, Handbook on Estimation of External costs in the Transport Sector (Maibach et al. (2008), Korzhenevych et al. (2014), EC (2019), ECMT (1998), HEATCO (Bickel et al, 2006), SafetyCube (Wijnen et al., 2017), InDeV (Kasnatscheew et al., 2016)). These projects include a discussion of the methodological issues and provide guidance on how to estimate the economic and social costs of road crashes.

Table 4.1. International orientations to cost estimation of road crashes

Study	Type of study	Objectives	Main results
COST313 (1994)	Main guidelines regarding the estimate of traffic accident cost, based on a revision of data of 14 European countries	Guidelines about cost components to include and evaluation methods to use	Orientations regarding cost components to include and evaluation methods to use. Cost components to include: - Human costs - Medical costs - Production loss - Property damage - Administrative costs - Other costs Methods of evaluation recommended by cost components: - Human Capital Approach (HC) - Willingness-to-Pay/Accept (WTP-WTA) - Restitution Cost Approach (RC)
EC (2019) ECMT (1998)	European study destined to internalize the external costs of transport. Includes estimate of external costs of traffic accidents.	Identify and estimate all external cost of accidents, (non covered costs, e.g., insurance policies)	Standardized cost estimates by victim type (fatality, severe injuries and light injuries) and respective method of evaluation used, comprising: - Human costs (VOSL) - Procution loss - Medical costs - Administrative costs
HEATCO (Bickel et al., 2006)	European study destined to develop general guidelines to an economic evaluation (cost-benefit analysis) of infra-structural projects.	Identify and estimate all external cost of accidents. Includes estimate of external transport cost	Standardized cost estimates by victim type (fatality, severe injuries and light injuries) and respective method of evaluation used, comprising: - Human costs (VOSL) - Procution loss - Medical costs - Administrative costs - Property costs
SafetyCube (Wijnen et al., 2017)	Community project (Horizonte 2020) destined to develop a Decision System of Support to road safety. Based on a revision of data from 31 European countries.	General guidelines towards implementation of strategies and effective measures to reduce costs and minimize traffic accident victims	Orientations about the cost components to include and evaluation methods to use. Cost components to include: human costs, medical costs, production loss, property damage, administrative costs, other costs. - Evaluation methods recommended by cost component: HC, WTP/WTA, RC.
IaDeV (2016)	Community project (H2020) destined to evaluate the cause of vulnerable users' traffic accidents; Based on a revision of data from 31 European countries	General guidelines towards the implementation of strategies and efective measures to reduce costs and minimize victims - vulnerable users	Orientations about the cost components to include and evaluation methods to use. Cost components to include: human costs, medical costs, production loss, property damage, administrative costs, other costs. - Evaluation methods recommended by cost component: HC, WTP/WTA, RC.

Source: Own elaboration based on Alfaro et al. (1994), ECMT (1998), HEATCO, SafetyCube (2017), InDeV (2016).

The results of the European Conference of Ministers of Transport (ECMT, 1998) include estimates of the costs per fatality and per serious injury, based on standardized European figures per road crash. The main methodological discussions included in this report concern the methods to be adopted to estimate the statistical value of a human life (VSL), pointing out VSL as a central component in the human costs of road crashes. The goal of this report was to internalize the negative impacts of transportation. The report estimates the standard value of VSL based on official VSLs used by national road safety bodies in five countries, arriving at a value of 1.5 million euros (values in 1998 prices).

Subsequent European projects include the HEATCO project (Bickel et al., 2006) and the EU manual on estimating external costs in the transport sector (Maibach et al., 2008; Korzhenevych et al., 2014; EC, 2019), which continued the same approach as ECMT (1998) by determining a standard VSL for road crash fatalities, but adding the estimation of human costs for serious and minor injuries based on a percentage of the VSL. In EC (2019) a synthesis of the main national and supranational studies carried out on VSL estimation is presented, reporting values ranging from one million to 3.6 million euros per fatality. For severely injured people, the studies point to VSL percentages ranging from 10% to 16%, while for slightly injured people, they point to VSL percentages ranging from 0.9% to 1.6% of the VSL.

More recently, the SafetyCube (2017) and InDeV (2016) projects updated the general guidelines on the cost components to be included and the assessment methods to be used in the estimation of the total economic and social cost (internal and external) of road crashes, which are the basis used by the European bodies in the area of transport. These studies, based on a review of data from 31 European countries, follow the recommendations of the COST313 project (Alfaro et al., 1994) and advise the inclusion of six components: human costs, medical costs, production loss, property damage, administrative costs and other costs. In terms of cost evaluation methods, they generally recommend the use of the Willingness-to-Pay method to estimate human costs, the human capital approach to estimate production loss, and the restitution cost method to estimate the remaining components (property damage, medical and administrative costs, other costs).

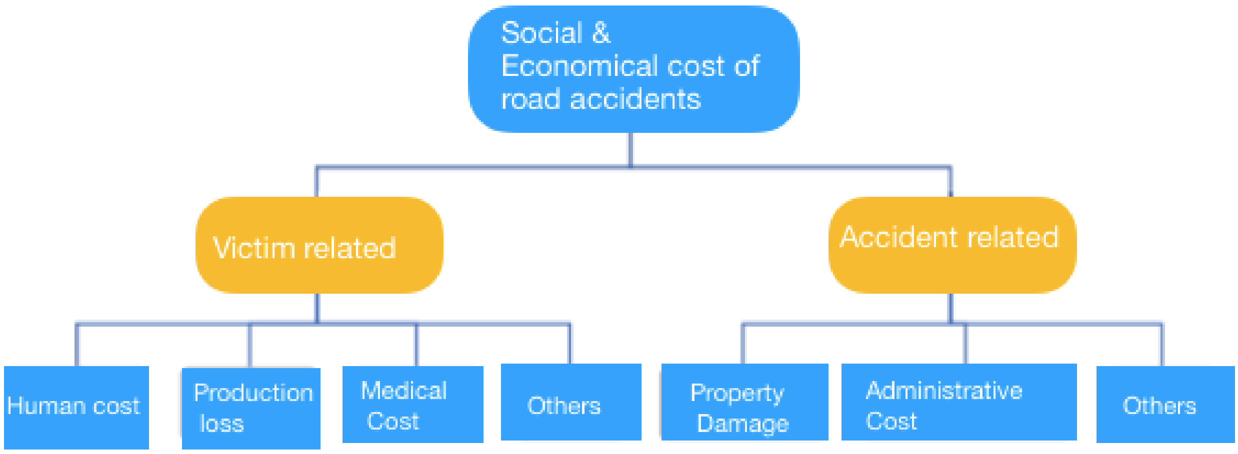
In the scientific and operational literature, we also highlight some studies where the costs to be included in the analysis and the methods for evaluating road crashes are systematized (e.g. Alfaro et al., 1994; Trawén et al., 2002; Bleaij et al., 2003a,b, 2004; Bickel et al., 2006; Boardman et al., 2006; BITRE, 2009; Wijnen & Stipdonk, 2016; Elvik, 1995, 2000, 2016; Schoeters et al., 2020).

4.2. Components of the economic and social cost

Based on the literature review and the international guidelines described above, in this study we decompose the economic and social cost of road crashes into costs directly related to the victims (human costs, production loss, medical costs, other costs) and costs related to the road crashes themselves (property damage, administrative costs, other costs). The breakdown of the total cost is summarized in Figure 4.1.

Human costs comprise the (statistical) value of human lives shortened or permanently affected by traffic crashes, the physical pain, the psychological and emotional upset caused to victims and their families and friends from injuries and medical treatment required for recovery, the anguish and suffering associated with the road crash and subsequent moments (*quantum doloris*), the aesthetic damage, the loss of quality of life, the temporary or permanent consequences on the victims' capacity for personal and social affirmation.

Figure 4.1. Components of the economic and social cost of traffic crashes



Source: Own elaboration.

The loss of production essentially reflects the permanent (fatalities or seriously injured) or temporary (minor injuries) consequences (fatal or seriously injured) or temporary (slightly injured) consequences on the market and non-market productive capacity of the production capacity until the end of the victim's working life, as well as other financial benefits that the victims no longer obtain as a result of their injuries.

Medical costs refer to the costs of medical treatment of road crash victims (including fatalities that were treated) in hospitals or other medical institutions), including expenses for medication and temporary or permanent assistance, following the road crash and in the future. It includes the cost of emergency services for road crash victims, the cost of hospital treatment for inpatient road crash victims, the cost of non-hospital treatment (e.g., in rehabilitation centers, physical therapy, home care), the cost of aids to road crash victims (e.g., wheelchairs, other medical devices) and other medical costs.

The property damage component refers to the costs of replacement or repair of vehicles, roads, buildings, fixed objects on the road (e.g. signs, traffic lights, lamp posts, barriers), transported goods and personal property affected by road crashes.

Administrative costs of road crashes include, among others, transport freight charges, costs of police operations, costs of emergency services (e.g. fire departments), administrative costs of vehicle insurance and health insurance, legal costs, congestion costs, costs arising from unavailability of the vehicle, costs of prison services.

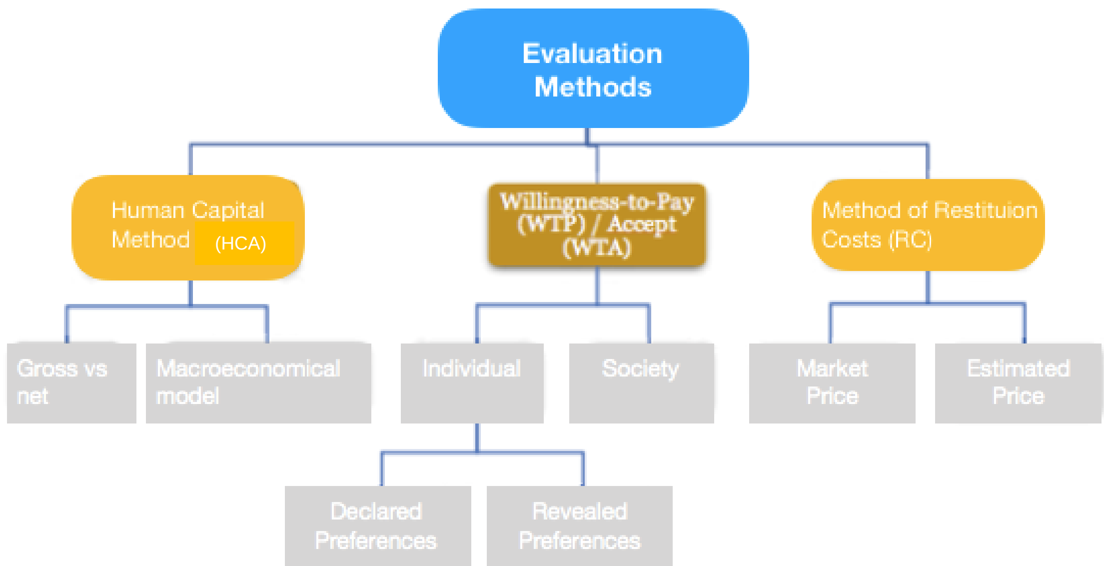
The residual Other costs component includes minor costs such as the unavailability of crashed vehicles, environmental costs (vegetation, fuel spills, trees, CO2 emissions) caused by the road crashes, the costs of adapting the house, the car, the job for more severely disabled road crash victims, the costs of anticipating funerals, accommodation, transportation, among others.

In most international studies where the detailed information required for the calculation is available, it is possible to estimate the total cost components separately and then obtain the total value by aggregating the individual components. It is also usually possible to break down the costs by component and total by type of victim (fatalities, seriously injured, and slightly injured). Another type of breakdown of traffic crash costs by variables such as road crash location, road crash type, time of the day or day of the week, age of users (drivers, passengers, pedestrians) involved, lighting conditions, weather factors, age of license or age of vehicles, is sometimes ascertained depending on the depth of the available database.

4.3. Cost evaluation methods

Figure 4.2 summarizes valuation methods recommended in international guidelines for assessing the cost to society of road traffic crashes.

Figure 4.2. Methods for evaluating the economic and social cost of road crashes



Source: Own elaboration.

The human capital approach (HCA) is based on quantifying the loss of productive capacity of road crash victims and will be adopted in this study in estimating the output loss component. In some studies (e.g., Chen et al., 2019), it can also be a traditional macroeconomic model considering a production function including physical capital and human capital stocks and total factor productivity, with each generation's human capital stock dependent on education and work experience. The impact of road fatalities on labor supply can be estimated as a function of mortality and morbidity for each generation, manifested in a reduction in the labor force and/or a reduction in the number of hours worked and a decrease in the activity rate. The impact of road crashes on the accumulation of physical capital occurs through the reduction in savings as a result of its use to finance medical expenses arising from road crashes. These models are subsequently calibrated using reference statistical information on mortality and morbidity, GDP, education, capital stock, savings rate, health expenditures, medical treatment costs. In estimating output loss, it is necessary to distinguish between gross output loss (including private consumption loss) and net output loss (excluding private consumption loss), as detailed in section 4.3.2.

The Willingness-to-Pay (WTP) / Accept (WTA) approach is commonly adopted to estimate the human costs of road fatalities, and will also be pursued in this study. Under this approach costs are estimated based on the amount that individuals are willing to pay (WTP) or accept (WTA) for risk reduction, to pay to exchange an outcome for its right equivalent. This approach is adopted in estimating human costs since there are no market prices to quantify the moral, intangible, or non-material costs of road crashes. The results of the WTP studies are used to estimate the statistical value of a human life (VSL), which is the basis for calculating the human costs associated with road crash fatalities but also serious and lightly injured victims.

The COST313 project distinguishes between individual WTP and social WTP, with the latter considering the value that society as a whole is willing to pay for a risk reduction. There are two major approaches to determining individual WTP. The first is based on preferences stated by individuals, for example in questionnaires. The second is based on preferences revealed by individuals through their actions, their behavior (e.g., purchasing). The approach based on revealed preferences is more common in studies determining OSLV (especially in Europe), and will be adopted in this study.

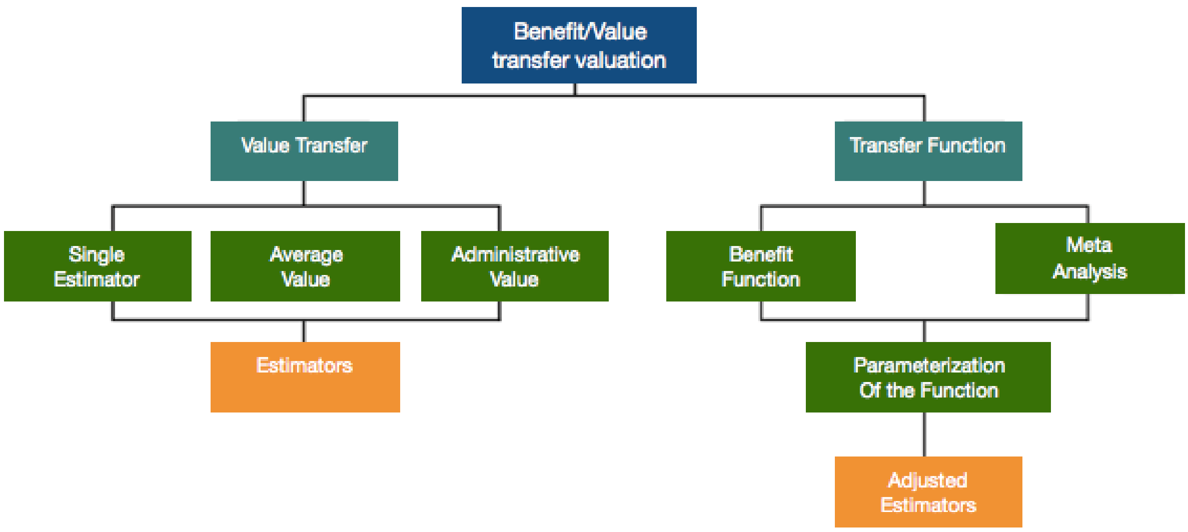
An alternative approach in quantifying the human costs of road crashes is based on disability-adjusted life years (DALYs). DALYs are a metric used to assess the impact of road crash injuries on the quality of life of victims by combining the impact of mortality, in the case of fatalities, and morbidity, in the case of serious and minor injuries (Bobinac et al., 2013).

Another approach for calculating human costs, adopted for example in some studies done in Germany (Baum et al., 2007) and Australia (BITRE, 2009), consists in using the value of financial compensation awarded by law (statutory values) by the courts to road crash victims and/or their relatives. In this approach the compensations are considered as the value that society assigns to the loss of (quality of) life as a result of the road crash. Other approaches use the cost of life insurance premiums in the event of death or the value of expenditures in improving road safety to estimate the cost. Previous studies find that the value of human costs obtained using these methodologies is much lower than those obtained using WTP (Elvik, 1995; Wijnen and Stipdonk, 2016).

The replacement or restitution cost method is based on the calculation of the costs necessary to compensate or repair, either by replacement with equal or equivalent goods or through the payment of a cash compensation, or by restoring the situation prior to the road crash. This method will be applied in the calculation of medical costs, property damage costs, administrative costs, and the residual other costs item. Whenever possible, market prices are used in applying this method. If not, estimated values using a Benefit/Value Transfer Valuation Approach are used.

The Benefit/Value Transfer Valuation Approach (VTVA), common in Benefit-cost analyses, consists of estimating economic values by transferring estimates of benefits or costs obtained in similar existing studies applied to another reality (e.g., another country).

Figure 4.3. Benefit/value transfer valuation approach



Source: Own elaboration.

This approach involves first fixing the type of transfer. The simplest way is to transfer a value or set of values from one place (or average values of a group) to another, considering purchasing power parity (location adjustment) and inflation (time adjustment) of the original values from a different country and/or a different year. Alternatively, it is possible in some cases to transfer not values but an estimated economic function based on the results obtained for one place or a group of places, in a kind of meta-analysis. Note that transfer is not always possible if the transfer function includes contextual variables that are difficult to obtain or calculate in the space/moment under evaluation. In this study, values obtained by VTVA using as a basis the results obtained in the Handbook on the external costs of transport (EC, 2019), and in the SafetyCube project (Wijnen et al., 2017), applying the respective space and time corrections, are applied whenever necessary due to insufficient statistical information.

4.3.1. Estimating the value of production loss

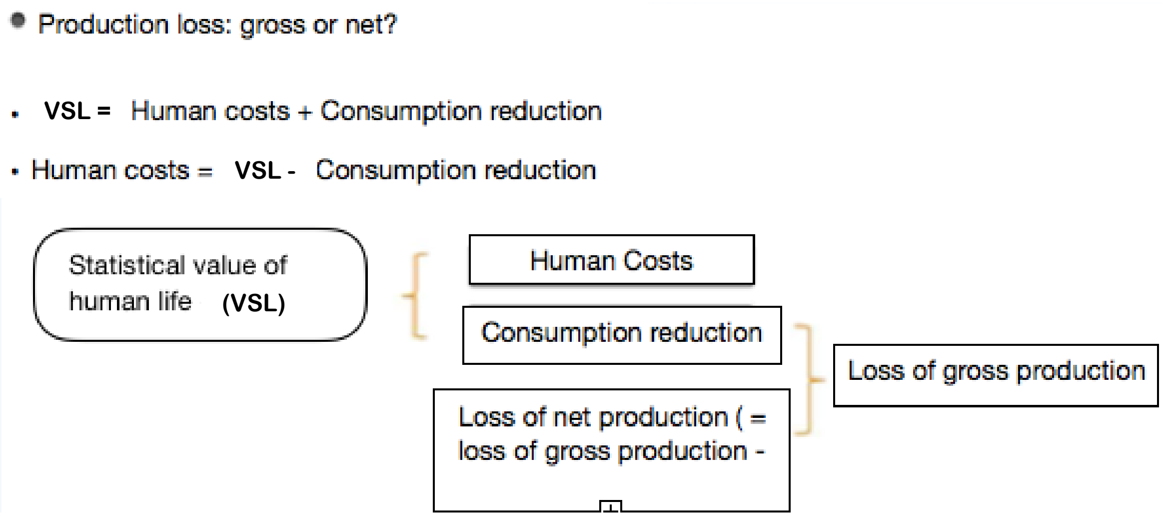
The value of production loss caused by traffic crashes comprises:

(i) The permanent (fatalities or seriously injured) or temporary (minor injuries) consequences on the potential productive capacity of the injured parties until the end of their working lives, particularly the lost income or production as well as other property benefits that the victims ceased to obtain as a result of the injuries caused;
(ii) The value of permanent or temporary loss of non-marketable production as a result of the injuries, particularly volunteer work, domestic work, service as a caregiver for children or adults with dependency and/or disability;
(iii) Other costs such as for employers the need to recruit and qualify new workers to replace temporarily or permanently the victims of road crashes.

Road crashes generate a reduction in private consumption, either permanently (fatalities) or temporarily, in the case of serious and slightly injured. For this reason, the literature usually distinguishes between gross production loss and net loss, including in gross production loss the reduction in private consumption, defining net production loss as the value of gross production loss less private consumption loss. The gross production loss is calculated by considering the value of production generated by each person employed, which from the income perspective includes compensation of labor, taxes net of subsidies on production and imports, and gross operating surplus (which in turn comprises taxes, interest, rents, distributed profits and retained earnings), part of which is used to finance private consumption expenditure. Gross production loss is the most common indicator used in quantifying the costs of traffic crashes (Wijnen & Stipdonk, 2016).

As the VSL concept comprises both human costs and private consumption loss arising from road crashes, to avoid accounting for production losses, one of two options should be adopted: (i) consider gross production loss in combination with human costs, assuming such that private consumption loss should be deducted from VSL when estimating human costs, or (ii) consider net production loss in combination with VSL (Evans, 2001; Wijnen et al., 2009). The two options for calculating production loss are schematized in Figure 4.4.

Figure 4.4. Relationship between VSL, human costs, lost output, and reduced private consumption



Source: Own elaboration based on Wijnen et al. (2017).

The first approach is usually recommended in estimating the production loss from traffic crashes, as it allows isolating the human costs of road crashes from the reduction in private consumption, and will also be adopted in this study.

The human capital approach is the recommended method for estimating the gross production loss associated with traffic crashes. The gross production loss is calculated by estimating the present (or discounted) value of the loss of production or income that victims ceased to produce either permanently (fatalities) or temporarily (seriously or slightly injured) until the end of their working life, considering for this purpose the statutory retirement age. In its calculation it is necessary to consider the age of the victims, their income by age and sex, the annual growth rate of production/income throughout the projection exercise, the probabilities of survival by age and sex, a social or intertemporal discount rate, and the levels of disability resulting from the road crashes. In formal terms, the value of the estimated gross merchant production loss for each type of victim (fatalities and light and seriously injured), is given by the following equation:

$$PPM_{k,i}(t) = \pi \times W_{x,A,t} + \sum_{j=x}^{x^R-1} \frac{G \times W_{j,A,t} \times (1+\delta)^{j-x} \times \ {}_jp_x(t+j-x)}{(1+y)^{j-x}}$$

where π denotes the percentage loss of production/income in the year the road crash occurs, $W_{j,A,t}$ represents the potential annual production/income of an individual of x age, of A sex in the year t, δ is the annual growth rate of potential production/income, y is a social or intertemporal discount rate (Bravo and Silva, 2006), G denotes the level of disability due to the road crash (total: G = 100%), ${}_jp_x(t+j-x)$ represents the probability that an individual aged x in year t survives until age j (cohort approach), x designates the age of the victim at the date of the road crash and x^R corresponds to the statutory normal retirement age.

In this study, we assume that the percentage of production/income loss in the year of the road crash is 50% (mainly relevant for fatalities and seriously injured). The annual potential output/income growth rates and inflation rates used in the projection correspond to the potential GDP growth rates estimated for Portugal in the latest exercise of the Ageing Working Group (AWG) of the European Commission (EC, 2018). We assume in the baseline scenario a social discount rate of 2% per year.

The value of annual output by age and sex was calculated based on the *per capita* GDP recorded in 2019 in Portugal taken from the national accounts, disaggregated by age and gender considering the wage structure verified in that year, i.e., it considers the evolution of victims' incomes throughout their working life cycle and the wage differences between men and women verified in the country. When considering the age of the victims, the value of lost production of younger road crash victims is naturally higher than that of older people. The levels of disability (Absolute Permanent Disability (IPA), Absolute Permanent Disability for Habitual Occupation (IPAPH), with or without vocational retraining, increased efforts) estimated for the slightly and seriously injured were based on international reference values, and are based on the losses of one fatal road crash victim.

Calculating gross production loss per victim also requires estimating the remaining longevity in the labor market and the normal retirement age in Portugal. For this purpose, it is necessary to estimate survival probability by age, sex and birth cohort in a generational approach (by cohort) (Bravo and Coelho, 2019). To this end, we used the age-specific mortality rate projection methodology based on a Bayesian combination of heterogeneous models developed by Bravo et al. (2020, 2021), Bravo and Ayuso (2020, 2021), Bravo (2019, 2020, 2021), Bravo and Mekkaoui de Freitas (2018), Bravo and Nunes (2021), Ayuso et al. (2021), which includes six generalized age-period-cohort (GAPC) models, the Hyndman and Ullah weighted time series method, a model based on a regularized principal component analysis (Regularized Singular Value Decomposition, RSVD), and the two-dimensional smooth constrained P-splines technique.

Let us call the candidate models $M_l \; (l = 1, \dots, K)$, representing the set of probability distributions (PDF) that comprise the likelihood function of the observed data in terms of the parameters $L(y|\theta_l, M_l)$, specific to each model θ_l and a set of prior probability density functions $p(\theta_l|M_l)$.

Let Δ be the variable of interest present in all models, for example, the future value of y. According to the total likelihood law, the posterior marginal distribution of the variable of interest considering the models is defined by:

$$p(\Delta|y) = \sum_{k=1}^{K} p(\Delta|y, M_k) p(M_k|y),$$

where $p(\Delta|y, M_k)$ designates the distribution of projected probability of Δ based on the M_k, model and $p(M_k|y)$ represents the posterior probability of the model M_k estimated from the data (*lookforward window*), i.e., mirroring its adherence to the data or its predictive power. The posterior probabilities of the models sum to unity, i.e., $\sum_{k=1}^{K} p(M_k|y) = 1$, and can be interpreted as weights. The probability distribution of the BME model combination is thus a weighted average of the PDF of the individual models, where the weights are theirs *a posteriori* probabilities (Bravo and Ayuso, 2020). To identify the models that integrate the model confidence set and their weights in the BME, for each of the three subpopulations, the models are first estimated in the training sample (training set) and then ranked according to their predictive power in the test sample (out-of-sample test set). Different metrics for evaluating the predictive power were considered, finally opting for the *Symmetric Mean Absolute Percentage Error* (SMAPE) indicator. The computation of the posterior probabilities of the models uses the normalized exponential function (also known as *softmax* or *softargmax* function). Sex-disaggregated mortality statistics for Portugal for the period 1960-2018 (Bravo et al., 2021) were used in the estimation of the models.

Table 4.2 summarizes the nine stochastic mortality projection models used in this study.

Table 4.2. Stochastic mortality projection models

Model	Model Structure	Reference
LC	$\eta_{x,t} = \alpha_x + \beta_x^{(1)}\kappa_t^{(1)}$	Brouhns et al. (2002)
APC	$\eta_{x,t} = \alpha_x + \kappa_t^{(1)} + \gamma_{t-x}$	Currie (2006)
RH	$\eta_{x,t} = \alpha_x + \beta_x^{(1)}\kappa_t^{(1)} + \beta_x^{(0)}\gamma_{t-x}$	Renshaw e Haberman (2006)
CBD	$\eta_{x,t} = \kappa_t^{(1)} + (x - \bar{x})\kappa_t^{(2)}$	Cairns et al (2006)
M7	$\eta_{x,t} = \kappa_t^{(1)} + (x - \bar{x})\kappa_t^{(2)} + ((x - \bar{x})^2 - \sigma)\kappa_t^{(3)} + \gamma_{t-x}$	Cairns et al. (2009)
Plat	$\eta_{x,t} = \alpha_x + \kappa_t^{(1)} + (x - \bar{x})\kappa_t^{(2)} + (\bar{x} - x)^+\kappa_t^{(3)} + \gamma_{t-x}$	Plat (2009)
HUw	$y_t(x_i) = f_t(x_i) + \sigma_t(x_i)\varepsilon_{t,i}, i = 1,.., p \quad t = 1, \dots, n$	Shang et al. (2011)
CPspl	$\eta = Ba, \qquad B = B_t \otimes B_x$	Camarda (2019)
RSVD	$m(x,t) = d_1U_1(t)V_1(x) + \dots + d_qU_q(t)V_q(x) + \varepsilon(x,t)$	Huang et al. (2009)

Source: *Bravo et al.* (2021), Bravo and Ayuso (2020).

The base set comprises six GAPC-type models, parametric models of the generalized linear models (GLM) class that link the response variable to a linear or bilinear predictor that includes as explanatory variables the individual's age, *x*, chronological time *t* and generation (year) of birth (or cohort), *c = t - x* to which are added model identification restrictions, a link function and univariate series methods to obtain projections.

The random component of the models assumes that the number of deaths at age x in the year t follows a Poisson distribution $D_{x,t} \sim Poi(\mu_{x,t}E^{c}_{x,t})$ with $E(D_{x,t}/E^{c}_{x,t}) = \mu_{x,t}$ or a Binomial distribution with $D_{x,t} \sim Bin(q_{x,t}E^{0}_{x,t})$, with $E(D_{x,t}/E^{0}_{x,t}) = q_{x,t}$,, where $E^{0}_{x,t}$ and $E^{c}_{x,t}$ denote, respectively, the population initially or centrally exposed to risk, and $\mu_{x,t}$ and $q_{x,t}$ denote the mortality rate and the probability of death at age x in the year t . The systematic component of the model links the response variable ($q_{x,t}$ or $\mu_{x,t}$) to a linear predictor $\eta_{x,t}$.

$$\eta_{x,t} = \alpha_x + \sum_{i=1}^{N} \beta_x^{(i)} \kappa_t^{(i)} + \beta_x^{(0)} \gamma_{t-x},$$

where $exp(\alpha_x)$ represents the overall configuration of age-specific mortality, $\beta_x^{(i)} \kappa_t^{(i)}$ refers to a set of N age-period terms describing the overall trends in mortality, noting that $\kappa_t^{(i)}$ is a time index and $\beta_x^{(i)}$ a parameter of sensitivity by age, and $\gamma_{t-x} \equiv \gamma_c$ constitutes generational effects, with $\beta_x^{(0)}$ being a modulating parameter by age. The temporal and generational indexes, $\kappa_t^{(i)}$ and γ_{t-x} respectively, are stochastic processes, modeled through univariate ARIMA(p,d,q) time series methods using Box-Jenkins methodology.

The subset of GAPC models used in this study comprises: [LC] the Poisson-Lee-Carter model; [APC] the age-period-cohort model of Currie (2006); [RH] the extension of the Lee-Carter model including cohort effects and $\beta_x^{(0)} = 1$; [CBD] the Cairns-Blake-Dowd model $\beta_x^{(1)} = 1$ and $\beta_x^{(2)} = (x - \bar{x})$, where $\bar{x}$ denotes the mean age in the sample (Cairns et al, 2006); [M7] the extension of the CBD model including cohort effects;

[Plat] the model of Plat (2009) with $\kappa_t^{(3)} = 0$. Parameters are estimated using maximum-likelihood methods. The range of mortality projection methods used in the study also comprises the *Functional Demographic Model* (FDM) of Hyndman and Ullah (2007), the two-dimensional penalized P-Splines technique proposed by Camarda (2019), and the two-dimensional (by age and period) approach based on regularized principal component analysis proposed by Huang et al. (2009). The closure of life tables at the age limit $\omega = 125$ is based on the method of Denuit and Goderniaux (2005). The models are calibrated using mortality statistics available at INE and Human Mortality Database (2020).

The normal retirement age is projected considering the legislation in force in Portugal that indexes and evolution of to the evolution of life expectancy by period (Bravo, 2016; Bravo and Herce, 2020) using the following equation:

$$x_{R,t} = 66 + \frac{\theta_t}{12},\ com\ \ \theta_t = \frac{2}{3}\left[\sum_{j=2015}^{t} 12 \times \left(\dot{e}^{P}_{65}(t-2) - \dot{e}^{P}_{65}(t-3)\right)\right],$$

Where $\dot{e}_{65}^{P}(t)$ stands for the 65 year-old life expectancy calculated by time frame for the total population based on

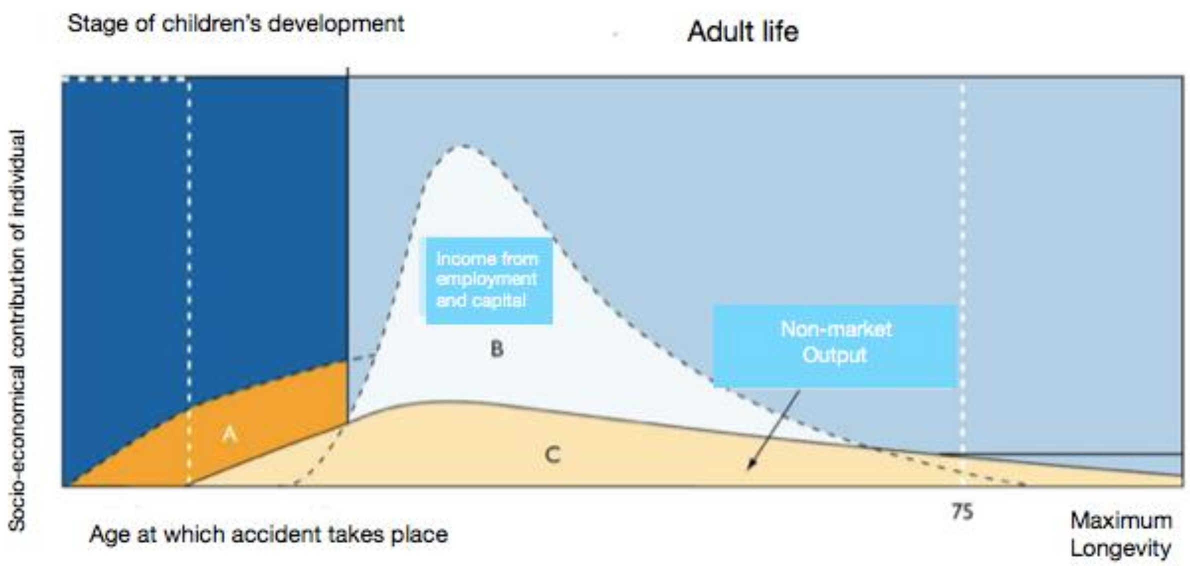
$$\dot{e}_{x,g}^{P}(t) := \frac{1}{2} + \sum_{k=1}^{\omega-x} exp\left(-\sum_{j=0}^{k-1} m_{x+j,g}(t)\right),$$

Where $m_{x,g}(t)$ denotes the mortality rate at the age x of the sex g. The normal retirement age in Portugal in 2019 was 66 years and five months and we project an almost linear growth of about one year per decade over the next decades.

In the estimation of the production loss, we also considered the gross value of non-market production lost as a consequence of the road crashes, including the value related to underage victims. To this end, we considered, as in international benchmark studies (e.g., BITRE, 2006), the loss of permanent or temporary non-market output associated with volunteer work, domestic work, services provided as formal or informal caregivers of children or adults with dependency and or disability that takes place during and after the end of working life and into old age. Figure 4.5 illustrates the socio-economic contribution of an individual over the life cycle. Area A corresponds to the losses associated with casualties - children and youth of developmental age (up to the age of majority), area B reflects the market contributions arising from the participation of individuals in the labor market in market activities and area C reflects the value of non-market output.

The values were estimated as a proportion of the gross value of the production of working-age workers decreasing exponentially with age from a maximum of 10%. In the case of children, the cost of educating a child up to the age of majority was used as an estimate of the value of market production (BITRE, 2006). As there are no estimated values for this cost in Portugal, we took as a reference 80% of the value estimated by age range for Spain by the international organization Save the Children, which obtained values for this country of 479€ a month between ages 0 and 3, 518€ a month between the ages of 4 and 6, 577€ a month between the ages of 7 and 12, and 588€ a month between the ages of 13 and 17.

Figure 4.5. Contribution to society over the life cycle



Source: Own elaboration based on BITRE (2006).

The gross production loss by degree of severity of the victims, disaggregated by age and sex, is calculated by aggregating the individual market and non-market losses $PPNM_{k,i}(t)$

$$PP(t) = \sum_{i=1}^{NV} \left(PPM_{k,i}(t) + PPNM_{k,i}(t)\right)$$

Where $k \in [VM, FG, FL]$ denotes the number of road crashes with victims, and *VM, FG* and *FL* denote the number of fatalities, seriously injured and slightly injured registered in 2019, respectively. The value obtained from equation translates the values corresponding to areas A, B and C in Figure 8.5 per traffic crash victim.

4.3.2. Human cost estimation

The WTP approach is adopted in the calculation of the statistical value of a human life and in the calculation of the human costs of road fatalities in Portugal. Table 4.3 summarizes the main national and supranational studies conducted internationally to estimate the VSL. The estimated values range from a minimum of 1 million euros (ExternE, EC 2005) to a maximum value of 4 million euros (Norwegian Ministry of Finance, 2012).

The study conducted by the OECD (OECD, 2012) is to date the largest meta-analysis of studies on the determination of VSL based on the WTP approach with stated preferences. The study is based on 261 estimated values for VSL from 28 studies conducted in OECD countries, and recommends for the countries of this organization (of which Portugal is part) a base value of 3 million US dollars, recommending for European Union (EU 27) countries a value of 3.6 million dollars (in 2005 prices), which translates into a value of 3 575,921 million euros in 2016 prices. Applying space and time corrections, the VSL value calculated for Portugal amounts to 2 766,424 euros per fatality.

To obtain the human costs, it is necessary to subtract the private consumption loss from the VSL as we mentioned above. In EC (2019) the estimate of the consumption loss made for the set of OECD countries is made assuming, by simplification, that fatalities lose, on average, 42 years of consumption, for a total of 668,000 euros. Considering that information on the age of the road crash victims is available in Portugal, we adopt in this study a more accurate approach by estimating the number of years of consumption lost based on the estimates of the remaining life (life expectancy) by age and gender at the date of the road crashes obtained in the previous section. As a result, the reference values for the human costs of a fatal traffic crash victim range from a minimum of 1.6 million euros to a maximum of 2.7 million euros.

To estimate the human costs of the severely and slightly injured, we follow international guidelines and quantify the cost by considering for these types of victims a percentage of the human costs of a fatality. Table 4.4 summarizes the values found in the main studies on the percentage of the VSL to apply to serious and light casualties. The values are very different across studies and countries and depend on the degree of severity of the injuries.

For Portugal, to calculate the human costs, we took as reference the values adopted by the European Commission (EC, 2019) and Wijnen & Stipdonk (2016), which place the percentage of the VSL between 10% and 16% in the case of seriously injured people and between 0.9% and 1.6% in the case of slightly injured people. In the baseline scenario, we consider 16% of the VSL (adjusted for private consumption loss) of a fatality for a seriously injured person and 1.3% of the VSL of a fatality for the slightly injured.

Table 4.3. Summary of the main international studies on the estimation of VSL

Supranational Studies	Country	Purpose	VOSL	Source
OECD	Countries member of OCDE	All areas	£3 million (3.6 million€)	Meta-analysis
ExternE (2005)	Europe	Air pollution	€1 million	ExternE
CE Delft (2008)	Europe	Roadway Accidents	€1.5million	HEATCO
(HEIMTSA, 2011)	Europe	Health	€1.65 million	Alberini (2006)
CE Delft (2008)	Europe	Roadway accidents	€1.67 million	UNITE
Ricardo et al (2014)	Europe	Roadway Accidents	€1.7 million	HEATCO
Ricardo et al (2014)	Europe	Air pollution	€1.65 million	HEIMTSA
WHO HEAT (2014)	Europe	Health	€3.4 million	OECD

National Studies				
Department for Transport (2007)	Ireland	Roadway Accidents	€1.3 million	Charty et al. (1999)
Abellan Perpinan et al. (2011)	Spain	Roadway Accidents	€1.3 million	Abellan Perpinan et al. (2011)
(Osterreichischer Verkehrssicherheitsfonds & BMVIT, 2012)	Austria	Roadway Accidents on Streets	€2.32million	HEATCO
Sachstandpapier Luft (2012)	Germany	Air pollution	€1.65 million	HEIMTSA
(DfT, 2012)	UK	Roadway accidents	1.1 million (~€1.4 million)	Charty el al. (1999)
Norwegian Ministry of Finance (2012)	Norway	All areas	30 million NOK (~€4.0 million)	NMF and OECD
(Commissariat general à la stratégie et à la prospective, 2013)	France	All area	€3.0 million	OECD
(Intraplan & Planco, 2014)	Germany	Roadway accidents	€1.3 million	HEATCO
(SWOV, 2014)	The Netherlands	Roadway accidents	€2.0 million	SWOV
(Trafikverket, 2015)	Sweden	Roadway accidents	€22.3 million SEK (~€2.4 M)	(Trafikverket, 2015)

Source: EC (2019), Ecoplan (2016).

Table 4.4. Summary of major studies on the percentage of the VSL to be applied to severely and slightly injured persons

Study	Country or Region	Serious Injuries with Long Term Incapacities	Serious Injuries with Short Term Incapacities	Standard serious Injury	Light Injury
Finland official	Finlândia	45.7%		0.5%	0.1%
Sweden official	Suécia			15.4%	0.7%
UK official	Reino Unido			11.4%	0.9%
Norway official	Noruega	55.2%		16.7%	2.9%
(Jones-Lee 1995)	Reino unido	15.1–87.5%	5.5–23.2%		
(ECMT, 1998)	Europa			13%	1%
(Trawén, et al., 1999)	Suécia	13.3–40.4%			0.5–32.1%
(Persson, et al., 2000)	Suécia	40%	11%	16%	1.5%
(Evans 2001)	Reino unido			11%	0.9%
(Persson 2001)	Suécia	40.4%	13.3%		0.9–1.8%
(UNITE 2001)	Europa	32.0%	9%	13%	1%
(Ecoplan, 2002)	Suiça	32.0%	9%		1%
(Goodbody, 2002)	Irlanda			13.9%	1%
(HEATCO, 2006)	Europa			13%	1%
(Sommer, et al., 2007)	Suiça	32%	3.5–15%		1%
(Hensher, et al., 2009)	Austrália	3–5%	0.9–1.2%		0.26–0.32%
(Institute of Transport Economics, 2010)	Noruega	51.1%	15.4%		1.8%
(Carlsson, et al., 2010)	Suécia			28.6%	
(dft, 2012)	Reino Unido			13.9%	1%
(Österreichischer Verkehrssicherheitsfonds & BMVIT, 2012)	Áustria			13%	1%
(Commissariat général à la stratégie et à la prospective, 2013)	França			15%	2%
(Ministry of Transport, 2013)	Nova Zelândia			10%	0.4%
(Intraplan & Planco, 2014)	Alemanha			13%	1%
(SWOV, 2014)	Holanda			12%	
(Ricardo-AEA, TRT, DIW Econ & CAU, 2014)	Europa			13%	1%
(bfu, 2015)	Suiça	37.3%	3.5–16.3%		0.4%
(B,S,S. Volkswirtschaftliche Beratung AG, 2015)	Suiça	33.6%	0.5–3.3%		0.03%
(irap, 2015)	Global			25%	
(Trafikverket, 2015)	Suécia			16.6%	0.65%
(Wijnen & Stipdonk, 2016)	Global			10-16%	0.9–1.6%

Source: EC (2019), Ecoplan (2016), Sommer, et al. (2007).

Once the human costs are calculated by severity of victims, disaggregated by age and sex, the total value of human costs $HC(t)$is obtained by aggregating the individual costs, i.e,

$$HC(t) = \sum_{i=1}^{NV} HC_{k,i}$$

where $k \in [VM, FG, FL]$, NV denotes the number of road crashes with casualties, and VM, FG and FL denote the number of fatalities, seriously injured and slightly injured recorded in 2019, respectively.

4.3.3. Application of the restitution cost method

The replacement or restitution cost method was applied in the calculation of medical costs, costs caused by property damage, administrative costs and in the residual other costs item using, whenever available, statistical information on market values. To this end, statistical information was collected from various institutions, among which we highlight the information on motor claims for insured vehicles obtained from the 2019 Automotive Technical Report made available by the Portuguese Insurers Association (APS), which contains, among others, information on the number of claims, number of insured vehicles, the total cost and average cost of claims. This information is fundamental in the evaluation of property damage.

For the quantification of the administrative costs statistical information and service price lists were collected from the safety forces (Public Safety Police and National Republican Guard), from fire departments, from the National Medical Emergency Institute, from the Ministry of Justice, from the Central Administration of the Health System, from the National Statistics Institute, from the Bank of Portugal, the Ministry of Health, from transport or rent-a-car companies, funeral undertakers, insurance companies, APS, ASF - Insurance and Pension Fund Supervisory Authority, among other institutions. In cases where it was not possible to obtain the statistical information or it does not have the necessary detail, the VTVA approach detailed above was applied.

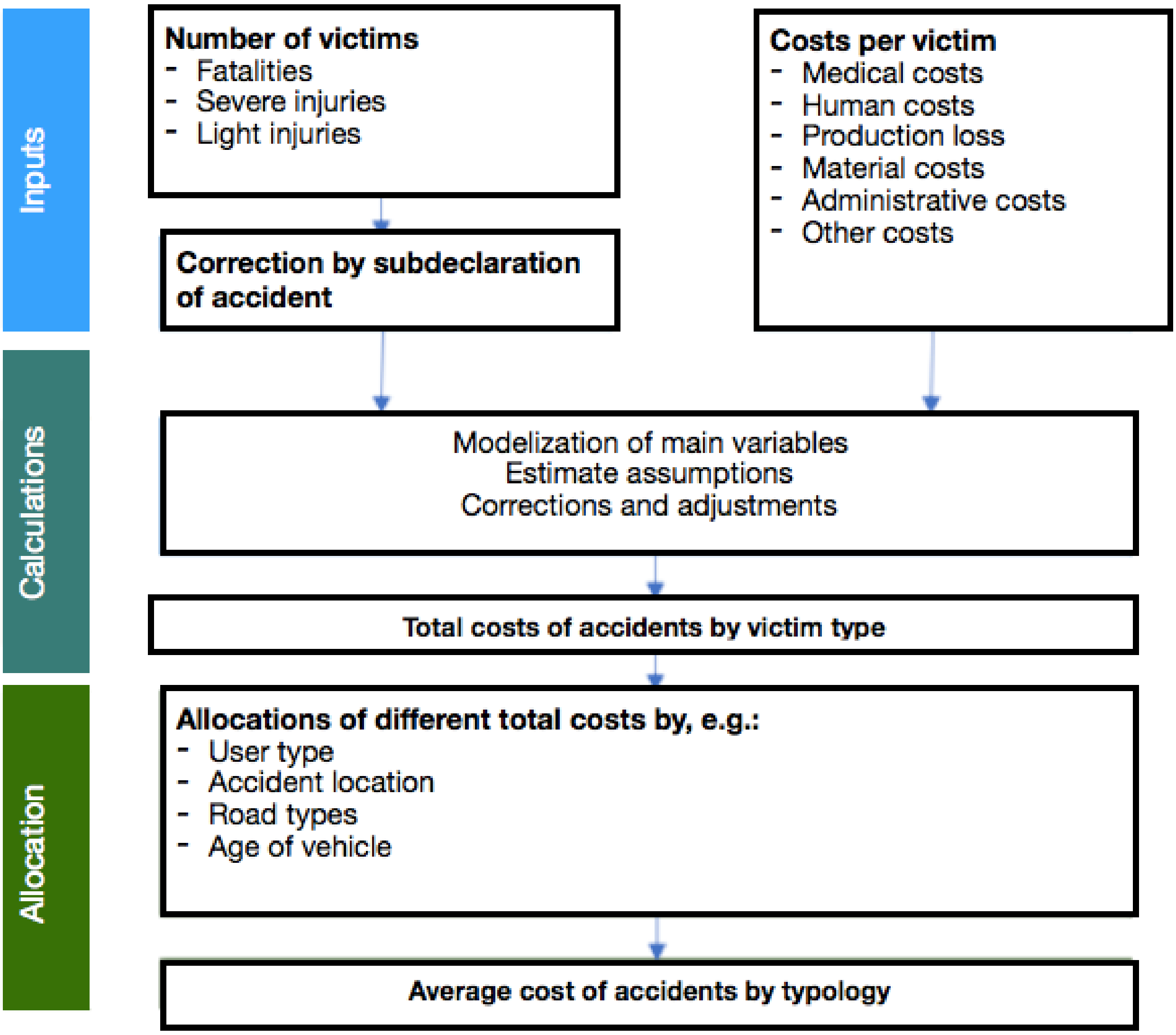
Once the medical costs, property damage, administrative costs, and other costs by type of victim have been calculated, the total value of these costs is obtained by aggregating the individual costs.

4.4. Framework of total and average cost calculation per victim type and road crash characteristics

Figure 4.6 summarizes the process of calculating the total and average economic and social costs of road traffic crashes adopted in this study. The costs are calculated using a top-down approach, using as inputs physical indicators of casualties by type of victim (fatalities, seriously injured and slightly injured) and the average costs calculated for the different cost components and type of victim. A correction factor for underreporting of road crashes with victims is considered, referring mainly to road crashes with only slightly injured.

Once the total and average costs by type of victim have been determined, it is possible to disaggregate the cost by type of user, location of the road crash, age of the vehicles, type of roads, lighting conditions, etc.

Figure 4.6. Framework for calculating average and total cost per victim and road crash



Source: Own elaboration based on EC (2019).

4.5. Synthesis of the evaluation methods by component of the economic and social cost

Tables 4.5 to 4.10 summarize the evaluation methods used to assess the economic and social cost of road fatalities by cost component and sub-component.

Table 4.5. Method for calculating output loss by cost component

Component	Sub Component	Method	Detail
Production Loss			
Main Components	a) Loss of mercantile production	**Human Capital (HC)**	Yearly per-capita-production (e.g. GDP/capita) x Estimated years of production lost Calculating gross value of production loss including the reduction of private consumption Consideration of loss of potential production Including an intertemporal discount factor
Other Components	b) Loss of non-mercantile production (e.g., domestic work, formal or informal carers, volunteering, etc.)	**Human Capital (HC)**	Calculation done through the estimate of nr of hours dedicated to non-mercantile production x Cost/Hour (e.g. average salary/hour) Including an intertemporal
Residual Components	c) Context costs / Friction	**Restitution Costs (RC)**	Recruitment and training of new employees and rehabilitation costs

Source: Own elaboration based on Wijnen et al. (2017).

Table 4.6. Method of calculating human costs by component

Component	Sub component	Method	Detail
Human Cost			
Main Components	a) Loss of human lives (loss of years of life)	Willingness to pay (WTP)	Calculation: (VOSL - Consumption reduction) multiplied by nr of fatalities. Individual WTP based on declared preference.
	b) Serious and Light injuries (loss o quality of life)	WTP	Severely injured: % VOSL x nr serious injury Lightly injured: % VOSL x nr light injuries
Residual	c) Human costs to family and friends	WTP	Included on WTP of fatalities or injured

Source: Own elaboration based on Wijnen et al. (2017).

Table 4.7. Method for calculating the value of property damage

Component	Sub component	Method	Detail
Property Damage			
Main Components	a) Intervening vehicles	Restitution Costs (RC)	Current cost of intervening vehicle repair or replacing it with equivalent vehicles Bottom Up Approach: Average cost of vehicle multiplied by nr of vehicles involved (potential non reported vehicles). Value/benefit transfer: Methos in cases where basic statistical info cannot be met.
Residual	b) Infrastructure, fixed objects in road, buildings, etc.	RC	Costs of repair or property replacement
	c) Tansported merchandise		
	d) Personal goods		

Source: Own elaboration based on Wijnen et al. (2017).

Table 4.8. Method of calculating medical costs by component

Component	Sub Component	Method	Detail
Medical costs			
Main Components	a) First aid at accident location and transportation	**Restitution Costs (RC)**	Calculated through the estimate of medical resources utilised (labor, equipment, etc.) Calculation: unit cost (e.g., per day of hospitalisation, per ambulance ride, per treatment, etc.) multiplied by nr of units (e.g., nr of ambulance trips, average duration of hospitalisation, frequency in non-hospital treatments, etc.) Value/Benefit transfer method for cases where basic statistical info cannot be found.
	b) Treatment at accident location and in emergency services in hopital	RC	
	c) In-patient hospital treatment	RC	
	d) Ambulatory hospital tretament	RC	
	e) Non-hospital treatment (rehabilitation centres, physiotherapists, etc)	RC	
Residual Components	f) Medication and aids	RC	

Source: Own elaboration based on Wijnen et al. (2017).

Table 4.9. Method of calculating administrative costs by component

Component	Sub Component	Method	Detail
Administrative costs			
Main Components	a) Costs with security forces	**Restitution Costs (RC)**	Unit costs with security forces (factor labor and capital) Non inclusion of prevention costs Bottom up Approach: Time spent on traffic accidents x unit costs Value/Benefit transfer method for cases where basic statistic info cannot be found.
	b) Costs with Fire Department and Civil Protection Services	RC	Unit costs with Fire Department and Civil Protection Services. Bottom-up Approach
	c) Costs with vehicle insurance	RC	Administrative costs associated to car insurance
	d) Judicial costs	RC	Judicial costs and prison costs in case of incarceration. Bottom-up Approach
Residual Components	e) Outros custos com seguros	RC	Administrative costs associated to other insurances (e.g. health insurance)

Source: Own elaboration based on Wijnen et al. (2017).

Table 4.10. Method of calculating other costs by component

Component	Sub Component	Method	Detail
Other costs			
Main Components	a) Funeral costs	**Restitution Costs (RC)**	Difference between current funeral cost and future end-of-life discounted cost; Remaining life expectancy estimate by gender and age
	b) Costs with traffic congestion	RC	Lost time due to traffic congestion caused by traffic accidents Calculation: Unit (Hh) x Cost/ Hour Potential inclusion of pollution costs and extra fuel consumption costs Value/Benefit transfer method for cases where basic statistic info cannot be found.
Residual Components	c) Non availability of vehicle	RC	Vehicle reposition costs (e.g. rent-a-car and loss of time)
	d) Follow up of hospitalized victims	RC	Costs with hospitalised victims' monitoring (materials, time)
	e) Moving costs and/or housing adaptation	RC	Moving costs and/or housing adapation

Source: Own elaboration based on Wijnen et al. (2017).

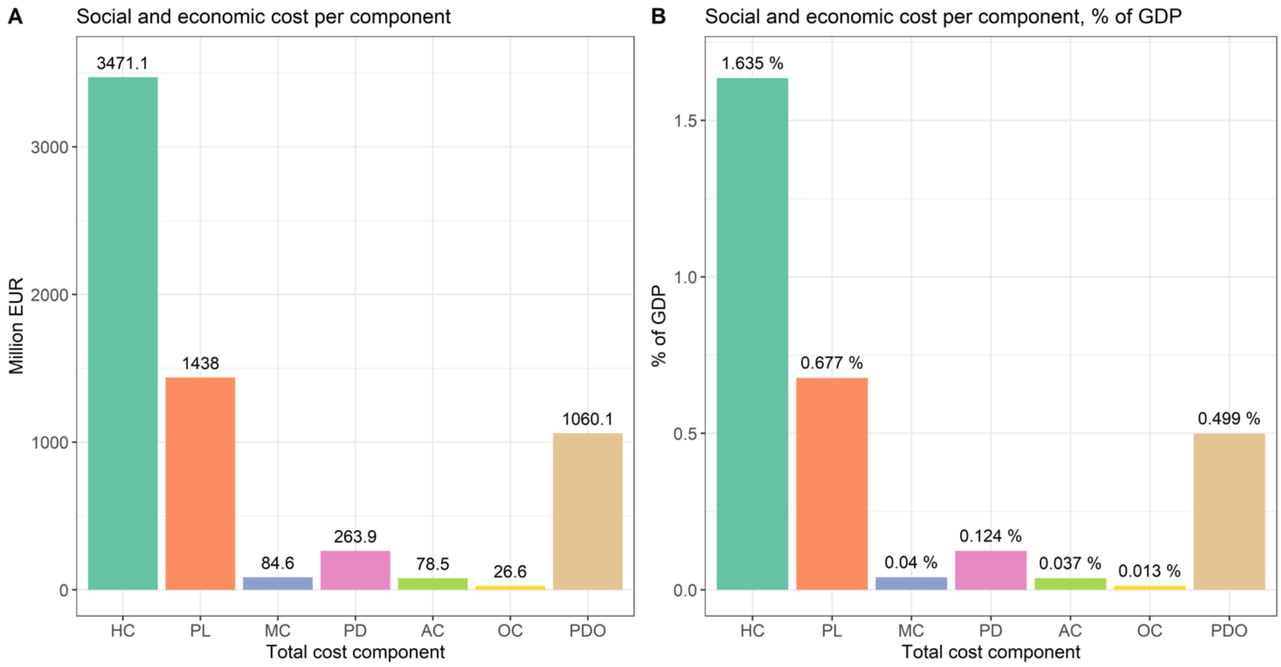
5. Estimates of the economic and social cost of road fatalities

In this chapter we present the estimates of the economic and social cost of road fatalities with victims in mainland Portugal in the year 2019, disaggregated by cost components and degree of severity of victims (fatalities, seriously injured and slightly injured) and by road crash characterization (day of the week, month of the year, type of vehicles involved, location in the territory, age of the vehicles involved, type of traffic lanes and nature of the road crash).

5.1. Total economic and social cost

Figure 5.1 represents the total economic and social cost of road crashes recorded in Portugal in 2019, disaggregated by components of the total cost (absolute values in million euros (Panel A) and as a percentage of the wealth created in the country (GDP) at current prices (Panel B). The information is complemented in Table 5.1.

Figure 5.1. Total economic and social cost by cost component, 2019



Source: Own elaboration. **Notes**: HC: human costs; PL: production loss; MC: medical costs; PD: property damage; AC: administrative costs; OC: other costs; PDO: road crash costs with only property losses. Figures in millions of euros and as a percentage of 2019 GDP at current prices.

Traffic crashes recorded in Portugal in 2019 had an estimated economic and social cost to the country of €6 422.9 million, a figure that represents 3.03% of the wealth created in the country that year. Of this total cost, the largest share (83.5% of the total) is related to road crashes with victims, totaling 5 362.7 million euros (2.53% of GDP), with the remaining 1 060.1 million euros (0.5% of GDP) referring to road crashes without victims that generated only property damage. If the estimated value of non-market production is considered in the country (estimated in this study at 0.7% of GDPmp based on the valuation of the total hours of voluntary work calculated in the 2018 voluntary work survey (INE)), accidents at work are recorded in Portugal in 2019 had a social and social cost for the country estimated at 3% of GDP (2.51% if we exclude road crashes without victims).

Table 5.1. Total economic and social cost of traffic crashes, 2019

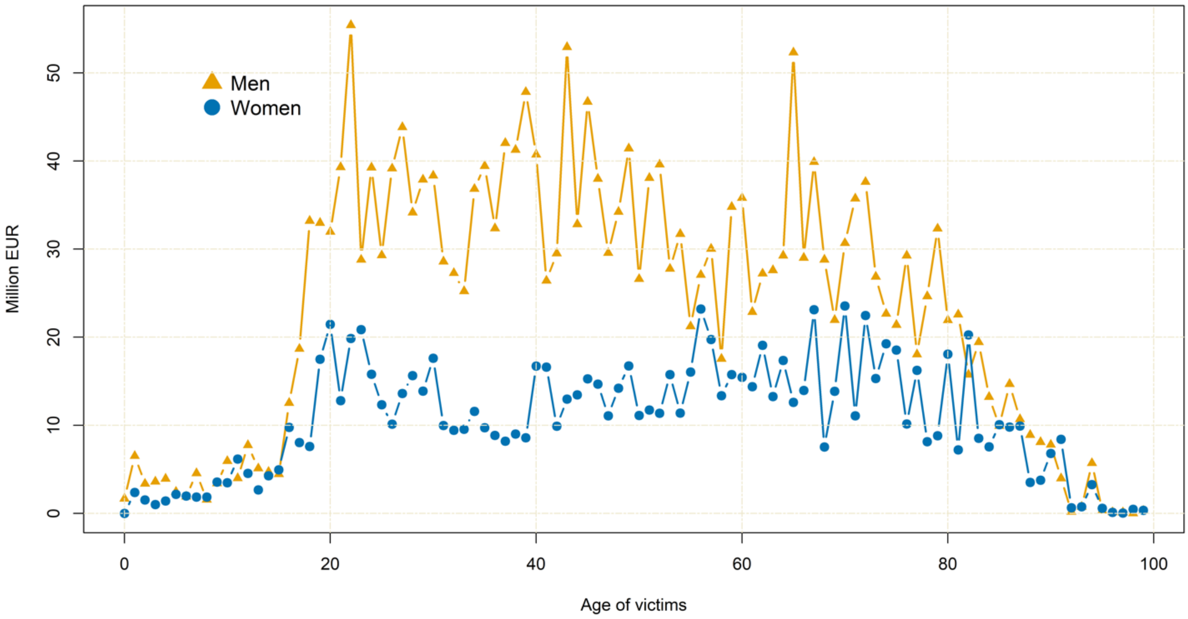
Social and Economic Cost Component	Millions EUR	Structural Tax	In GDP %
Human Costs (HC)	3471.1	64.7%	1.63%
Production Loss (PL)	1438.0	26.8%	0.68%
Medical Costs (MC)	84.6	1.6%	0.04%
Property Damage (PD)	263.9	4.9%	0.12%
Administrative Costs (AC)	78.5	1.5%	0.04%
Other Costs (OC)	26.6	0.5%	0.01%
Total Accidents with victims	**5262.7**	**100.0%**	**2.53%**
Accidents without victims (PDO)	1060.1		0.50%
Total	**6422.9**		**3.03%**

Source: Own elaboration. **Note:** Numbers at 2019 price value.

Among the road crashes with victims, the largest component of the total cost, representing 64.7% of this value, is related to human costs (HC) estimated at 3 471.1 million euros (1.635% of GDP). The second most significant component (representing 26.8% of the total) relates to gross production loss (GP), estimated at €1 438 million (0.677% of GDP) in 2019. Together, human costs and gross production loss represent 91.5% of the total cost of traffic crashes in Portugal. Property damage (PD) caused by traffic crashes with victims is estimated at €263.9 million (0.124% of GDP). Costs for medical treatment of road crash victims are estimated at €84.6 million (0.04% of GDP), while administrative costs are quantified at €78.5 million (0.037% of GDP). Other costs amount to €26.6 million (0.013% of GDP). If we consider also road crashes with only material damage without victims, the damage to property resulting from road crashes with and without victims is estimated at €1 324.1 million (0.62% of GDP).

Figure 5.2 represents the total human costs of road traffic crashes by age and sex of the victims, providing a more detailed perspective on the impact of road traffic crashes in these dimensions. We note that in almost all ages the human costs are higher among male victims (drivers, passengers, pedestrians) when compared to female victims, the greatest differences are found in the ages corresponding to active life, where there were the highest number of road crashes in Portugal in 2019. Human costs with male victims represent 68.7% of the total and are particularly high in the ages between 18 and 65. Human costs with underage victims amounted to 157.7 million euros in 2019, corresponding to a total of 3,764 victims, including 20 fatalities, 136 seriously injured and 3,608 minor injuries.

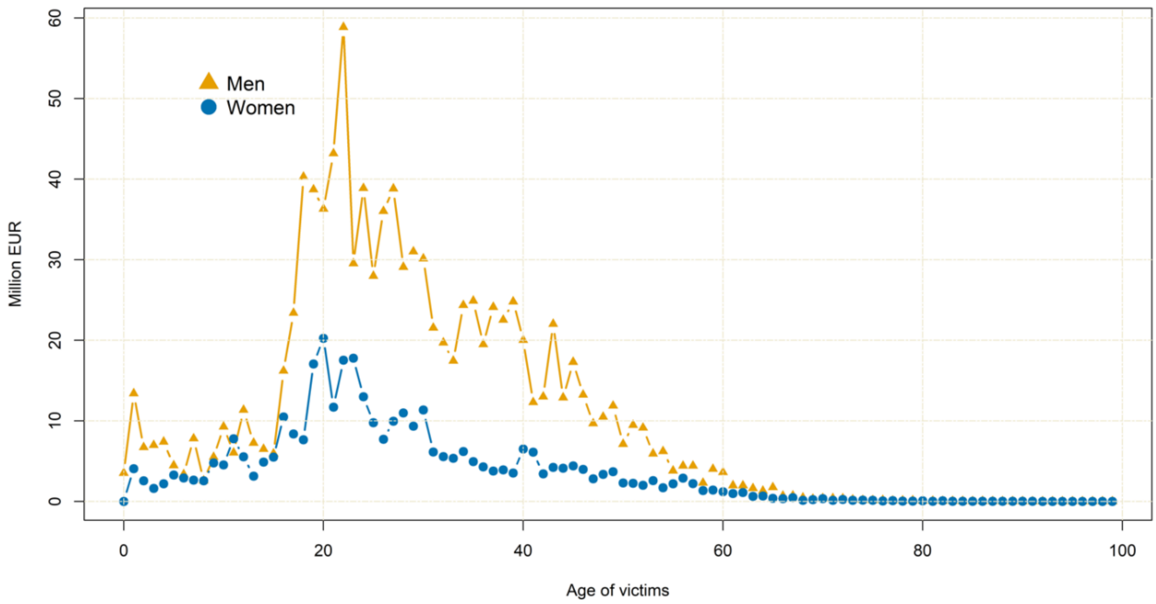
Figure 5.2. Total human costs by age and sex of victims



Source: Own elaboration. **Note:** Numbers in millions of euros refer to road crashes with victims.

Figure 5.3 represents the gross production loss from road traffic crashes by age and sex of victims. Again, at almost all ages, the gross production loss is higher for male victims compared to female victims, with the largest differences at early working ages. At these ages, the total life expectancy and the remaining life expectancy in the labor market are higher, so the occurrence of a traffic crash, especially with severe consequences for the affected road users, has more impact on the potential contribution of victims to wealth generation. The gross value of output loss naturally declines with age in both sexes, mainly due to the lower remaining longevity of victims in the labor market as the statutory retirement age approaches, and the value of non-market output is also lower, especially at older ages.

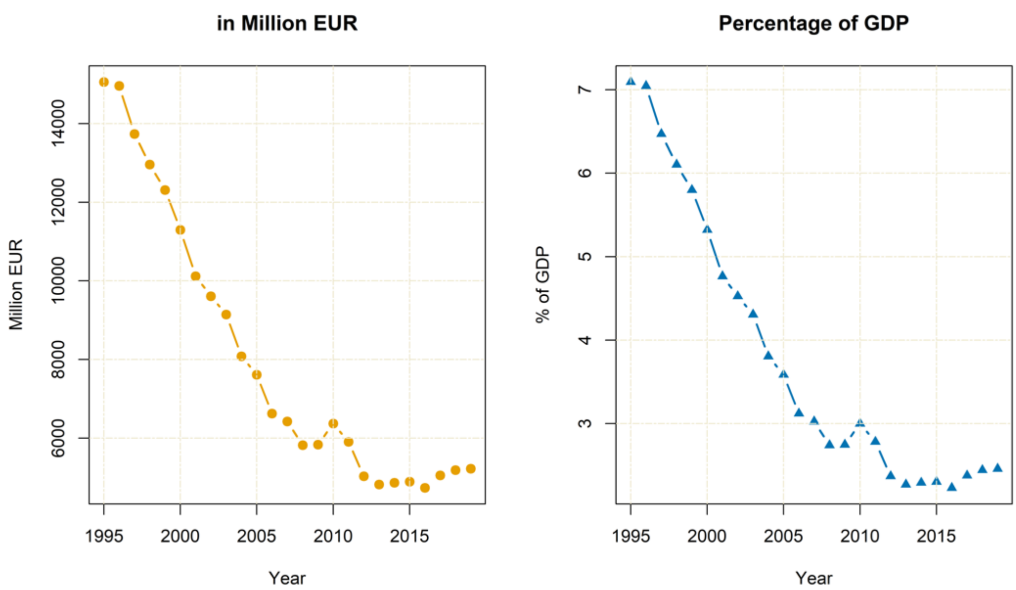
Figure 5.3. Gross production loss by age and sex of victims



Source: Own elaboration. **Note:** Numbers in millions of euros refer to road crashes with victims.

Figure 5.4 represents the evolution between 1995 and 2019 of the total economic and social cost of road crashes with victims recorded in Portugal, both in absolute value (million euros) and as a percentage of the wealth created in 2019. In this exercise it is assumed that the average cost per type of victim is calculated using the estimates ascertained in this study for the year 2019.

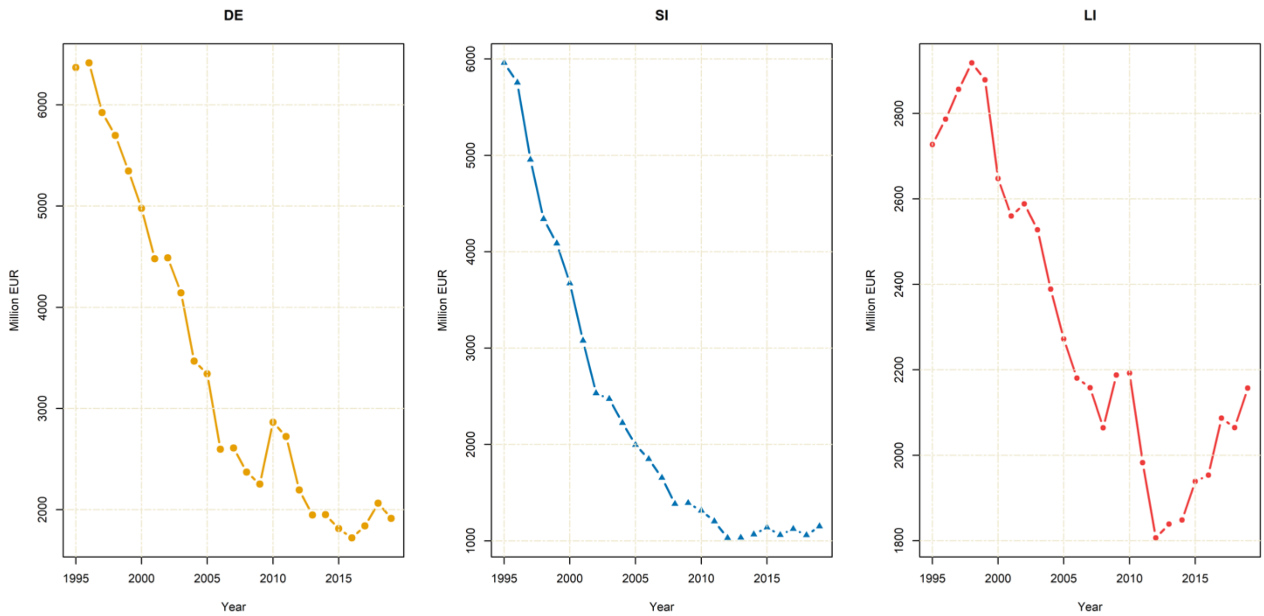
Figure 5.4. Evolution of the total cost of traffic crashes 1995-2019



Source: Own elaboration. **Notes**: Values in million euros calculated using the estimated average cost per type of victim and road crash at 2019 prices referring only to road crashes with victims. Values in percent of GDP calculated using the 2019 GDPmp value.

Figure 5.5 complements the information by presenting the trajectory of the total cost per type of victim. The significant reduction in the economic and social cost of road fatalities in the last 25 years is noteworthy, from an annual value that reached more than 7% of GDP to a value that has stabilized in recent years around 2.5% of GDP at current 2019 prices.

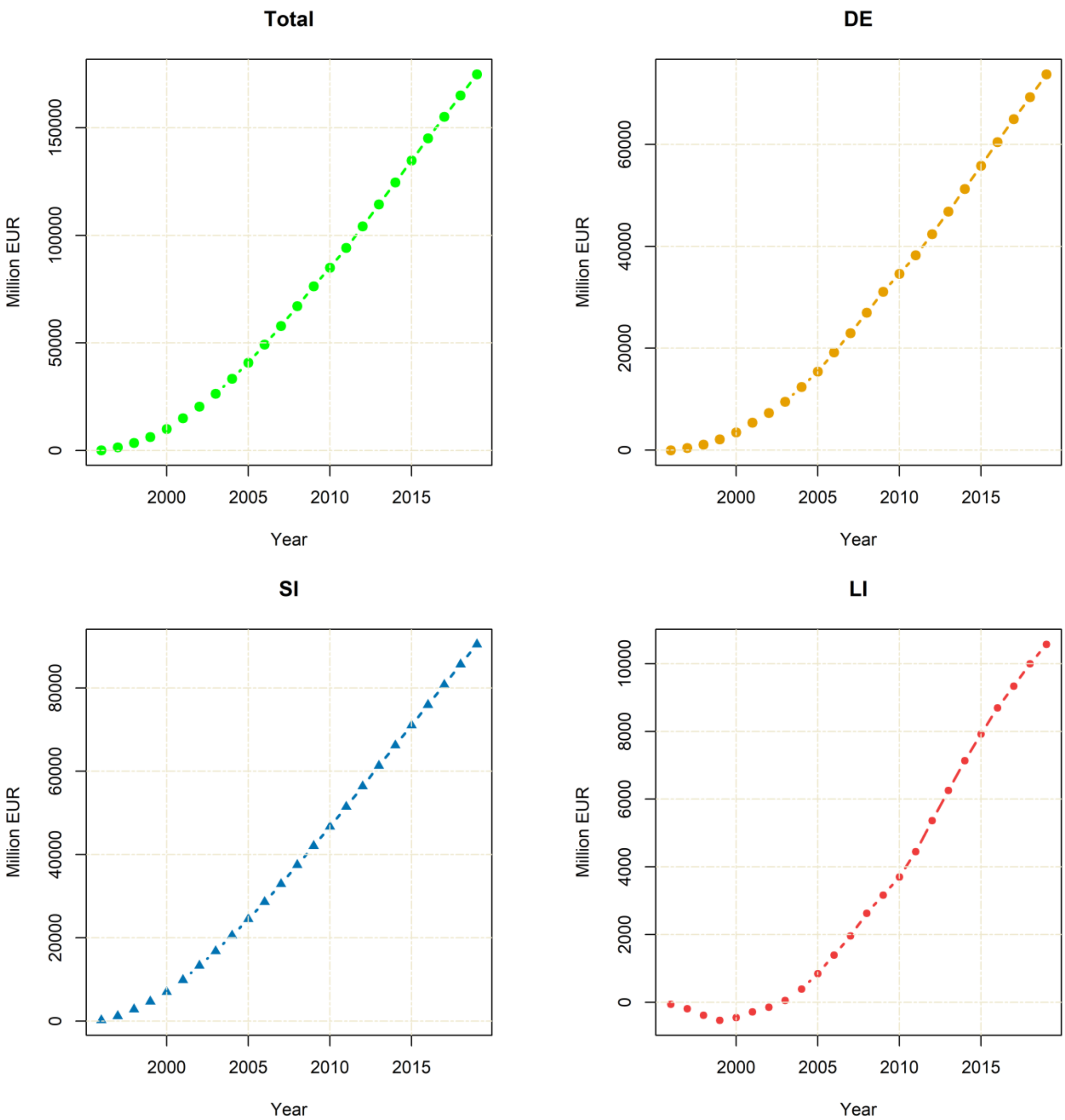
Figure 5.5. Evolution of total cost of traffic crashes by type of victim, 1995-2019



Source: Own elaboration. **Notes**: Values in million euros calculated using the estimated average cost per type of victim and road crash at 2019 prices referring only to road crashes with victims. Values in percent of GDP calculated using the 2019 GDPmp value. MV: fatalities; FG: seriously injured; FL: slightly injured.

The main contribution to the annual reduction in the economic and social cost of road crashes was made by the significant gains recorded in the reduction in the number of victims with a higher degree of severity, highlighting in particular the 70% reduction in the number of fatalities in this period and the 80,7% decrease in the number of seriously injured. In recent years, however, there has been a reversal in the downward trend in the number of slightly injured people, resulting in a significant increase in the cost to society of this type of road crash. Figure 5.6 shows the cumulative economic and social costs avoided with the reduction in road fatalities that occurred between 1995 and 2019, disaggregated by type of victim.

Figure 5.6. Cumulative costs avoided through the reduction of fatalities between 1995 and 2019: Total and by type of victim



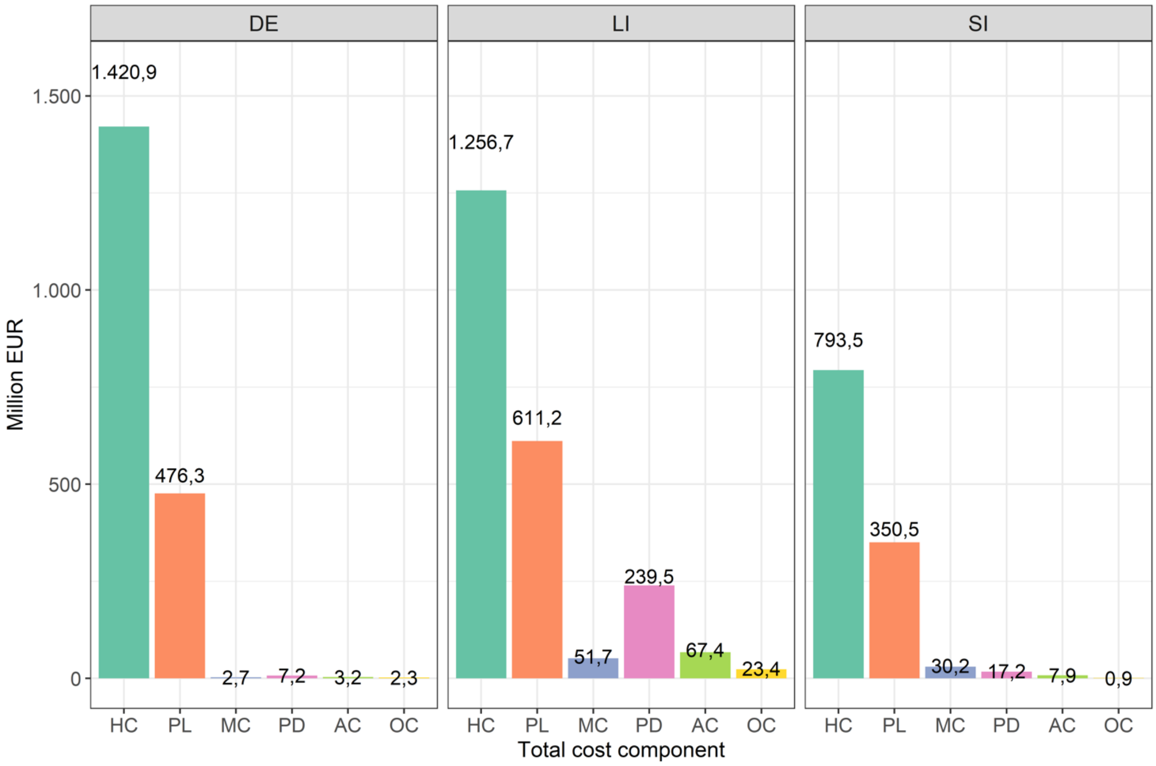
Source: own elaboration. **Notes**: Values in million euros calculated using the estimated average cost per type of victim and road crash at 2019 prices referring only to road crashes with victims. DE: fatalities; SI: seriously injured; LI: slightly injured.

Compared to 1995 values, the improvement in road safety indicators has avoided the loss of 24,140 lives by 2019, and a cumulative reduction of 170,456 seriously injured and 211,615 slightly injured. This reduction in fatalities translates into a reduction in economic and social costs to society estimated at 174 810 million euros, a figure that corresponds to about 82.3% of the wealth created in Portugal in 2019. As shown in Figure 5.6, the main contribution to saving society these economic and social costs comes from the reduction in the most serious road crashes.

5.2. Economic and social cost by type of victim

Figure 5.7 and Table 5.2 present disaggregated information on the economic and social cost of road casualties from road crashes with victims (i.e., excluding ODP-type road crashes) by severity of victims and cost components, both in absolute value and as a percentage of wealth created in 2019.

Figure 5.7. Economic and social cost by type of victim and cost component, 2019



Source: Own elaboration. **Notes**: HC: human costs; PL: production loss; MC: medical costs; PD: property damage; AC: administrative costs; OC: other costs; Values in millions of euros referring only to road crashes with casualties. DE: fatalities; SI: seriously injured; LI: slightly injuries.

Table 5.2. Total economic and social cost by type of victim and cost component

Social and Economical Cost Component	Total Cost per Victim Type (Million EUR)			
	Total	VM	FG	FL
Human Costs (HC)	3471.1	1420.9	793.5	1256.7
Production Loss (PL)	1438.0	476.3	350.5	611.2
Medical Costs (MC)	84.6	2.7	30.2	51.7
Property Damages (PD)	263.9	7.2	17.2	239.5
Administrative Costs (AC)	78.5	3.2	7.9	67.4
Other Costs (OC)	26.6	2.3	0.0	23.4
Total	5362.7	1912.7	1200.2%	2249.9
In GDP % 2019	2.53%	0.90%	0.57%	1.06%

Source: Own elaboration. **Notes**: Numbers in millions of euros at 2019 price value refer to road crashes with victims. VM: fatalities; FG: seriously injured; FL: slightly injured.

It is observed that the moral, immaterial or non-property costs (human costs) of traffic crashes are particularly important in the case of fatalities and seriously injured, but their value is also substantial in slightly injured being even higher than the value of costs in seriously injured for the high number of victims (43,183) recorded in 2019.

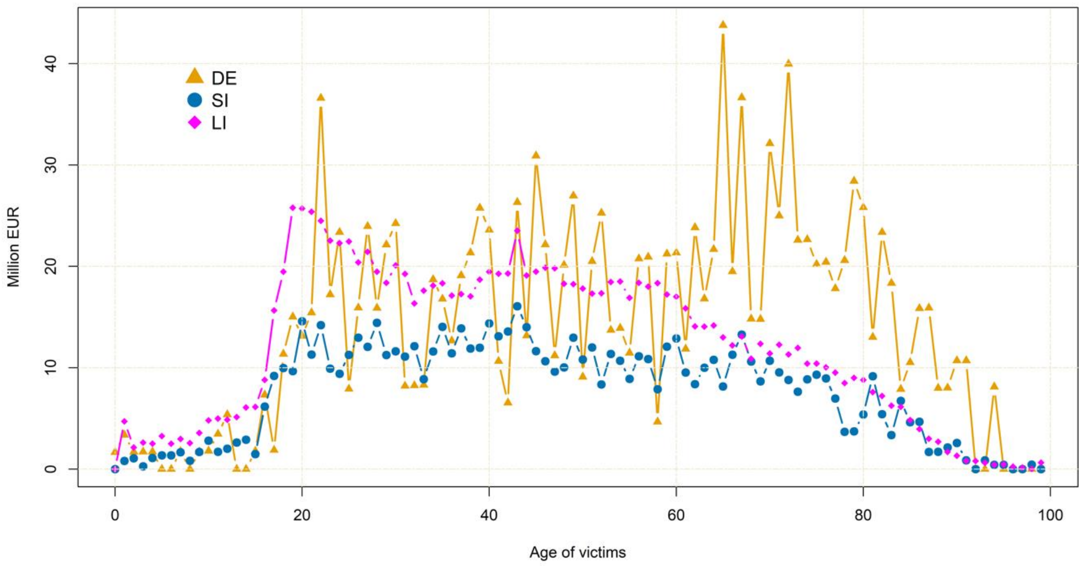
The costs associated with lost production are quite significant in all three categories of victims, but particularly high in the case of the slightly injured due to the high number of work days/hours lost and the prolonged impact on productive capacity in the case of the seriously injured. Medical costs, property damage and administrative costs are generated to a large extent by the slightly injured road crashes.

Notwithstanding the very high costs of the loss of human victims, mainly of a non-property nature, the costs referring to slightly injured represent the largest share of the economic and social cost of road crashes with victims registered in Portugal in 2019, a total of 2 249.9 million euros (1.06% of GDP), a value mainly explained by the human costs, by the loss of productive potential and by the material damage.

The second most important share of the total cost of casualty road crashes is associated with fatalities, which accounted for a total of €1 912.7 million (0.90% of GDP) in 2019. The economic and social costs related to the seriously injured amounted to €1 200.2 million, which is equivalent to 0.57% of 2019 GDP at current prices.

When we disaggregate the total human costs of road traffic crashes by age and severity of the victims (Figure 5.8), we observe that the fatalities have the greatest impact in the vast majority of ages. We note, however, the important contribution of the slightly and seriously injured to the human costs, mainly due to the high number of victims of this type recorded annually and to the ages at which the road crashes occur. The seriousness of road crashes involving older age users is also noteworthy, where the weight of fatalities and seriously injured in relation to total victims is more than double that recorded at younger ages.

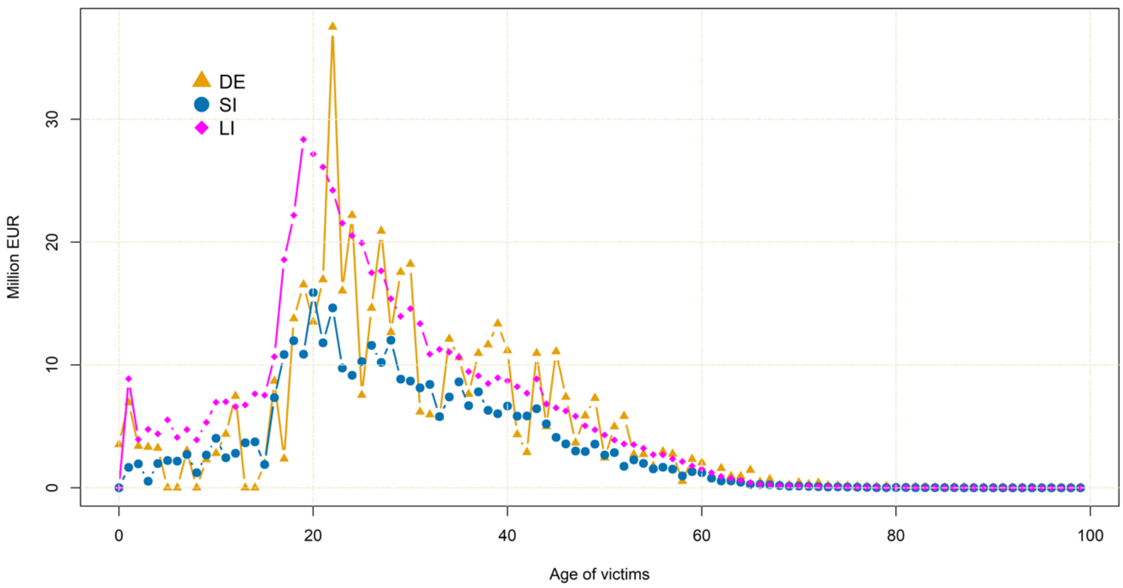
Figure 5.8. Total human costs by age and severity of victims



Source: Own elaboration. **Notes:** DE: fatalities; SI: severely injured; LI: slightly injured. Numbers in millions of euros refer to road crashes with victims.

Figure 5.9 represents the gross value of production loss caused by traffic crashes by age and severity of victims. In addition to the significant impact of young age fatalities on the country's productive potential, we again point out the consequences of the high number of slightly injured people at working ages on the country's wealth creation capacity. The gross value of production loss decreases with age across all victim types, for the reasons mentioned above.

Figure 5.9. Gross production loss by age and severity of victims



Source: Own elaboration. **Notes:** DE: Fatalities; SI: Severely injured; LI: Slightly Injured. Numbers in millions of euros refer to road crashes with victims.

Table 5.3 presents detailed information on the estimates for the year 2019 of the average cost of traffic crashes with victims by degree of severity of the victims and component of the total economic and social cost (values in thousands of euros).

Table 5.3. Average cost by type of victim and component of total cost

Social and Economical Cost Component	Total Cost per Victim Type (Million EUR)			Average Cost per victim
	VM	FG	FL	
Human Costs (HC)	2269.837	350.943	27.902	72.425
Production Loss (PL)	760.927	155.023	13.570	30.005
Medical Costs (MC)	4.334	13.344	1.148	1.765
Property Damages (PD)	11.555	7.622	5.317	5.507
Administrative Costs (AC)	5.067	3.483	1.497	1.637
Other Costs (OC)	3.638	0.413	0.519	0.555
Total	3055.358	530.828	49.953	111.894

Source: Own elaboration. **Notes:** VM: fatalities; FG: severely injured; FL: slightly injured. Numbers in millions of euros refer to road crashes with victims. Average total cost of all road crashes with victims including the estimate of road crashes not reported to the safety forces.

The average cost is naturally higher in the case of fatalities, amounting to €3 055,358 million per fatal victim, a figure mainly explained by the high moral, immaterial or non-patrimonial costs for the victims' families and friends (€2 269,837 million) and the value of the gross loss of production (€760,927 per victim).

The average cost to society of a seriously injured person is estimated at 530,828 euros per victim, resulting mainly from the value attributed to the physical pain and psychological and emotional damage caused to the injured and their families as a result of the injuries and medical treatment required for recovery, the suffering, the absence from family, social and professional life, the loss of quality of life, the damage caused to physical appearance and the temporary or permanent consequences in the victims' capacity for personal and social affirmation (350,943 euros per victim), the value of the gross loss of productive capacity for the country (155,023 euros per victim), and the average medical costs associated with this type of victim (13,344 euros).

The average cost to society of a slightly injured person is naturally much lower than that of a fatal victim and of a seriously injured person, and is estimated at 49,953 euros per victim, summing all the cost components, where human costs (27,902 euros), the value of lost production (13,570 euros) and costs of a material nature assume predominance. The average cost of one victim for all road crash victims estimated in 2019 (i.e., including the estimate of road crashes not reported to the safety forces) is estimated at €111,894 per victim.

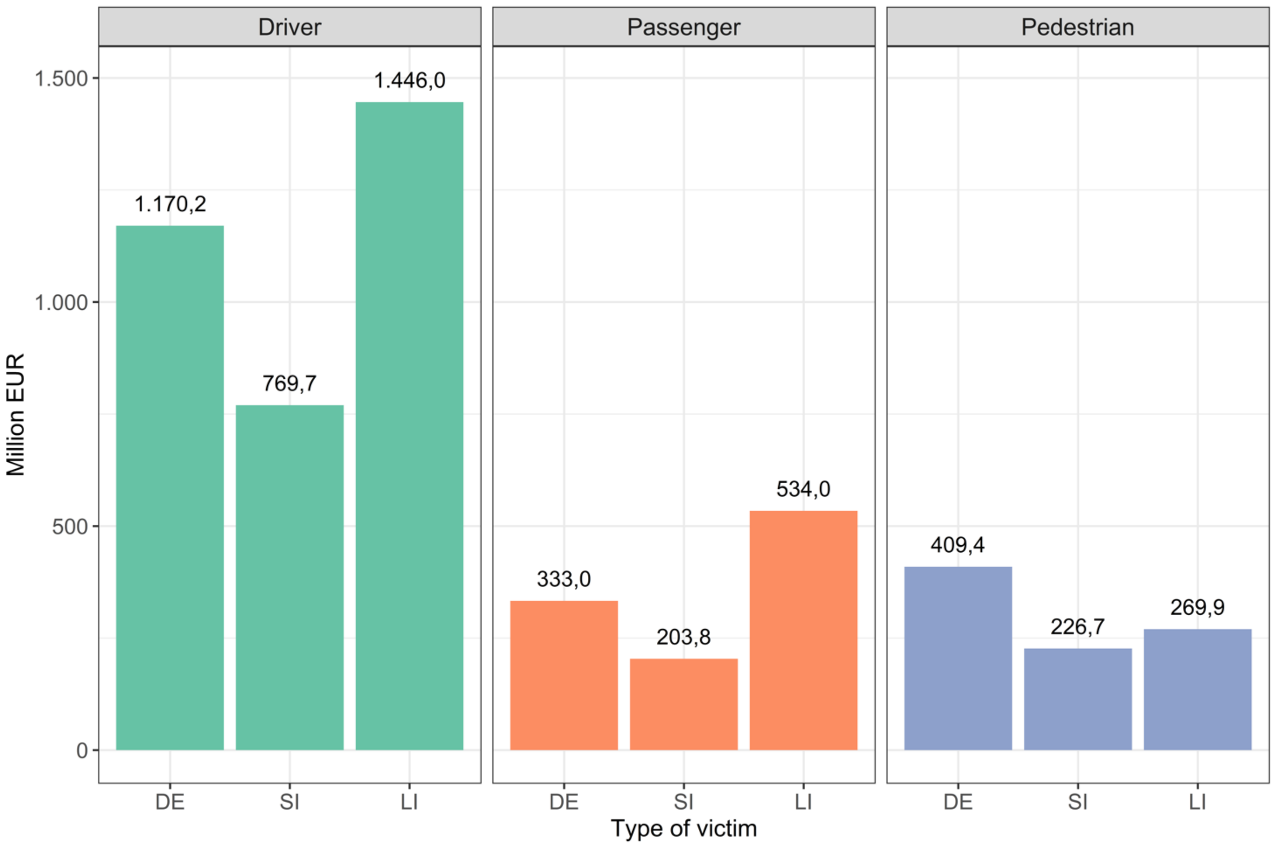
5.3. Economic and social cost by type of user

Figure 5.10 represents the estimated total costs of road crashes with victims recorded in 2019 disaggregated by user and victim type. It can be seen that the largest contribution to the human costs of traffic crashes is made by road crashes involving the drivers of the vehicles themselves as victims (€3 385.9 million), followed by road crashes from which passenger victims result (€1 070.9 million) and road crashes from which pedestrian victims result (€906.0 million).

The total cost to society in 2019 of driver victims breaks down to €1 170.2 million associated with drivers who died as a result of the road crash, €769.7 million on account of seriously injured victims, and €1 445.99 million associated with drivers who suffered only minor injuries.

The total cost to society of passenger victims recorded in 2019 breaks down as €333.03 million for passengers who died as a result of the road crash, €203.84 million on account of the seriously injured and an estimated €534 million for passengers who suffered only minor injuries.

Figure 5.10. Total costs by user and victim type, 2019

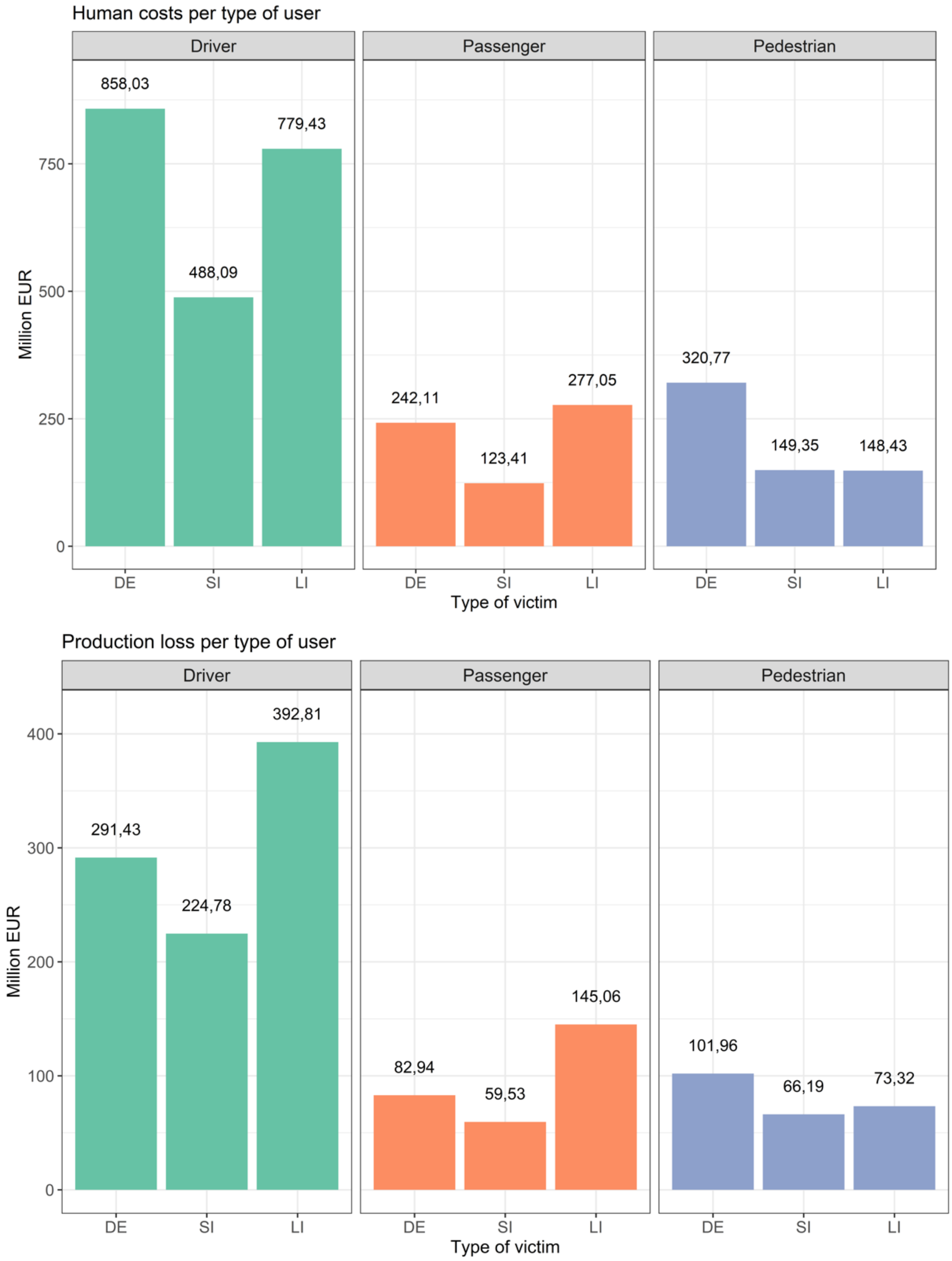


Source: Own elaboration. **Notes:** DE: fatalities; SI: severely injured; LI: slightly injured. Numbers in millions of euros refer to road crashes with victims.

The total cost for pedestrian victims is broken down into €409.42 million for pedestrians who lost their lives as a result of the traffic crash, €226.66 million on account of seriously injured pedestrians and an estimated €269.9 million for pedestrians who suffered minor injuries.

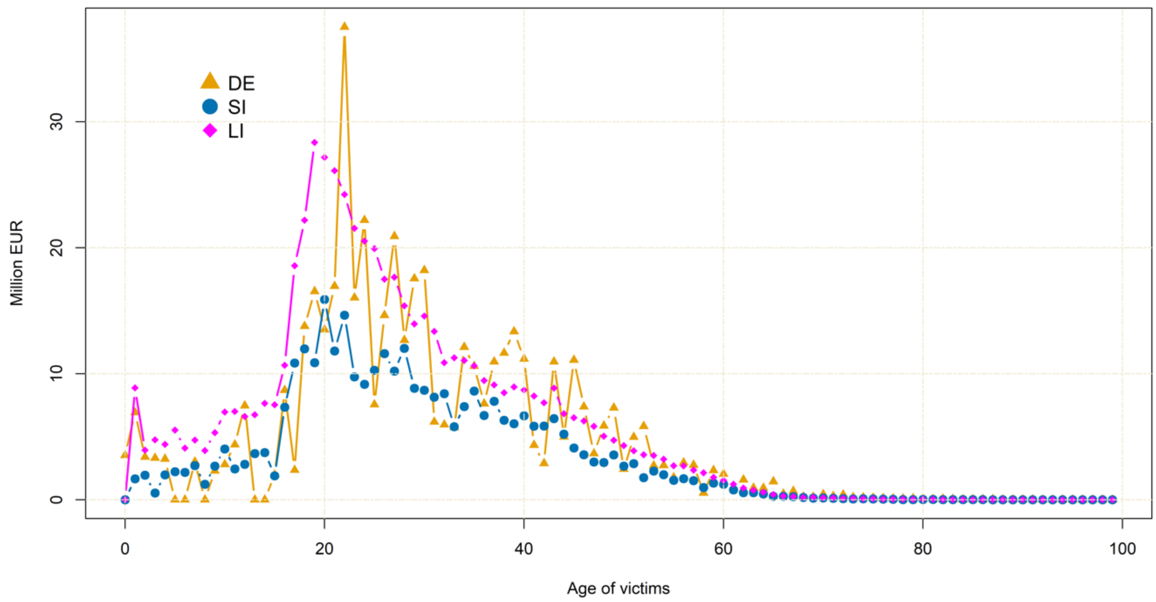
Figure 5.11 complements the analysis of total costs by user type by presenting the estimated values for the main components of the total cost: human costs and gross value of production loss.

Figure 5.11. Human costs and production loss by user type, 2019



Source: Own elaboration. **Notes:** DE: fatalities; SI: severely injured; LI: slightly injured. Numbers in millions of euros refer to road crashes with victims.

Figure 5.12. Value of production loss by type of user and age, 2019



Source: Own elaboration. **Notes:** DE: fatalities; SI: severely injured; LI: slightly injured. Numbers in millions of euros refer to road crashes with victims.

5.4. Economic and social cost per road crash

5.4.1. According to the type of victims caused by the road crash

Table 5.4 summarizes the information on the average number of victims and their typology per 100 traffic crashes with victims recorded in 2019 in mainland Portugal. In 2019, 35,704 road crashes with victims were registered in Portugal. For every 100 road crashes with victims, 1.753 fatalities, 6.072 seriously injured and 120.947 minor injuries were recorded. In the particular case of the 573 road crashes in which there were fatalities, for every 100 road crashes 109.25 fatalities, 22.339 seriously injured and 44.154 slightly injured were recorded. For every 100 of the 2,421 road crashes in which there were fatalities and/or seriously injured, 25.857 fatalities, 89.55 seriously injured and 42.255 minor injuries were recorded.

In the particular case of the 1,941 road crashes from which only serious or minor injuries resulted, for every 100 road crashes in 2019, 110.39 seriously injured and 41.667 minor injuries were recorded. Finally, in the more common case of the 33,283 road crashes in which only slightly injured were recorded, per such 100 road crashes 126.671 slightly injured were reported.

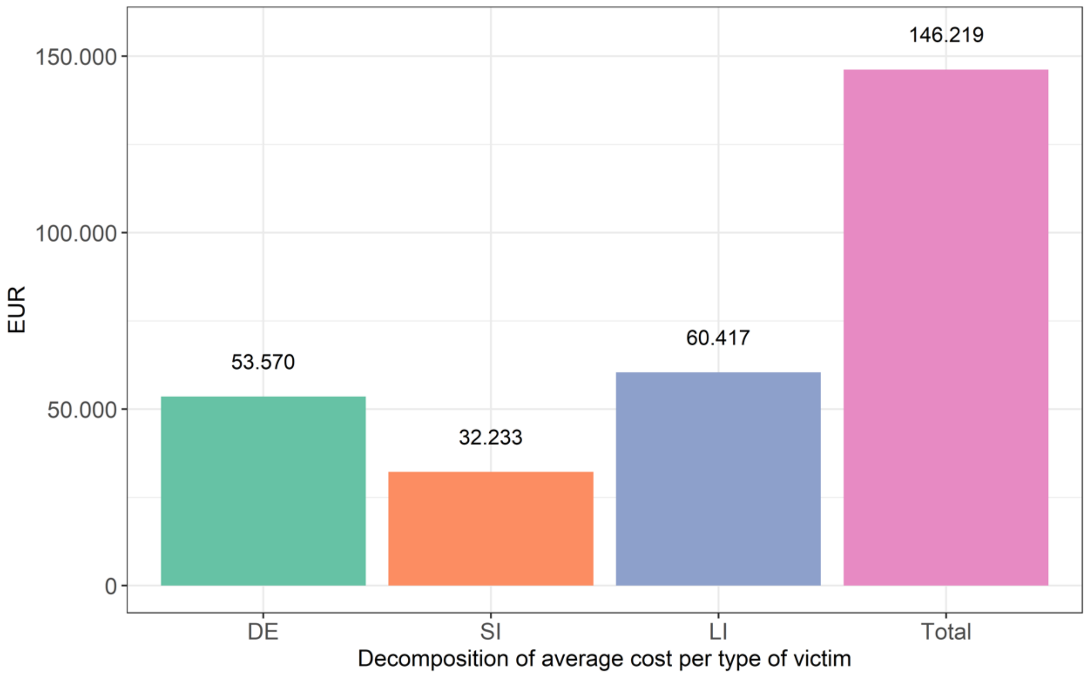
Table 5.4. Average number and type of victims per 100 traffic crashes recorded in 2019

Type of Accident	Nr. Accidents	VM	FG	FL
Accident w/ victims	35704	1,753	6,072	120,947
Accident w/ fatalities	573	109,250	22,339	44,154
Accident w/ fatalities or severe injuries	2421	25,857	89,550	42,255
Accident w/ injured but without fatalities	1941	0,000	110,390	41,667
Accident w minor injuries	33283	0,000	0,000	126,671

Source: Own elaboration. **Notes**: VM: fatalities; FG: severely injured; FL: slightly injured. Numbers in millions of euros refer to road crashes with victims.

Figure 5.13 represents the estimate in euros of the average economic and social cost of a road crash with casualties at 2019 prices. The cost is estimated at €146,219 per road crash, of which €53,570 is attributable to the resulting fatalities, while €32,233 and €60,417 are attributable to the seriously injured and slightly injured, respectively. In the case of road crashes with victims, the greatest contribution (41.3%) to the total cost is generated by the slightly injured resulting from the road crash.

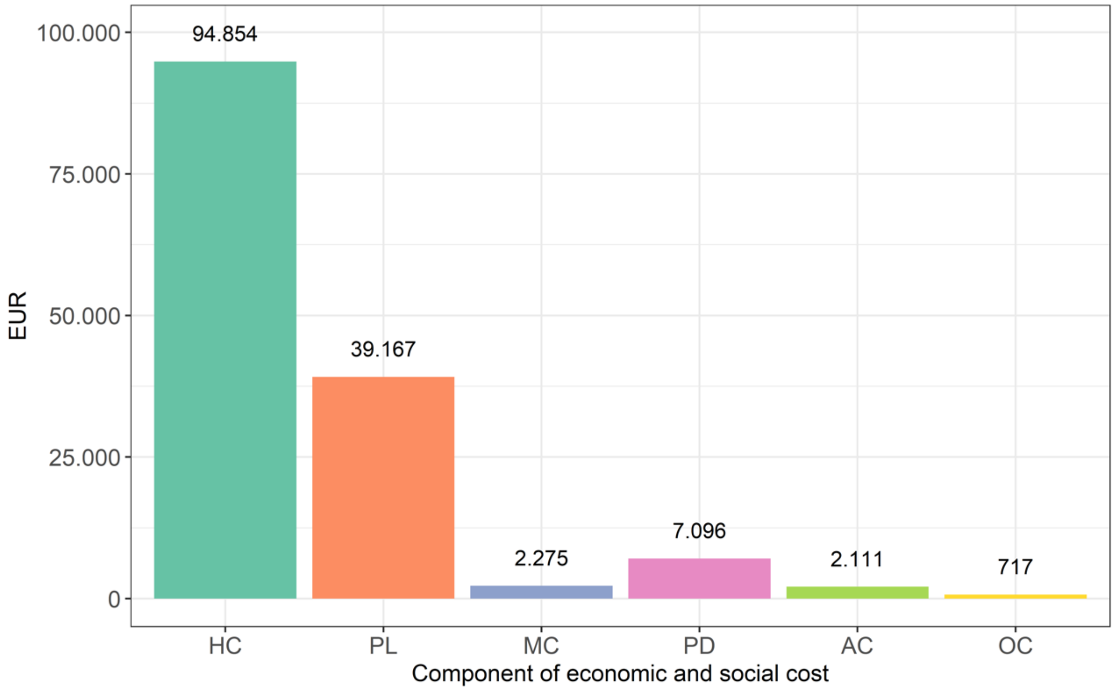
Figure 5.13. Estimate of the average cost of a road crash with victims, 2019



Source: Own elaboration. **Notes**: DE: fatalities; SI: severely injured; LI: slightly injured. Numbers in euros refer to road crashes with victims.

The breakdown of the average cost of a casualty road crash by economic and social cost components (Figure 5.14) shows that the largest share of the cost is related to human costs (94,854 euros per road crash), followed by the value of lost production as a result of the road crash (39,167 euros), property damage (7,096 euros) and medical costs (2,275 euros).

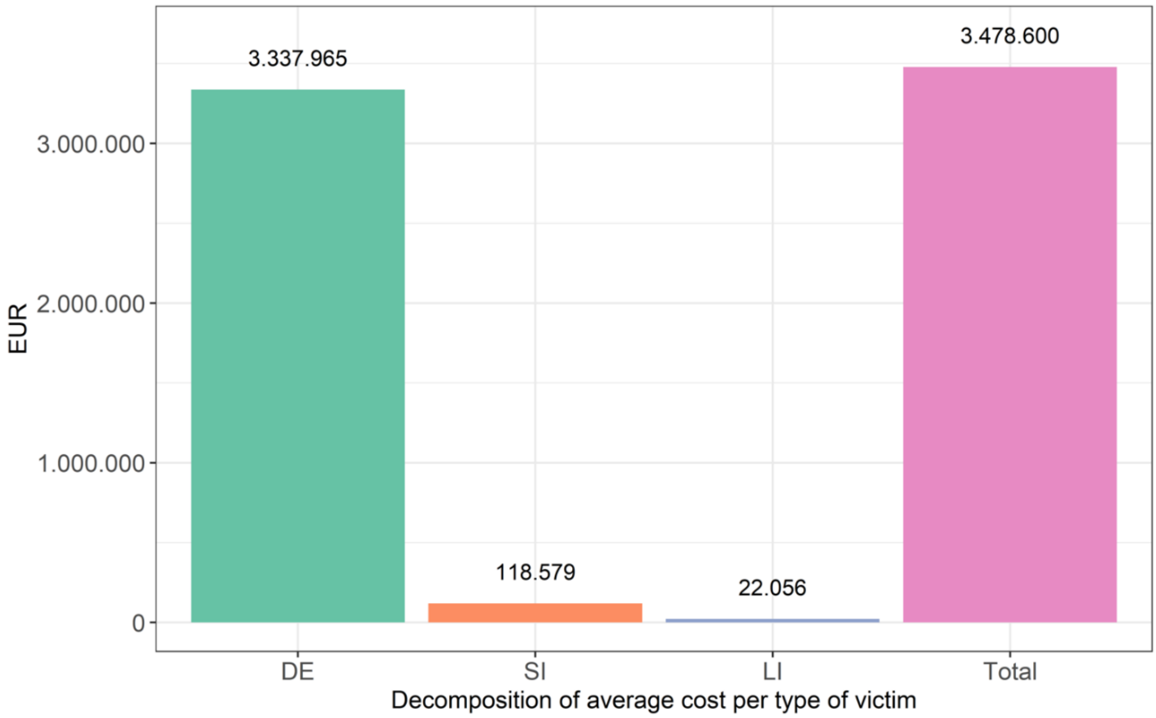
Figure 5.14. Breakdown of the average cost of a road crash with victims, 2019



Source: Own elaboration. **Notes**: HC: human costs; PL: production loss; MC: average cost; PD: property damage; AC: administrative costs; OC: other costs.

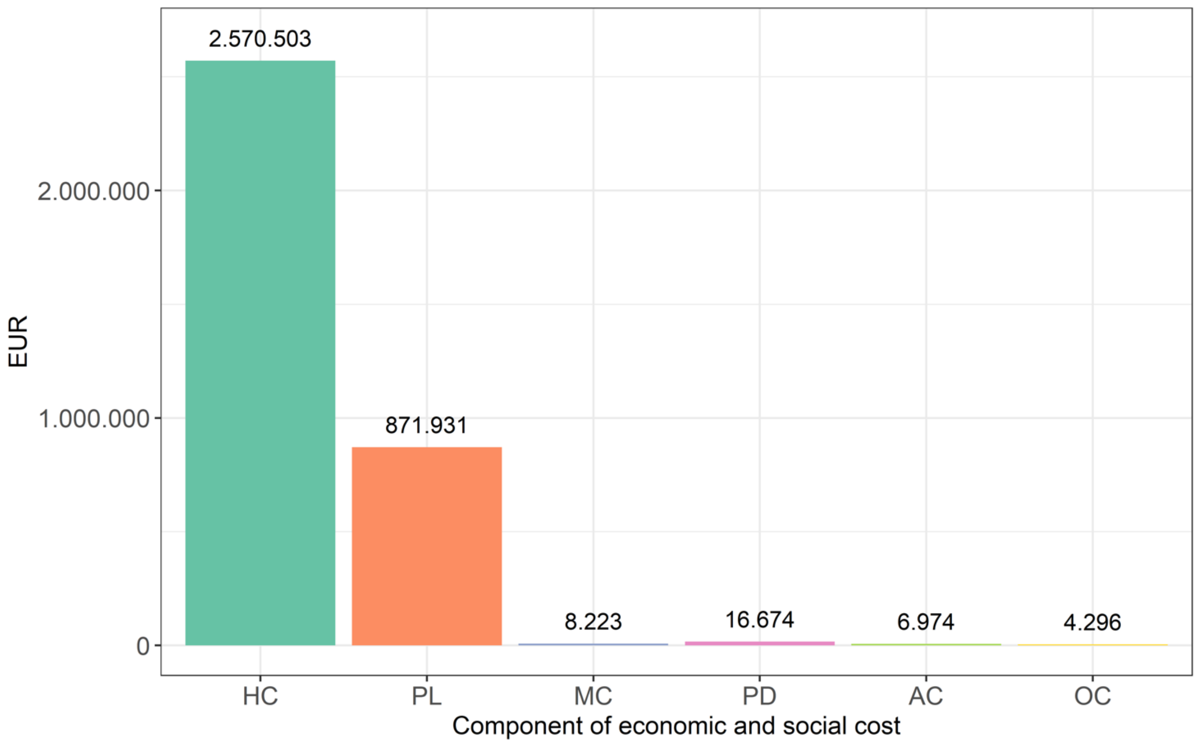
For road crashes with at least one fatality, the estimated average cost to society is much higher and amounts to €3 478.6 million per road crash in 2019 prices (Figure 5.15). The justification for this high figure stems from society's valuation of the human costs associated with road fatalities (€2 570,503), as well as the loss of production (€871,931) from the loss of a human victim (Figure 5.16).

Figure 5.15. Estimated average cost of a fatality road crash, 2019



Source: Own elaboration. **Notes**: DE: fatalities; SI: severely injured; LI: slightly injured. Numbers in euros refer to road crashes with victims.

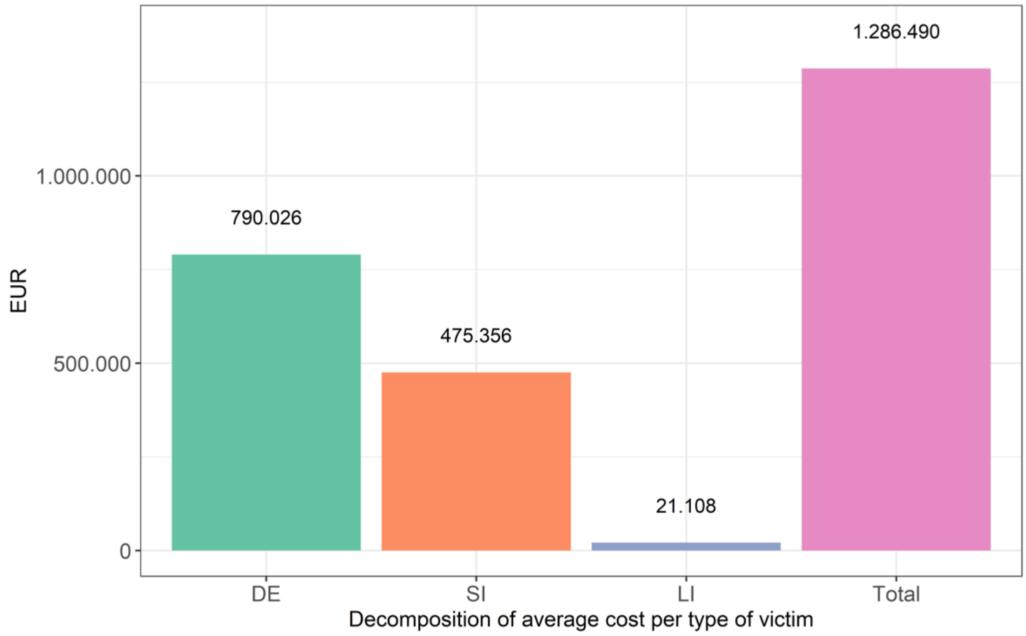
Figure 5.16. Breakdown of the average cost of a road crash with fatalities, 2019



Source: Own elaboration. **Notes**: HC: human costs; PL: production loss; MC: average cost; PD: property damage; AC: administrative costs; OC: other costs.

The estimated average economic and social cost of a road crash resulting in at least one fatality and/or one seriously injured person amounts to €1 286.49 million per road crash in 2019 prices (Figure 5.17). The largest share of this figure relates to the victims with the highest degree of severity (€7 900.26, corresponding to 61.4% of the total), followed from the seriously injured resulting from the road crash (€475,356, or 36.9% of the total) and €211,008 referring to the slightly injured.

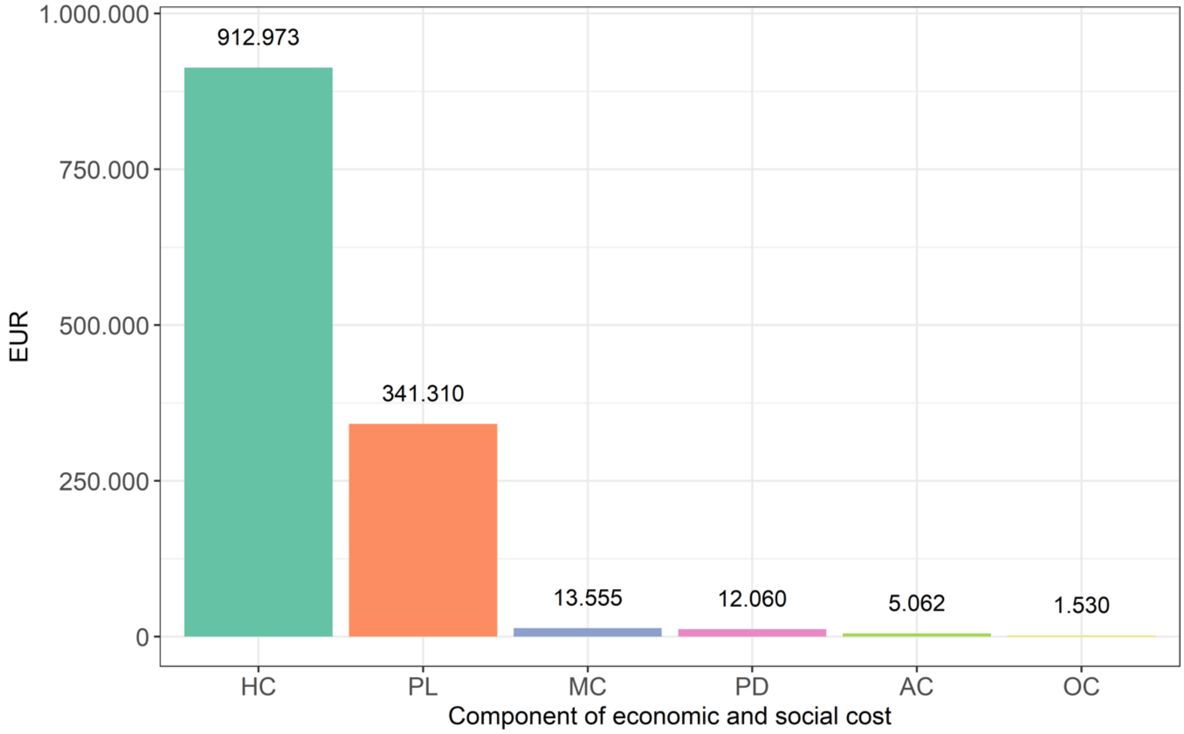
Figure 5.17. Estimated average cost of a road crash with fatalities or seriously injured, 2019



Source: Own elaboration. **Notes**: DE: fatalities; SI: severely injured; LI: slightly injured. Numbers in euros refer to road crashes with victims.

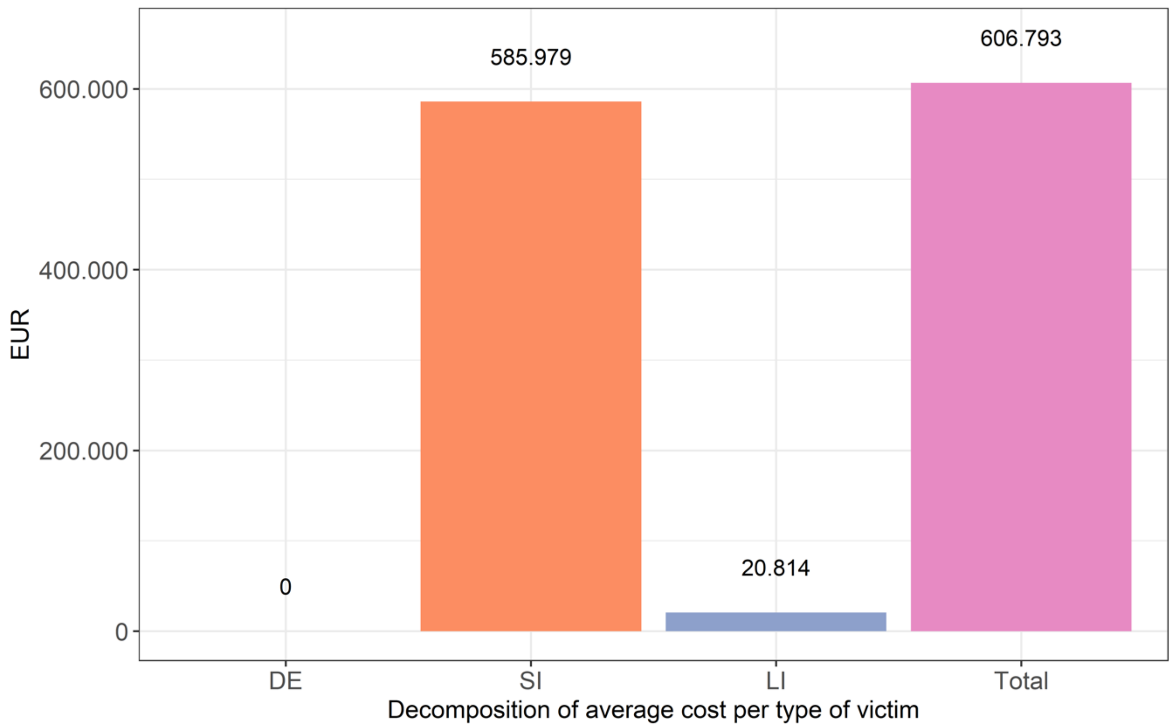
The breakdown of the average cost estimate by economic and social cost components (Figure 5.18) shows that the largest share of the cost is related to human costs (€912,973 per road crash), followed by the value of production loss as a result of the road crash (€341,310), medical costs (€13,555) and property damage (€12,060). For road crashes from which only injuries (serious or minor) resulted, the estimated average economic and social cost of a road crash amounts to €606,793, values in 2019 prices (Figure 5.19). The largest share of this amount relates to injuries with the highest degree of severity (€585,979, corresponding to 96.6% of the total), followed by minor injuries resulting from the road crash (€20,814, or 3.4% of the total).

Figure 5.18. Breakdown of the average cost of a road crash with fatalities or seriously injured, 2019



Source: Own elaboration. **Notes**: HC: human costs; PL: production loss; MC: average cost; PD: property damage; AC: administrative costs; OC: other costs.

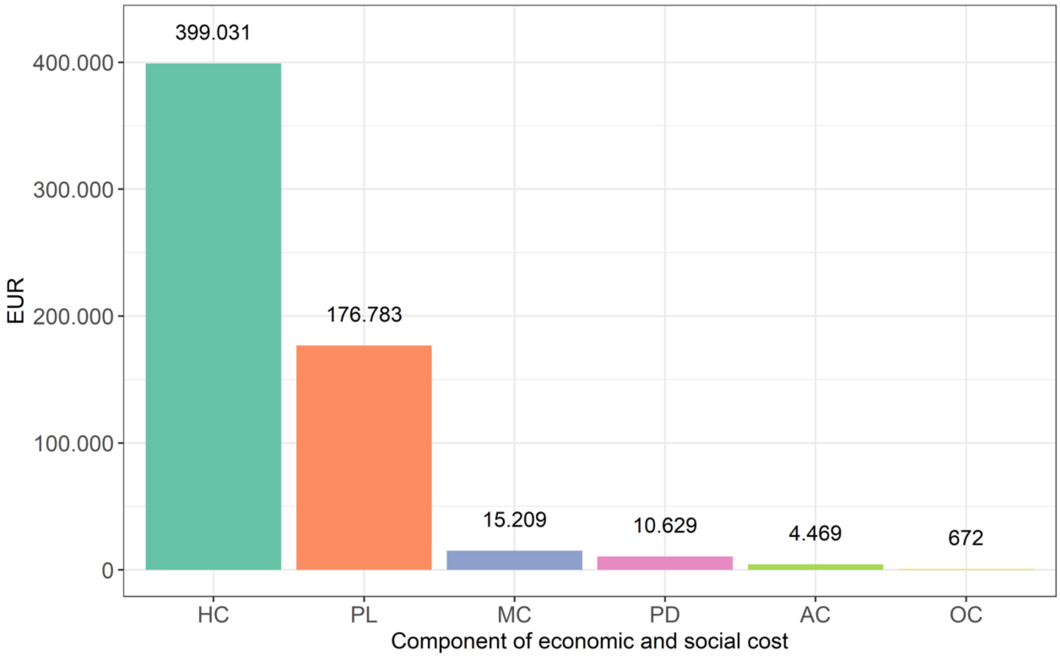
Figure 5.19. Estimated average cost of a road crash with injuries only, 2019



Source: Own elaboration. **Notes**: DE: fatalities; SI: severely injured; LI: slightly injured. Numbers in euros refer to road crashes with victims.

Disaggregating this estimate by components of the economic and social cost (Figure 5.20), we find that the most important share is related to human costs (€399,031 per road crash), followed by the value of lost production as a result of the road crash (€176,783), medical costs (€15,209) and property damage (€10,629).

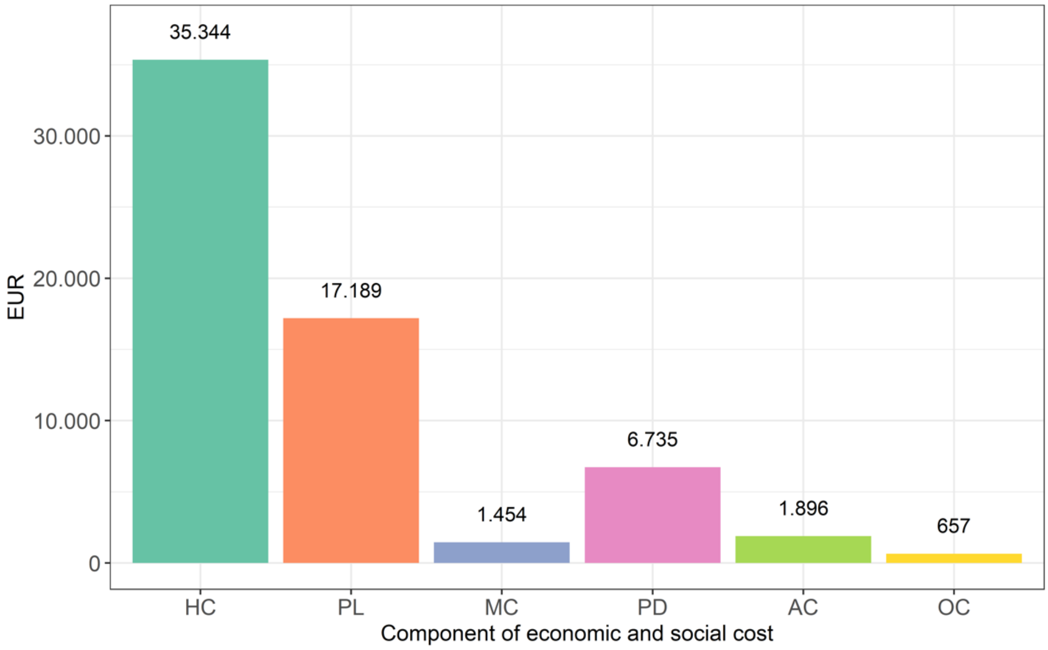
Figure 5.20. Breakdown of the average cost of a road crash with injuries only, 2019



Source: Own elaboration. **Notes**: HC: human costs; PL: production loss; MC: average cost; PD: property damage; AC: administrative costs; OC: other costs.

The estimated average economic and social cost of a road crash from which only minor injuries result amounts to €63,276 per road crash in 2019 prices. This average cost can be broken down into €35,344 regarding human costs, €17,189 regarding the value of lost production, €1,454 regarding medical costs, €6,735 regarding property damage, €1,896 regarding administrative costs and €657 regarding other costs (Figure 5.21).

Figure 5.21. Breakdown of the average cost of a road crash with only slightly injured, 2019



Source: Own elaboration. **Notes**: HC: human costs; PL: production loss; MC: average cost; PD: property damage; AC: administrative costs; OC: other costs.

5.4.2. According to the day of the week on which the road crash occurs

Table 5.5 summarizes the information on the number of road crashes and victims and the average number of victims per road crash recorded in 2019 in mainland Portugal, disaggregated according to the day of the week on which the road crash occurs.

Table 5.5. Average number and type of victims per day of the week

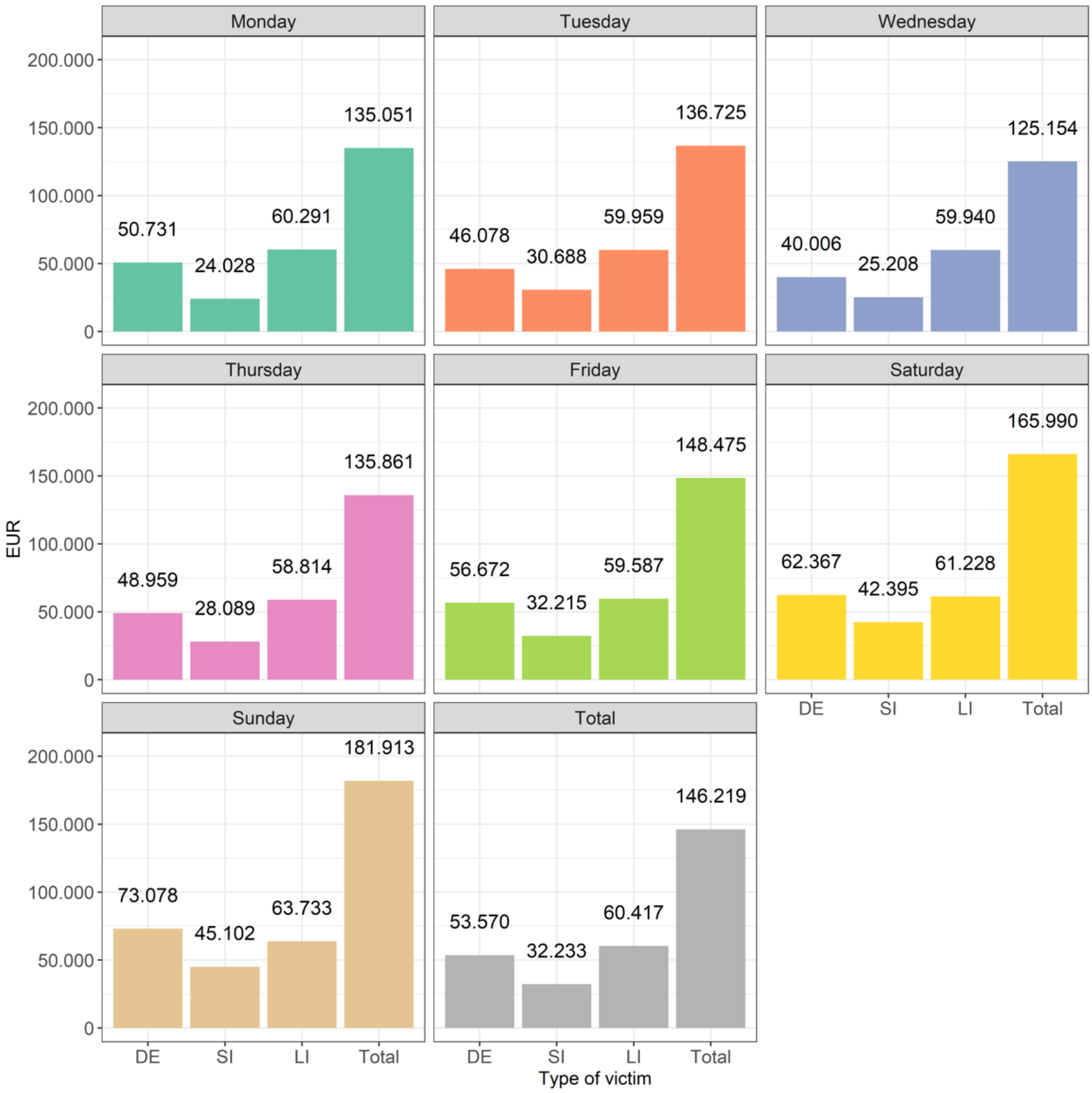
Day of week	Number of				Number of victims per 100 road crashes		
	Accid.	DE	SI	LI	DE	SI	LI
Monday	5 059	84	229	6 106	1,66	4,53	120,70
Tuesday	5 172	78	299	6 208	1,51	5,78	120,03
Wednesday	5 117	67	243	6 140	1,31	4,75	119,99
Thursday	5 367	86	284	6 319	1,60	5,29	117,74
Friday	5 553	103	337	6 624	1,85	6,07	119,29
Saturday	5 046	103	403	6 185	2,04	7,99	122,57
Sunday	4 390	105	373	5 601	2,39	8,50	127,59
Total	**35 704**	**626**	**2 168**	**43 183**			

Source: Own elaboration. **Notes**: DE: fatalities; SI: severely injured; LI: slightly injured. Numbers in euros refer to road crashes with victims.

In 2019, the day of the week on which the most serious victims per road crash were recorded is clearly Sunday, with 2.39 fatalities, 8.50 seriously injured and 127.59 slightly injured per 100 road crashes with victims. It should be noted that, although Sunday is the day of the week when there are fewer road crashes, they are on average more serious in terms of their human consequences. Weekends are, as shown in Table 5.5, particularly tragic in terms of the severity of road fatalities, with Saturday and Friday having the second and third worst rates for serious road crashes.

Figure 5.22 summarizes the information on the estimated average cost of a casualty road crash according to the day of the week on which the road crash occurs.

Figure 5.22. Estimated average cost of a casualty road crash by weekday, 2019



Source: Own elaboration. **Notes**: DE: fatalities; SI: severely injured; LI: slightly injured. Numbers in euros refer to road crashes with victims, calculated at 2019 prices.

Unsurprisingly, Sunday is the day of the week when the cost of fatalities to society is the highest, with an average value of 181,913 euros per road crash, the largest share of which is attributable to the most severe victims resulting from the road crash – 73,078 euros for those killed and 45,102 euros for those seriously injured. The average economic and social cost of a road crash registered on Saturdays amounts to 165,990 euros, the second-highest value day of the week, followed by Fridays with an average cost of 148,475 euros. The results presented in Figure 5.22 also show that the day of the week with the lowest average cost per road crash to society is Wednesday, with an estimated 125,154 euros per road crash.

5.4.3. According to the month of the year in which the road crash occurs

Table 5.6 summarizes the information on the number of road crashes and victims and the average number of victims per road crash recorded in 2019 in mainland Portugal, disaggregated according to the month of the year in which the road crash occurred.

Table 5.6. Average number and type of victims per month of the year, 2019

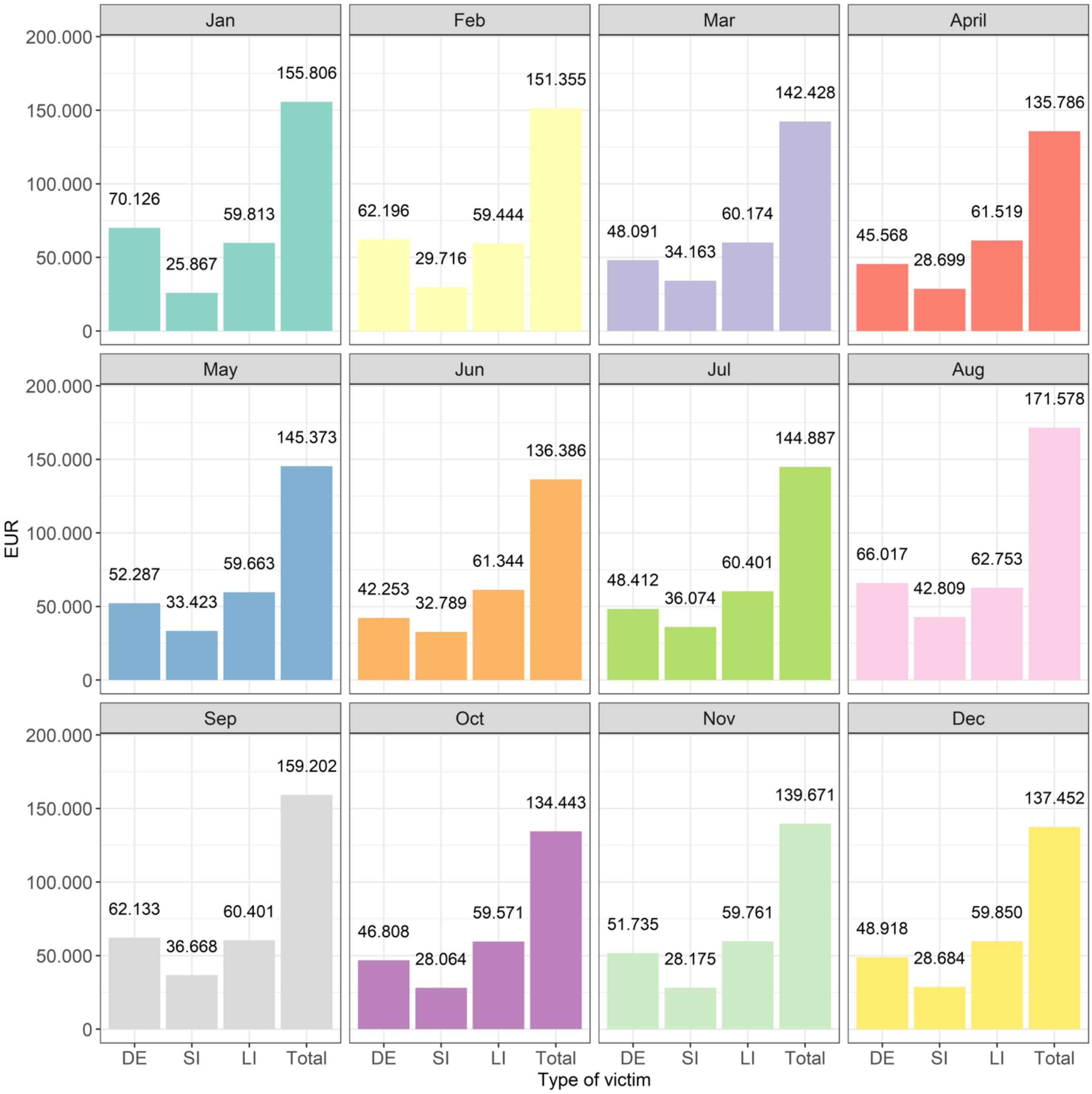
Day of week	Number of				Number of victims per 100 road crashes		
	Accid.	DE	SI	LI	DE	SI	LI
January	2 832	65	138	3 391	2,30	4,87	119,74
February	2 358	48	132	2 806	2,04	5,60	119,00
March	2 859	45	184	3 444	1,57	6,44	120,46
April	2 682	40	145	3 303	1,49	5,41	123,15
May	3 097	53	195	3 699	1,71	6,30	119,44
June	3 254	45	201	3 996	1,38	6,18	122,80
July	2 840	45	193	3 434	1,58	6,80	120,92
August	3 286	71	265	4 128	2,16	8,06	125,62
September	3 098	63	214	3 746	2,03	6,91	120,92
October	3 329	51	176	3 970	1,53	5,29	119,26
November	3 071	52	163	3 674	1,69	5,31	119,64
December	2 998	48	162	3 592	1,60	5,40	119,81
Total	**35 704**	**626**	**2 168**	**43 183**			

Source: Own elaboration. **Notes**: DE: fatalities; SI: severely injured; LI: slightly injured. Numbers in euros refer to road crashes with victims.

In 2019, the month of the year in which there were more road crashes was October, soon followed by August. In terms of fatalities per road crash with victims, January was the month with the worst indicators with 2.3 fatalities per 100 road crashes, followed by August with 2.16 fatalities per 100 road crashes and February with 2.04 fatalities per 100 road crashes.

As regards the number of seriously injured per road crash, August is the month of the year with the worst rates (8.06 seriously injured per 100 road crashes), followed by September and March with 6.91 and 6.44 seriously injured per 100 road crashes, respectively. In terms of seriously injured per traffic crash, August is once again the month with the worst record, with 125.62 slightly injured per 100 road crashes with victims. Figure 5.23 summarizes the information on the estimate of the average economic and social cost of a road crash with victims according to the month of the year in which the road crash takes place.

Figure 5.23. Estimate of the average cost of a road crash by month of the year, 2019



Source: Own elaboration. **Notes**: DE: fatalities; SI: severely injured; LI: slightly injured. Numbers in euros refer to road crashes with victims.

The results obtained indicate that August is the month of the year in which a road crash has the highest cost to society, estimated at 171,578 euros per road crash with victims, a figure explained above all by the seriousness of the consequences of the road crashes recorded in this month. September presents the second-highest value in terms of average cost per road crash with victims (159,202 euros per road crash) and January the third (155,806 euros per road crash). The months of the year with the lowest average economic and social costs are October (134,443 euros per road crash), April (135,786 euros per road crash) and July (136,386 euros per road crash). The graph also confirms that in many months of the year the contribution of the slightly injured to the average cost per road crash is quite significant and, in some cases, the most important component.

5.4.4. According to location in mainland Portugal

Table 5.7 summarizes the information on the number of road crashes and victims and the average number of victims per road crash recorded in 2019 in mainland Portugal, broken down by district of occurrence. In terms of fatalities per road crash with victims, the district of Beja had the most fatalities per road crash with victims in 2019 (7.91 fatalities per 100 road crashes), followed by the district of Portalegre (5.61 fatalities per 100 road crashes). The district of Lisbon presents, in this indicator, the lowest severity index in terms of fatalities per road crash. The districts with the worst indicators in terms of the average number of seriously injured per road crash are the Alentejo districts of Portalegre (17.16 injured per 100 road crashes), Évora (15.99 injured per 100 road crashes) and Beja (14.53 injured per 100 road crashes). In terms of slightly injured, the district of Vila Real has the worst rates with 131.96 injuries per 100 road crashes with victims.

Figure 5.24 summarizes the information on the estimated average economic and social cost of a road crash with victims according to the district where the road crash takes place. The results obtained in this study indicate that it is in the district of Beja that road crashes with victims present by far the highest economic and social cost, with an estimated value of 379,098 euros for each road crash with victims, a value mainly explained by the high number of fatalities and seriously injured resulting from road crashes recorded in this district.

Table 5.7. Average number and type of victims by district, 2019

District	Number of				Number of victims per 100 road crashes		
	Accid.	DE	SI	LI	DE	SI	LI
Aveiro	2 815	42	135	3 362	1,49	4,80	119,43
Beja	468	37	68	566	7,91	14,53	120,94
Braga	3 180	45	153	3 988	1,42	4,81	125,41
Bragança	412	8	48	488	1,94	11,65	118,45
Castelo Branco	527	14	66	628	2,66	12,52	119,17
Coimbra	1 624	40	79	1 952	2,46	4,86	120,20
Évora	444	17	71	545	3,83	15,99	122,75
Faro	2 154	44	214	2 449	2,04	9,94	113,70
Guarda	433	19	58	509	4,39	13,39	117,55
Leiria	1 822	45	123	2 132	2,47	6,75	117,01
Lisboa	8 232	76	337	9 820	0,92	4,09	119,29
Portalegre	303	17	52	365	5,61	17,16	120,46
Porto	6 245	79	205	7 738	1,27	3,28	123,91
Santarém	1 612	41	211	1 953	2,54	13,09	121,15
Setúbal	2 605	32	159	3 183	1,23	6,10	122,19
Viana do Castelo	859	18	53	1 038	2,10	6,17	120,84
Vila Real	654	14	46	863	2,14	7,03	131,96
Viseu	1 315	38	90	1 604	2,89	6,84	121,98
Total	**35 704**	**626**	**2 168**	**43 183**			

Source: Own elaboration. **Notes**: DE: fatalities; SI: severely injured; LI: slightly injured. Numbers in euros refer to road crashes with victims.

The districts of the Alentejo have a particularly negative record in this regard. In fact, the districts of Portalegre (322,696 euros per road crash) and Évora (263,185 euros per road crash) have the second and third-worst record in terms of the consequences of road crashes for society.

The district in mainland Portugal with the lowest average cost to society of road crashes in 2019 is the district of Lisbon, with an estimated cost of 109,528 euros per road crash with victims.

Figure 5.24. Estimated average cost of a road crash by district, 2019

Source: Own elaboration. **Notes**: DE: fatalities; SI: severely injured; LI: slightly injured. Numbers in euros refer to road crashes with victims.

5.4.5. According to the type of road in which the road crash occurs

Table 5.8 summarizes the information on the number of road crashes and victims and the average number of victims per road crash recorded in 2019 in mainland Portugal, disaggregated by type of traffic road on which the road crash is recorded. In 2019, road crashes recorded on forest roads were those with the highest severity rates with 8.40 fatalities and 18.49 seriously injured per 100 recorded road crashes. Road crashes on main routes also showed high severity rates, with 7.22 fatalities, 9.89 seriously injured and 132.70 slightly injured per 100 road crashes. The number and severity of victims per road crash registered in road crashes that occur on complementary routes and municipal roads is equally relevant.

Table 5.8. Average number and type of victims by type of road, 2019

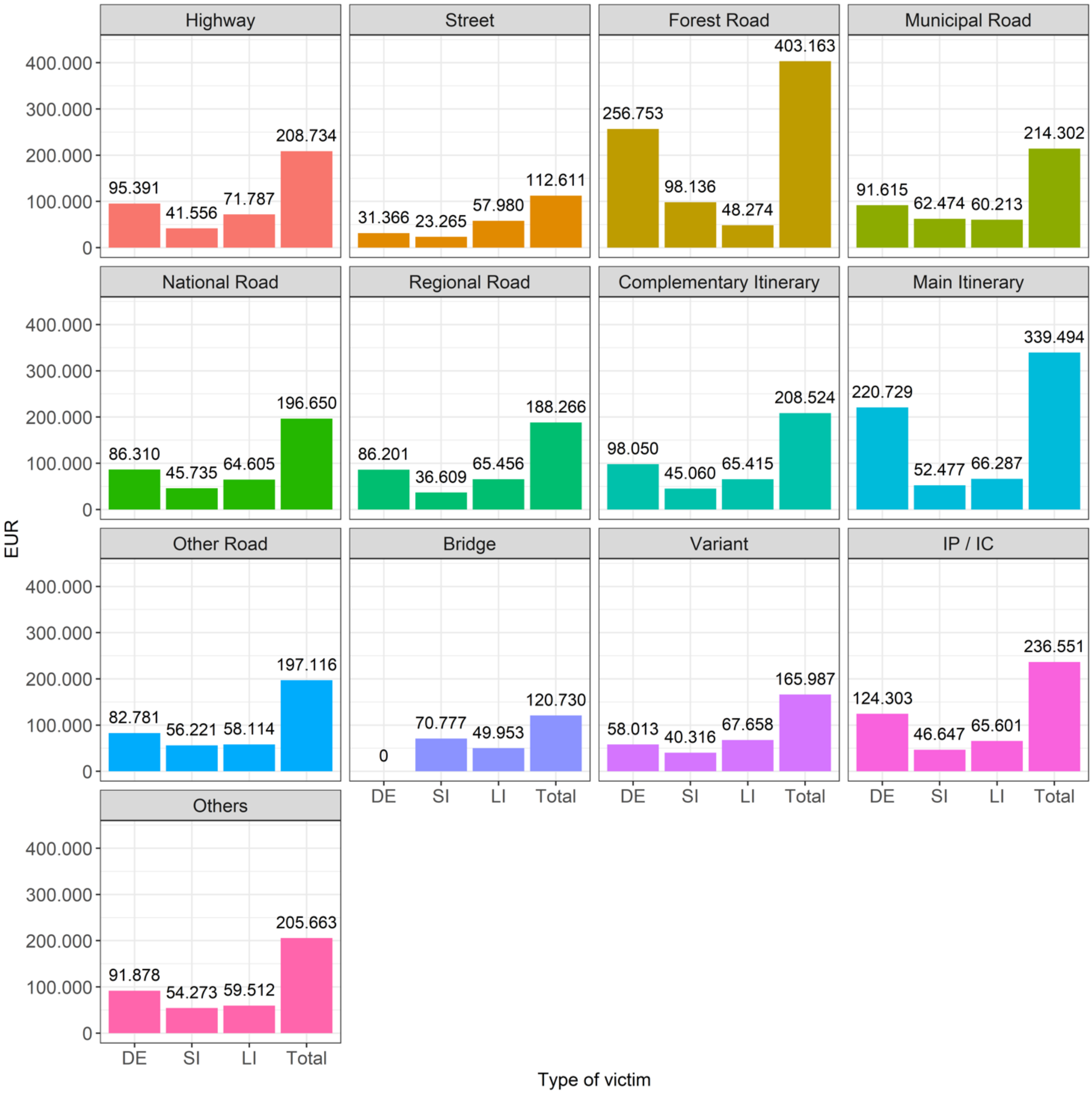
Type of road	Number of				Number of victims per 100 road crashes		
	Accid.	DE	SI	LI	DE	SI	LI
Highway	2 146	67	168	3 084	3,12	7,83	143,71
Street	22 794	234	999	26 457	1,03	4,38	116,07
Forest road	119	10	22	115	8,40	18,49	96,64
Municipal road	1 334	40	157	1 608	3,00	11,77	120,54
National road	6 372	180	549	8 241	2,82	8,62	129,33
Regional road	319	9	22	418	2,82	6,90	131,03
Complementary itinenerary	966	31	82	1 265	3,21	8,49	130,95
Main itinenerary	263	19	26	349	7,22	9,89	132,70
Other road	1 218	33	129	1 417	2,71	10,59	116,34
Bridge	15	0	2	15	0,00	13,33	100,00
Variant	158	3	12	214	1,90	7,59	135,44
Others	1 829	55	187	2 179	3,01	10,22	119,14
Total	**35 704**	**626**	**2 168**	**43 183**			

Source: Own elaboration. **Notes**: DE: fatalities; SI: severely injured; LI: slightly injured. Data refers only to road crashes with victims.

Freeways are the roads that register the most slightly injured per road crash (143.71 injuries per 100 road crashes with victims). Streets continue to be the place where there are more traffic crashes, with 63.84% of the road crashes with victims recorded in 2019, 37.38% of the fatalities, 46.08% of the seriously injured, and 61.27% of the slightly injured.

In terms of economic and social cost, Figure 5.25 presents the estimated average cost of a road crash according to the type of road on which it occurs. Unsurprisingly, road crashes on forest roads are by far the costliest to society, with an estimated average cost of 403,163 euros per road crash with victims, a figure explained by the high number of fatalities and seriously injured caused by these road crashes. Road crashes occurring on main routes also have a very high cost to society, estimated at 339,494 euros per road crash, as do those occurring on municipal roads, with an estimated average cost of 214,302 euros per road crash with victims.

Figure 5.25. Estimated average cost of a road crash by type of road, 2019



Source: Own elaboration. **Notes**: DE: fatalities; SI: severely injured; LI: slightly injured. Numbers in euros refer to road crashes with victims.

In terms of total annual cost, the biggest contribution is made by accidents on roads (2,567 million euros), followed by accidents on trunk roads (1,253 million euros).

5.4.6. According to the age of the vehicles involved in the road crashes

Table 5.9 summarizes the information on the number of road crashes and victims and the average number of victims per road crash recorded in 2019 in mainland Portugal, disaggregated by age of the vehicles intervening in the road crash.

Table 5.9. Average number of victims and respective typology by age of the intervening vehicles, 2019

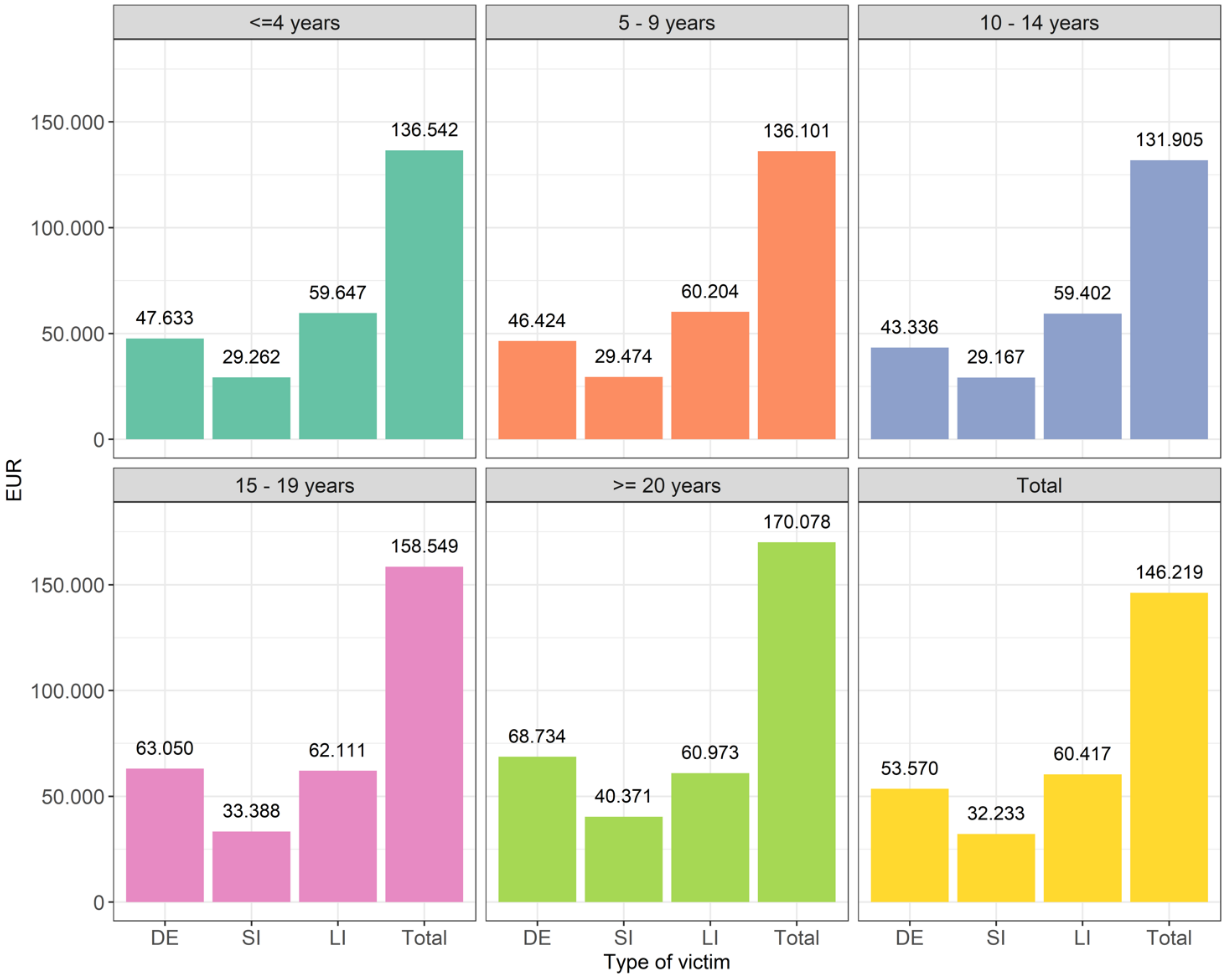
Vehicle age	Number of				Number of victims per 100 road crashes		
	Accid.	DE	SI	LI	DE	SI	LI
<= 4 years	8 018	125	442	9 574	1,56	5,51	119,41
5 - 9 years	5 331	81	296	6 425	1,52	5,55	120,52
10 - 14 years	8 390	119	461	9 977	1,42	5,49	118,92
15 - 19 years	7 075	146	445	8 797	2,06	6,29	124,34
>= 20 years	6 890	155	524	8 410	2,25	7,61	122,06
Total	**35 704**	**626**	**2 168**	**43 183**			

Source: Own elaboration. **Notes**: DE: fatalities; SI: severely injured; LI: slightly injured. Numbers in euros refer to road crashes with victims.

In 2019, registered accidents involving vehicles at least 20 years old were those with the highest severity rates with 2.25 fatalities, 7.61 serious injuries and 122.06 light injuries per 100 registered accidents. The indicators suggest that the age of the vehicle fleet has a positive correlation with fatality rates. In fact, accidents involving vehicles between 15 and 19 years of age come immediately after in terms of the seriousness of the consequences, with 2.06 fatalities, 6.29 serious injuries and 124.34 light injuries for every 100 accidents registered.

The estimated average cost to society of an accident by age of the vehicles involved is presented in Figure 5.26. Accidents involving vehicles at least 20 years old are those with the highest average economic and social cost in unit terms, with a value of 170,078 euros per accident with victims. This is followed by accidents involving vehicles aged between 15 and 19 years, with a cost of €158 549 per accident. The results for the year 2019 indicate that it is among accidents involving vehicles aged 10 to 14 years that the recorded accidents have a lower average cost, with an estimated value of €131 905 per accident.

Figure 5.26. Estimation of the average cost of a road crash by age of the intervening vehicles, 2019



Source: Own elaboration. **Notes**: DE: fatalities; SI: severely injured; LI: slightly injured. Numbers in euros refer to road crashes with victims. Age of intervenient vehicles in years.

5.4.7. According to the nature of the road crash

Table 5.10 summarizes the information on the number of road crashes and victims and the average number of victims per road crash recorded in 2019 in mainland Portugal, disaggregated according to the nature of the road crash (hit-and-run, collision between vehicles or crash).

Table 5.10. Average number and type of victims according to the nature of the road crash, 2019

Nature of road crash	Number of				Number of victims per 100 road crashes		
	Accid.	DE	SI	LI	DE	SI	LI
Run over	5 337	128	391	5 296	2,40	7,33	99,23
Collision	18 771	253	936	24 959	1,35	4,99	132,97
Crash	11 596	245	841	12 928	2,11	7,25	111,49
Total	**35 704**	**626**	**2 168**	**43 183**			

Source: Own elaboration. **Notes**: DE: fatalities; SI: severely injured; LI: slightly injured. Numbers refer to road crashes with victims.

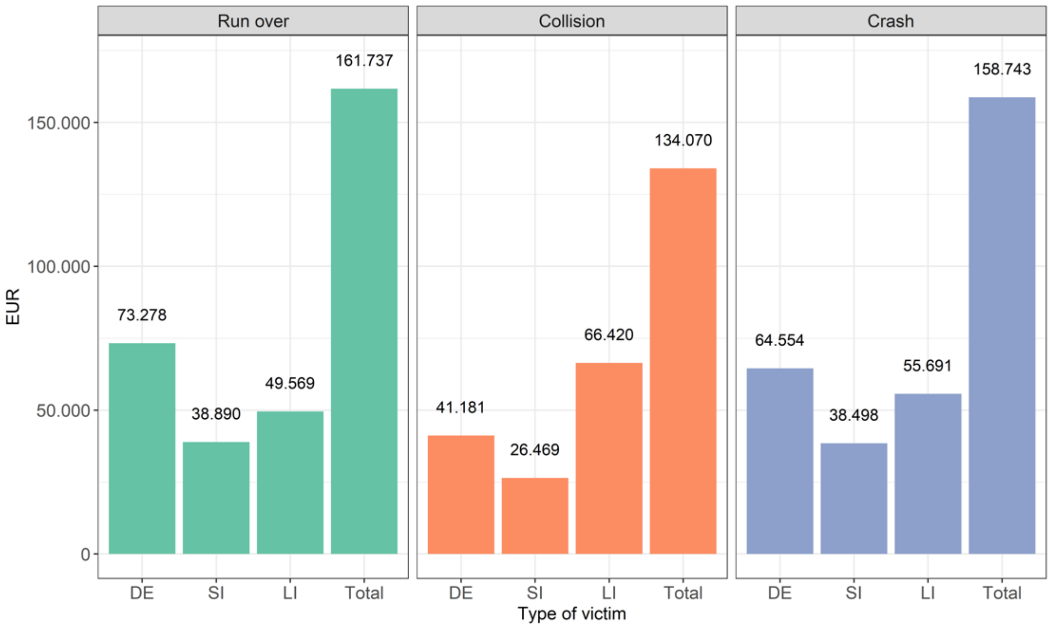
In 2019, pedestrian collisions (pedestrian collisions, hit-and-run collisions and animal collisions) are the most serious road crash type in terms of victims, mainly fatalities (2.40 fatalities per 100 road crashes) and slightly injured (7.33 injuries per 100 road crashes).

Although collisions, especially lateral collision with another moving vehicle, but also rear-end collision with another moving vehicle, frontal collisions or collisions with obstacles on the road, are the most frequent type of road crash in 2019, this is not, as can be seen in Table 5.10, the type with the most serious consequences for society. In fact, after pedestrian collisions, road crashes (in particular simple road crashes, but not forgetting rollover road crashes, collisions with a vehicle stopped on the road or obstacle, road crashes with lateral restraint device transposition and road crashes with a restraint device) are the type of road crash with the highest average number of victims per road crash (2.111 fatalities, 7.25 seriously injured and 111.49 slightly injured per 100 road crashes recorded).

The estimate of the average cost to society of a road crash according to its nature is presented in Figure 5.27. The results obtained in this study indicate that pedestrian collisions are the type of road crash with the highest average economic and social cost among the different categories, with an estimated value of 161,737 euros per road crash. In terms of total annual costs, collisions are by far the type of road crash with the highest costs to society with an estimated €2.517 million in 2019, followed by mishaps with €1.841 million.

Of this amount, 73,278 euros refer to costs with fatalities, 38,890 euros to seriously injured resulting from road crashes and 49,569 euros to slightly injured. Road crashes are the second most costly road crash to society, at an estimated 158,743 euros per road crash with victims. Collisions represent an average cost to society quantified at 134,070 euros per road crash.

Figure 5.27. Estimate of the average cost of a road crash according to its nature, 2019



Source: Own elaboration. **Notes**: DE: fatalities; SI: severely injured; LI: slightly injured. Numbers in euros refer to road crashes with victims. Age of intervenient vehicles in years.

5.4.8. According to the type of vehicles involved in the road crashes

Table 5.11 summarizes the information on the number of road crashes and victims and the average number of victims per road crash recorded in 2019 in mainland Portugal, disaggregated according to the type of vehicles involved (light or heavy car, moped, motorcycle, quadricycle, agricultural vehicle, bicycle with or without motor, other vehicles).

In 2019, casualty road crashes involving agricultural vehicles were by far the most serious in terms of casualties, mainly fatalities (10.07 fatalities per 100 road crashes), but also seriously injured (20.86 seriously injured per 100 road crashes) and slightly injured (97.12 slightly injured per 100 road crashes). In terms of severity, road crashes involving heavy vehicles (4.84 fatalities and 9.69 seriously injured per 100 road crashes) and road crashes involving high-powered motorcycles (3.90 fatalities and 12.71 seriously injured per 100 road crashes) follow. The highest number of slightly injured per road crash results from road crashes involving light motor vehicles.

Table 5.11. Average number and type of victims according to the type of vehicles involved, 2019

Type of vehicle	Number of				Number of victims per 100 road crashes		
	Accid.	DE	SI	LI	DE	SI	LI
Light vehicle	26 809	425	1 462	33 980	1,59	5,45	126,75
Heavy weight vehicle	929	45	90	1 162	4,84	9,69	125,08
Moped	1 577	22	103	1 583	1,40	6,53	100,38
Motorbike <= 125cc	2 652	25	127	2 744	0,94	4,79	103,47
Motorbike > 125cc	1 873	73	238	1 832	3,90	12,71	97,81
Quadricycle	279	11	35	293	3,94	12,54	105,02
Farm vehicle	139	14	29	135	10,07	20,86	97,12
Bicycle	848	8	45	851	0,94	5,31	100,35
Motorized bicycle	381	0	16	388	0,00	4,20	101,84
Other vehicles	217	3	23	215	1,38	10,60	99,08
Total	**35 704**	**626**	**2 168**	**43 183**			

Source: Own elaboration. **Notes**: DE: fatalities; SI: severely injured; LI: slightly injured. Other vehicles: unknown, industrial machine, non-defined, tricycle, animal-drawn vehicle, rail vehicle. Data referring only to road crashes with victims.

The estimate of the average cost to society of a road crash according to the type of vehicles involved in the road crash is represented in Figure 5.28. The results obtained in this study indicate that casualty road crashes involving agricultural vehicles are by a large margin those with the highest cost to society, estimated at 466,998 euros per road crash.

This is followed by road crashes involving heavy vehicles with an estimated cost of 261,906 euros per road crash, road crashes involving quadricycles with an estimated cost of 239,513 euros per road crash, and road crashes involving motorcycles with an engine capacity greater than 125cc, with an estimated average cost of 235,393 euros per road crash. Road crashes involving motorcycles are those whose estimated average cost to society is the lowest (73,163 euros per road crash).

In terms of total annual costs, accidents involving light cars were those that in 2019 represented the greatest cost to society with €3.772 million, followed by accidents involving motorbikes with an engine capacity of over 125cc with €441 million.

Figure 5.28. Estimate of the average cost of a road crash according to the type of vehicles involved, 2019

Source: Own elaboration. **Notes**: DE: fatalities; SI: severely injured; LI: slightly injured. Other vehicles: unknown, industrial machine, non-defined, tricycle, animal-drawn vehicle, rail vehicle. Data referring only to road crashes with victims.

5.4.9. According to the state of maintenance of the roads

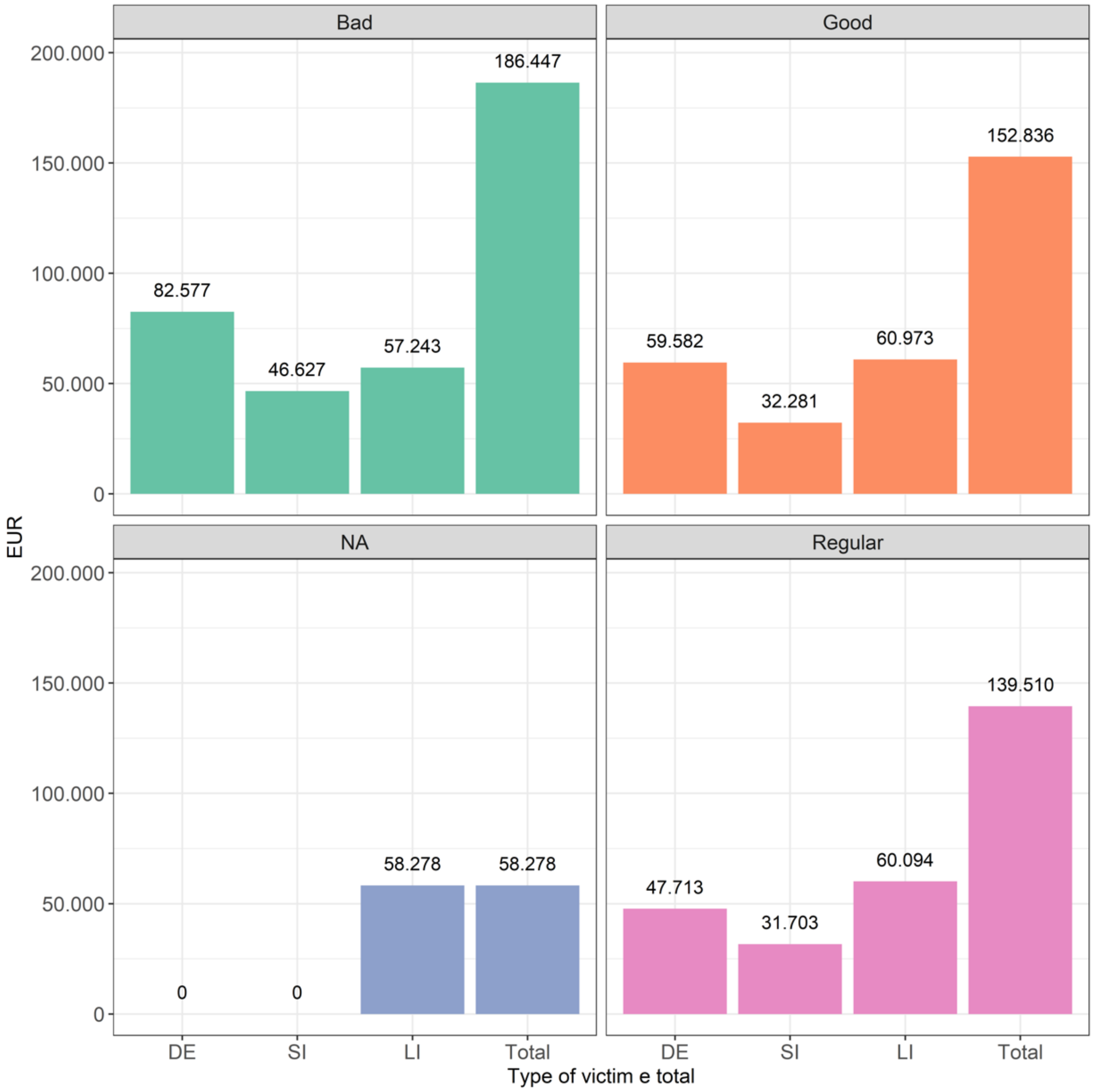
Table 5.12 summarizes the information on the number of road crashes and victims and the average number of victims per road crash recorded in 2019 in mainland Portugal, disaggregated according to the state of conservation of the roads (in good condition, in fair condition, in poor condition, not defined). In 2019, road crashes with victims recorded on roads in poor condition were those that, by a large margin, had the most serious consequences in terms of victims, mainly fatalities (2.7 deaths per 100 road crashes), but also seriously injured (8.78 seriously injured per 100 road crashes) and slightly injured (114.59 slightly injured per 100 road crashes).

Table 5.12. Average number of victims and type of road condition, 2019

Road condition	Number of				Number of victims per 100 road crashes		
	Accid.	DE	SI	LI	DE	SI	LI
In good conditions	15 589	304	948	19 028	1,95	6,08	122,06
In regular conditions	19 339	302	1 155	23 265	1,56	5,97	120,30
In bad conditions	740	20	65	848	2,70	8,78	114,59
Not defined	36	0	0	42	0,00	0,00	116,67
Total	**35 704**	**626**	**2 168**	**43 183**			

Source: Own elaboration. **Notes**: DE: fatalities; SI: severely injured; LI: slightly injured.

Figure 5.29. Estimate of the average cost of a road crash by road condition, 2019



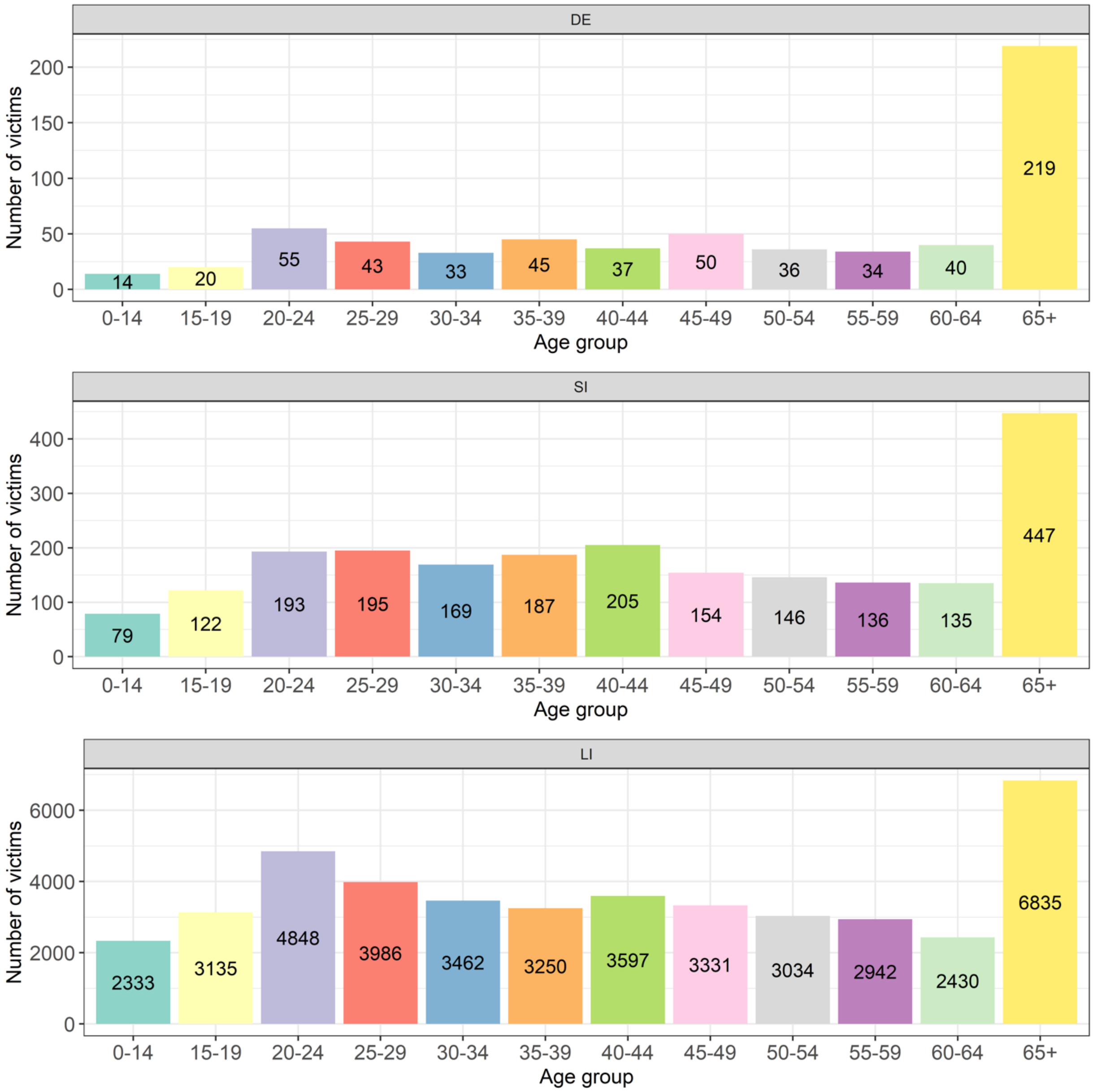
Source: Own elaboration. **Notes**: DE: fatalities; SI: severely injured; LI: slightly injured. Data referring only to road crashes with victims.

Road crashes occurring on roads in poor condition are also those with the highest average economic and social cost to society, estimated at 186,477 euros per road crash with victims (Figure 5.29). In terms of total annual costs, the biggest contribution comes, however, from accidents on roads in fair condition (€2.698 million) and on roads in good condition (€2.383 million).

5.4.10. According to age group

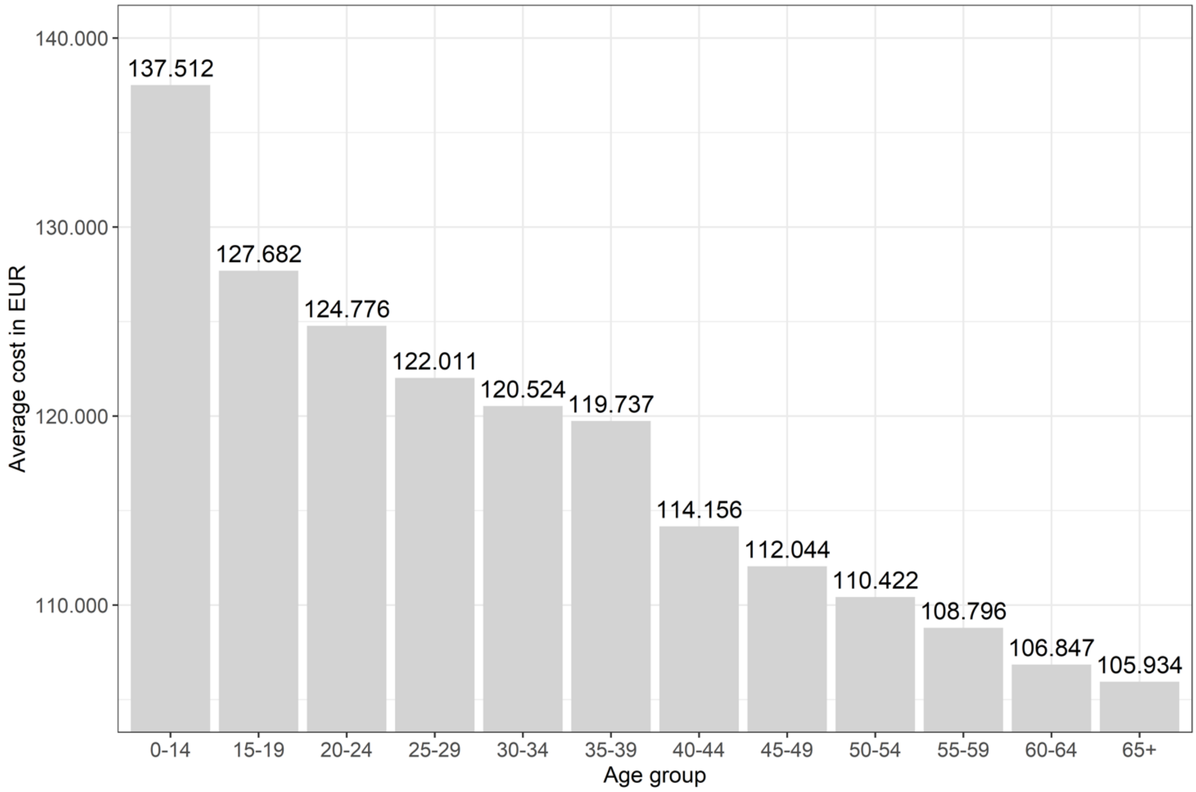
Finally, we present in Figures 5.30 and 5.31 the number of victims of road accidents recorded in 2019 in mainland Portugal, broken down by type of victim, and the average cost per accident victim, also broken down by age group. The analysis of the results points out the significant number of victims between 20 and 30 years of age and after 65 years of age.

Figure 5.30. Number of road crash victims by age group, 2019



Source: Own elaboration. **Notes**: DE: fatalities; SI: severely injured; LI: slightly injured. Data referring only to road crashes with victims.

Figure 5.31. Average cost of a road crash victim by age group, 2019



Source: Own elaboration.

In terms of average cost to society, road fatalities naturally have a greater impact when they affect younger age groups, where remaining life expectancy and the potential contribution to wealth creation and society are greater.

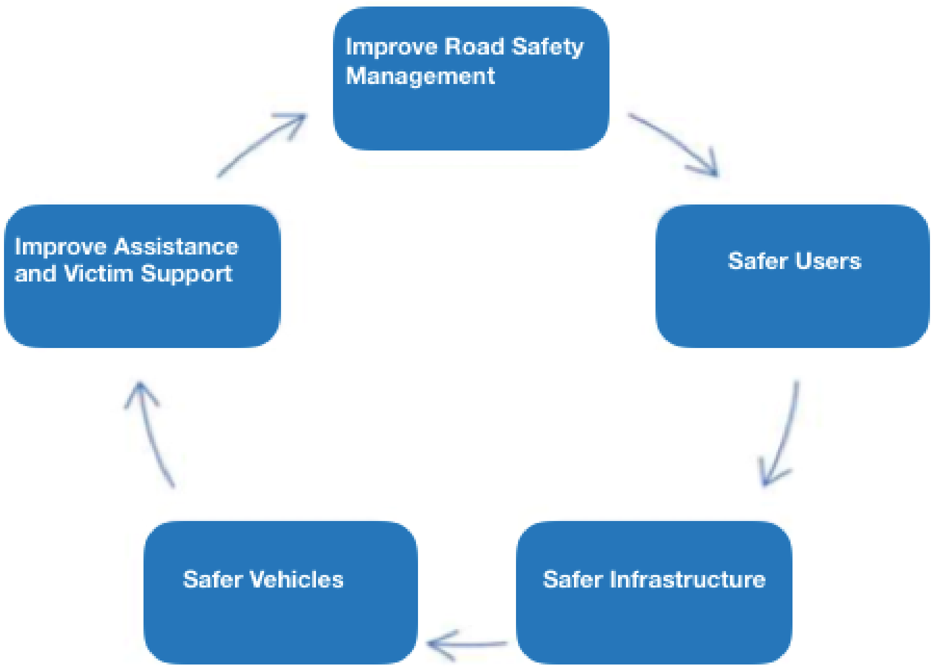
6. Public policy recommendations

Within the framework of road safety public policies, Portugal, like other countries, has been designing strategies and setting targets in order to bring the national road crash rate indicators closer to the European Union average values and, in the medium term, to the countries with better performance in this area, as referred in the National Strategic Plan for Road Safety 2020 (PENSE).[21]

In line with the guidelines set by the UN[22], the following five strategic objectives were defined in PENSE 2020:

- Improve road Safety Management; Safer Users;
- Safer Users;
- Safer Infrastructure;
- Safer Vehicles; and
- Improve victim Assistance and Support.

Figure 6.1. Strategic objectives



Source: Own elaboration.

[21] Council of Ministers Resolution No 85/2017, of 19th June 21.

[22] Age of Action towards traffic safety 2011-2020.

Notwithstanding the actions and measures that have been planned and implemented, particularly in the last decade, for that purpose, and the measures set out in PENSE 2020, many with positive evidence in terms of the results achieved, as shown by the available data[23], we must, nevertheless, insist on the development of initiatives that enable the enhancement of road safety in Portugal and the reduction of the economic and social costs of road crashes.

In this field, we focus on the road safety practices included in the Manual of National Measures of the European Commission "(…) effectiveness or that show promise (…)" (EC, 2010:59), on the results of the road safety study for the interim evaluation of Policy Orientations on road Safety 2011-2020, and on the supporting information handled by the European Road Safety Observatory, whose contributions support the initiatives planned under the national strategic goals and enhance them.

Main recommendations (in terms of measures)[24]

- (Re)construction and design of reduced speed zones in residential areas (M)
- (Re)construction and design of traffic circles (M)
- (Re)construction and design of management tools for high-risk areas (B)
- Road signaling and marking with audible guides (M)
- Road signs and markings with variable message signs (B)
- Quality assurance of road safety inspections (B)
- Mandatory use of helmet by cyclists (P)
- Cars with daytime running lights (M)
- Cars with side reflectors for bicycles (M)
- Driving assistance systems with intelligent speed control (P)
- Alcohol ignition interlock (B)
- Registration of occurrences (black boxes) (M)
- Road safety education (B)
- Campaign against driving under the influence of alcohol (B)
- Campaign for the use of seat belts (B)
- Excessive speed with route control (M)
- Drunk driving with random control of the alcohol level (M)
- Targeted control of seat belt use (B)
- License penalty point system (B)
- Rehabilitation of serious offenders with mandatory driver improvement course (B)
- Training course for recidivist drunk drivers (B)
- Rehabilitation of young offenders with participation in a rehabilitation seminar for young drivers (B)
- First aid courses included in driving instruction (B)

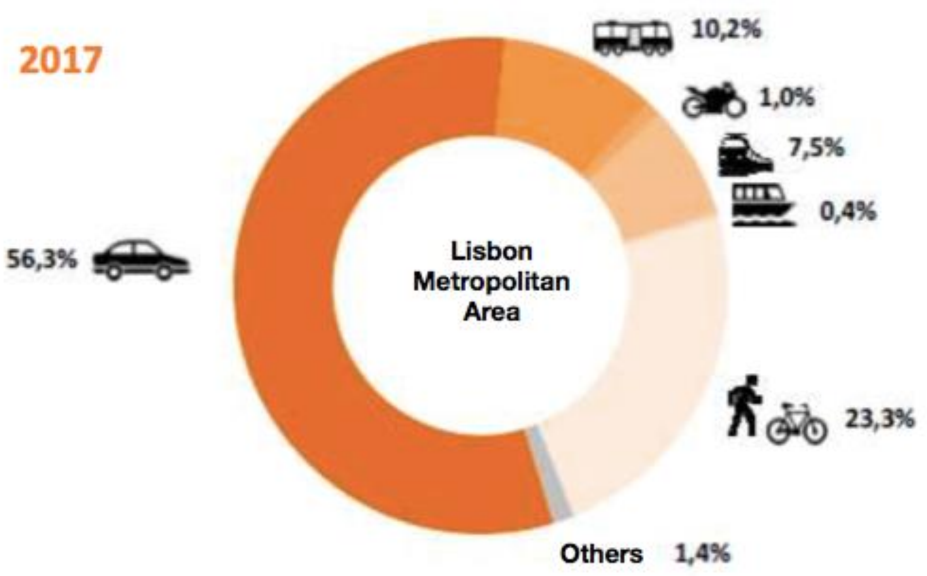
[23] Road Safety Annual Report 2020; Road Safety Annual Report 2019.

[24] (B) Good practice; (M) Best practice; (P) Promising practice.

- Creation of mobile intensive care units (B)
- Transport of road crash victims by helicopter (M)
- Psychosocial support for victims of road crashes (P)
- Control of the use of cell phones while driving (B)
- Information system [integrated, for management,] on road safety [and road crashes] (P)

In the particular case of the Lisbon metropolitan area, the study Road Safety in European Cities (ITF, 2019b), supported by national indicators, finds that most trips in that area are made by car, which inevitably creates a challenge to road safety given the very concentrated and large-scale traffic flows (Figure 6.2), considering that the excessive dependence on private vehicles is the result of inadequate road circulation planning combined with poor alternative public transport options.

Figure 6.2. Distribution of the number of trips by main means of transport, on weekdays, 2017



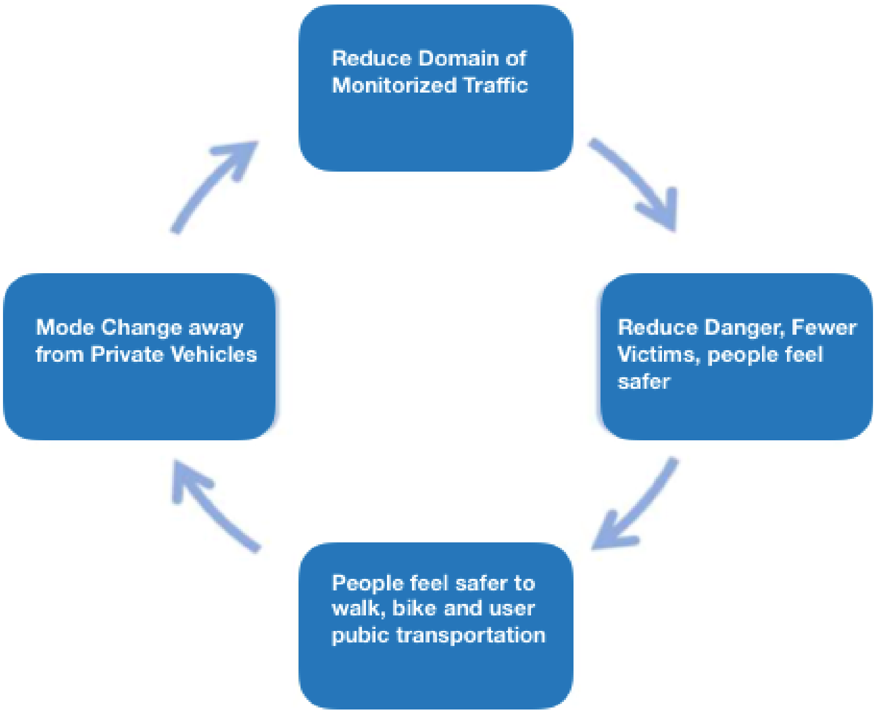
Source: INE, 2018. Consulted on ITF (2019b:38).

In this case, along with the progressive development that has been observed of creating pedestrian and bicycle paths in order to achieve safe and sustainable urban environments, it is necessary, according to the study Road Safety in European Cities (ITF,2019b:56), the involvement of civil society, a political commitment, legislative production that regulates the implementation of defined policies and a strong local leadership that encourages and ensures the coordination of a set of entities interested in this field, from ministries, local authorities, parliamentarians, politicians, road agencies and society itself.

According to the aforementioned study (ITF, 2019b:11) the effectiveness of road safety management needs regular evaluation that, in addition to the results achieved, assesses the level of institutional intervention and the range of measures implemented, fundamental information for the definition of new priorities and more appropriate measures.

In this context, for some, cities are faced with much larger public health problems, air pollution is one example, chronic diseases associated with poor physical activity are another ailment, hence local authorities encourage residents to exercise by walking or cycling, admitting however, that there will be a direct relationship between road safety and public health objectives, in that people will not adopt other practices if they do not feel safe on the streets (ITF, 2019b: 11). Figure 6.3 illustrates this relationship, where increased road safety leads to public health benefits.

Figure 6.3. Virtuous circle of road hazard reduction



Source: TfL (2018), Vision Zero Action Plan. Consulted in ITF (2019b: 12).

The adoption of sustainable urban mobility plans or road safety plans are, according to the study, instruments of potential benefits.

In this area of best practice, the London authorities, for example, based on the Swedish Vision Zero model, have relied on preventative measures that promote safe speeds, street layout, vehicles and road behaviors, as well as measures that reduce the severity of injuries following a collision, based on the principle that no loss of life is acceptable (ITF, 2019b:57).

The Vision Zero approach requires reducing the dominance of motor vehicles by creating safe streets, healthy circulation spaces with an emphasis on human health and well-being where residents want to get around, whether walking, cycling or on public transport (TfL, 2018:19).

Figure 6.4 presents a set of healthy streets indicators designed in the context of Vision Zero in the action plan for the City of London.

Figure 6.4. Indicators of healthy streets

Source: Lucy Saunders, Vision Zero action plan.

7. Conclusion

The evolution of road fatalities, their causes and the resulting problems, namely at the social and economic level, are a constant challenge in the definition of promising policies to fight against fatalities and to promote a civic culture with an impact on the improvement of the quality of life of citizens and on the effectiveness of the social functions of the State.

Therefore, for the definition of policies and implementation of corrective and innovative measures and to support decision-making in the field of road fatalities, the estimation of the economic and social costs of road crashes plays a key role in public road safety policies. As a rule, the approval and construction/remodeling/improvement of a major road undertaking or the definition and implementation of a road safety and prevention plan require, among other procedures, a reliable cost-benefit analysis that identifies the nature of the risks, quantifies their economic and social importance and proposes and prioritizes efficient measures to mitigate the main impacts.

It was in this context and with this purpose that we developed the study on the Economic and Social Impact of Road Fatalities in Portugal, delimited to the mainland, whose main conclusions are presented below.

The breakdown of the economic and social cost of road crashes into costs directly related to the victims, including human costs, loss of production, medical costs and other costs, and into costs related to the road crash itself, considering property damage, administrative costs and other costs, yielding the following results based on road crashes recorded in 2019:

- Road crashes with victims recorded a total cost of 5 362.7 million euros (2.53% of GDP), with human costs representing the largest share of that figure, 64.7%, corresponding to 3 471.1 million euros, followed in order of magnitude by the costs of lost production 1 438.0 million euros, medical costs (84.6 million euros), property damage (263.9 million euros), administrative costs (78.5 million euros) and other costs (26.6 million euros);

- Considering the costs of road crashes without victims (1 060.1 million euros), the total economic and social cost of road crashes reached 6 422.9 million euros, representing 3.03% of the GDP;

- The human costs of male victims are higher than those of female victims, the biggest difference being observed in the working age period of the victims;

- The gross value of the production loss is higher for male victims when compared with the value of the production loss for female victims, with particular emphasis on the first years of working life;

- A longitudinal analysis of the economic and social cost of road fatalities in the last 25 years shows a significant reduction in that value, from about 7% of GDP to approximately 2.5% of GDP at current prices in 2019, as a result of the decrease in the number of fatalities and the reduction in the number of slightly injured people;

- The moral, immaterial or non-patrimonial costs (human costs) of road crashes are quite significant for the more serious victims and even for the slightly injured due to the high number of victims recorded;

- Costs related to loss of production are also quite high among the victims (drivers, passengers and pedestrians), especially for the slightly injured due to lost work time and due to the continued impact on productive capacity by the seriously injured;

- Slightly injured cause the largest share of the economic and social cost of casualty road crashes recorded in 2019, a total of €2 249.9 million (1.06% of GDP), due mainly to human costs, loss of productive potential and material damage suffered;

- The average cost is higher for fatalities, amounting to €3 055,358 million per fatal victim, which is mainly explained by the high moral, immaterial or non-patrimonial costs for the victims' families and friends, totaling €2 269,837 million, and the value of the gross loss of production (€760,927 per victim);

- Of the victims (drivers, passengers and pedestrians), it is the drivers who contribute most to the human costs of traffic crashes (3 385.9 million euros), followed by passengers (1 070.9 million euros) and pedestrians (906.0 million euros);

- The average economic and social cost of a road crash with victims at 2019 prices is estimated at €146,219 per road crash, of which €53,570 is attributable to the resulting fatalities, while €32,233 and €60,417 are attributable to the seriously injured and slightly injured, respectively;

- The estimate for society of the average cost in road crashes with at least one fatality exceeds 3 478.6 million euros per road crash at 2019 prices due to society's valuation of the human costs associated with road crashes (2 570,503 euros), plus the effect of lost production (871,931 euros);

- In the case of road crashes with at least one fatality and/or serious injury, the average economic and social cost is more than €1 286.49 million per road crash at 2019 prices. The largest share of this figure relates to the most seriously injured victims (€790,026), followed by the seriously injured resulting from the road crash (€475,356) and €211,008 referring to the slightly injured;

- In road crashes resulting only in serious or slightly injured, the estimated average cost of a road crash reaches 606,793 euros, figures in 2019 prices, respecting most of this figure to the most seriously injured (585,979 euros), followed by the slightly injured resulting from the road crash (20,814 euros);

- It was found that Sunday is the day of the week when the cost to society of road crashes is highest, with an average value of 181,913 euros per road crash, the largest share being attributed to the most serious victims, 73,078 euros for the fatalities and 45,102 euros for the seriously injured, while the lowest cost is on Wednesday with an estimated 125,154 euros per road crash;

- In a monthly evaluation, it was found that August is the month of the year in which a road crash presents the highest cost to society, estimated at 171,578 euros per road crash with victims, whose value is mainly due to the severity of the road crashes recorded in this month;

- It was also found that, at district level, the districts of Alentejo are those with the highest economic and social costs from road crashes, due in large part to the high number of fatalities and seriously injured that have been registered – Beja recorded a total of 322,696 euros per road crash with victims, followed by the districts of Portalegre and Évora with a cost of 322,696 euros and 263,185 euros, respectively. In contrast, the Lisbon district has the lowest cost per road crash, 109,528 euros;

- With regards to the economic and social costs of traffic crashes by type of road, the highest costs to society are found in road crashes that occur on forest roads, with an estimated 403,163 euros per road crash with victims, due to the high number of fatalities and seriously injured that occur, while the estimated cost per road crash with victims on main roads is 339,494 euros and on municipal roads 214,302 euros;

- Road crashes involving vehicles that are at least 20 years old are those with the highest average economic and social value, in the order of 170,078 euros per road crash with victims;

- With regards to road crashes according to their nature, the results obtained indicate that it is the pedestrian road crashes that have the highest average cost for society, with an estimated of this amount, 73,278 euros refer to the cost of fatalities, 38,890 euros to the seriously injured resulting from road crashes and 49,569 euros to minor injuries. In descending order of cost, next are the road crashes (158,743 euros) and collisions (134,070 euros) per road crash;

- Still with regard to the estimated average economic and social cost of a road crash according to the type of vehicles involved, it was found that road crashes involving agricultural vehicles are the most significant, at 466,998 euros per road crash, followed by road crashes involving heavy vehicles (261,906 euros), road crashes involving quadricycles (239,513 euros); road crashes involving motorcycles with a cylinder capacity greater than 125cc (235,393 euros), with road crashes involving motorcycles reaching the lowest cost (73,163 euros per road crash).

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Notes

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[i] WHO Global Road Safety Report.

[ii] This structure allows maximum flexibility and potential with regard to the analysis of the information contained in the system and opens up a whole set of new possibilities in the field of accident analysis. National datasets are integrated into the CARE database in their original national structure and definitions, with confidential data erased. However, transformation rules are implemented in the CARE database to increase the compatibility of the data and thus improve the functioning of the system. The process of improving the "homogenization" of accident data within CARE is ongoing. However, the inherent incompatibility of national accident data remains a source of possible misinterpretation when carrying out comparative analyzes at an international level. Therefore, online access to the CARE database is currently restricted to experienced investigators. The summary statistical tables and figures contained here provide an overview of road accident data from 2007 to 2016. For some figures, sources other than CARE were used to give an overview of EU road accident data.

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