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# A Cost-Benefit Approach for Analysing the Impact of eCall Technology on the EU Passenger Vehicles

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*Increasing road traffic safety is a requirement for the growth and development of economies and society in general, and any endeavour contributing to an increase in the safety of road traffic participants must be evaluated and even encouraged, as there is no measurement for the value of human life. An important technological improvement that contributes to road traffic safety by reducing response time in case of an accident is the eCall In Vehicle System, which provides real-time data on-site, even without human intervention. The aim of the present study is to approach the introduction of the eCall In Vehicle System from a cost-benefit standpoint of equipping aftermarket passenger vehicles with this technology. To this end, we propose an analytic research approach in the form of a conclusive study on statistical data, in order to support decisions regarding future implementation.*

Keywords: *eCall; Road Traffic Safety; Economic and Social Impact; Aftermarket, Cost Benefit Analysis; Passenger Vehicles.*

## Introduction

Increasing the safety of road traffic participants, regardless of the mode of transport, is one of the central pillars of the European Union (EU) policy in this area. According to the information available in various reports, analyses, databases, articles etc., injuries resulting from road accidents occupy a disturbing place in the top 10 causes of death worldwide. For example, Global Health Estimates 2016, published by the World Health Organization (WHO) in 2018, shows that in the year 2000 road injury was ranked 10th in the classification, generating over 1.2 million deaths. In just 6 years, it climbed to the 8th place, becoming the cause for the loss of life of about 1.4 million people as a result of severe injuries in road accidents.

If we look at Global Health Estimates during the period 2000–2019 (WHO, 2020), we may notice that data is differentiated on several levels, namely, in 2019, in the ranking of the first 10 causes of death it is as follows: at the global level and in high-income countries, road injury no longer appears in the ranking; in low-income countries, road injury is in the 7th place; in lower-middle-income and upper-middle-income countries, road injury is in the 10th place (the classification of countries according to the income of citizens in 2019 was provided by the World Bank in 2020). An additional indicator worth mentioning refers to the disability-adjusted life years. The same report (WHO, 2020) shows that among the top 10 causes of disability-adjusted life years, the road injury ranks sixth, which is an undesirable issue for decision-making forums and citizens in general.

Over the last decades, significant progress has been made in increasing the safety of road users to meet their transport needs. In this case we refer to the technological improvements brought to the vehicles, such as the installation of devices to help: control and adapt the speed of travel to traffic conditions; ensure passenger and driver safety; reduce the number of situations in which the driver of the vehicle is distracted for various reasons while driving; detect the drivers who have consumed alcohol and wish to use the vehicle etc. A more recent technology should be added to this list, namely, eCall In Vehicle System, whose role, among other things, is to help reduce the intervention time at the scene of road accidents.

From an Internet of Things (IoT) perspective, devices that can be used in the present day can be grouped into three categories: devices that ensure connectivity between vehicles; devices that allow connectivity between the vehicle and the surrounding or external infrastructure; devices dedicated to ensuring vehicle connectivity with other devices (Iqbal & Rana, 2019, p. 1378). ECall technology is part of the third group, both in terms of functionality and utility, because it allows real-time data communication without human intervention, i.e. data about the type of vehicle involved in the accident, the direction of travel, the number of passengers, the location etc.

Efforts to develop and implement the eCall technology in passenger road vehicles began more than ten years ago, but it became mandatory to install the device for new M1 and N1 vehicles only in April 2018 (according to Directive 2007/46/EC). According to the EU Vehicle Definitions, M1 vehicle type is a vehicle that can have a maximum of 8 passenger seats, apart from the driver's seat and N1 vehicle type is a vehicle used for the transport of goods, which can have a maximum mass of 3.5 tons. Along with other aspects, the implementation decision for new vehicles was too slow to decrease the number of fatalities and severe injuries resulting from accidents on European roads. There was a reduction of fatalities with an average rate of 2.2 % per year in the period 2010–2019, and the number of severe injuries at an average annual value of over 268,662 cases in the period 2010–2018 (Carson *et al.*, 2020).

The positive effects of installing eCall technology in all road vehicles (both new and aftermarket) are numerous, namely: reduction by up to 50 % of delays in achieving accident interventions and streamlining rescue operations for better and more complete communication; reduction in the number of secondary accidents and the negative impact on the environment, which occur due to traffic congestion; reduction of negative, economic and social consequences, affecting people involved in serious road accidents resulting in fatalities and severe injuries etc. (McClure, Forestieri & Rook, 2016, p. 9–16; EC, September 8, 2011, p. 10-15).

To see whether the benefits of installing eCall technology in aftermarket vehicles outweigh the costs warrants a cost-benefit analysis. In support of this statement, we note the important changes produced by the Covid-19 pandemic in the automotive industry, such as the significant reduction in sales of new road vehicles during 2020 (ACEA, 2021), forced social isolation, travel restrictions and the current economic and social context.

Finally, this paper considers only the fleet of passenger vehicles traveling on European roads. First, only passenger vehicles are being studied because they (46 %), along with pedestrians (21.4 %) and motorcyclists (15.2 %), generate the highest rate of deaths (the cumulative value of the three categories mentioned is 82.6 %) and serious injuries caused by road accidents (EC, 2018). Secondly, the passenger vehicles are the best suited for the installation of eCall technology on a large scale (there are constructive options developed both for the equipment of new vehicles - M1 and N1, and for the equipment of passenger vehicles in the after-market segment). For pedestrians, this option does not exist yet, and for motorcycles, the development of the corresponding technology is still at a relatively early stage.

The main aim of this study is to approach the introduction of the eCall IVS from a cost-benefit standpoint. This requires an analytic research approach in the form of a conclusive study, where the area of research is the cost-benefit analysis (CBA) of the application of eCall in the aftermarket passenger vehicles.

## Methodology and Data

Any investment decision must be based on a well-documented analysis (which can be, for example, a cost-benefit analysis). The more the project requires the allocation of a consistent volume of resources and its impact affects a wider range of beneficiaries, the more complex and difficult it is to perform the analysis. The same happens with the increase of the territorial dimension of the project implementation or of the diversity in types of effects that are generated.

Documentation of the cost-benefit analysis (CBA) involves in-depth research of the field in which the investment is made, the factors that contribute to the formation of various types of costs involved in project implementation, the categories of benefits and beneficiaries, the characteristics of the current economic and social environment, the perspective of its evolution etc. There are several approaches to the significance and content of CBA. According to some opinions, CBA is a mechanism dedicated to making decisions on the implementation of a project, regardless of its nature, in which the project coordinates are established, the relevant effects are identified (from an economic perspective, with reference to costs and benefits), which is then quantified physically and monetarily (Liu *et al.*, 2010, p. 65).

Many authors note that the cost-benefit methodology is probably one of the oldest used (Adler & Posner, 1999; Persky, 2001) to determine whether or not an investment project is appropriate. They note that CBA has been used in the United States since the early 19th century, initially to evaluate investment projects for waterborne transportation, and has since been applied in all areas, around the world, to a range of increasingly extensive projects. For example, the evaluation of the impact of various legislative initiatives, such as the implementation of eCall IVS technology, changes, or modernizations of various public systems (education, health, social security, transport, utility networks etc.), the introduction of a new quality management system, or other types of projects in this category. In this situation, for many of the projects, a comparative analysis of the current situation is made with the one desired after the implementation.

Other authors (Prest & Turvey, 1965; Vanhove, 2017) have defined CBA as a practical methodology, which can assess the opportunity or need to carry out a particular project, emphasizing the importance of adopting a comprehensive view of evaluators. The vision covers both the various aspects of the project (categories of costs and benefits to be identified and evaluated) and a sufficiently comprehensive timeframe (for short- and long-term impact analysis), so that the results of the analysis can be considered relevant. Other opinions address the feasibility of investment projects when defining CBA (Boardman *et al.*, 2017), showing that its purpose is to assess their impact, from an economic and social perspective. The basis of the evaluation is the identification, monetary evaluation, and comparison of the costs and benefits associated with the project and the comparison of the results obtained with the objectives initially considered.

With reference to the field of transport, there are several evaluation methods that can be applied (Macharis *et al.*, 2009, p. 183–184), of which the most common are: Private Investment Analysis; Economic Effects analysis; Cost Effectiveness Analysis; Social or Economic Cost Benefit Analysis; Multi Criteria Decision Analysis.

The first three focus on the economic effects, considering a single aspect, namely the viability of the project from a financial point of view. The last two are much more complex and allow considering several aspects related to the implementation of the investment project. The Social and / or Economic Cost Benefit Analysis consider both economic and social or market-related aspects. Of course, it is very difficult to capture and evaluate from a monetary point of view all the effects generated or the impact of a project, such as the implementation of eCall technology. Equally, considering the complexity of the investment approach we refer to in the paper, the level of uncertainty regarding the input data is important. Thus, there are various corrections that can be made (such as: discounting annual costs and benefits, in order to calculate relevant indicators, such as Net Present Value - NPV, or Benefit Cost Ratio - BCR); a more pessimistic approach to quantifying benefits; oversizing the various categories of associated costs; choosing a long forecast interval etc.), so that the relevance of the obtained results can be considered satisfactory.

A final classification to which we refer (Beria *et al.*, 2012, p. 137–139), divides the methods of analysis, respectively of evaluating transport projects in single criteria methods (approach of evaluation from the monetary point of view), such as CBA (recommended for policies and infrastructure projects), and multi-criteria methods (multi-point approach to evaluation, which is why it is also called the non-monetary approach), such as Multi Criteria Decision Analysis (recommended for assessing the sustainability of mobility projects) , mentioned above.

With regard to the stages of application the CBA methodology, there are several opinions. A synthetic image of the CBA steps can be seen in Figure 1.

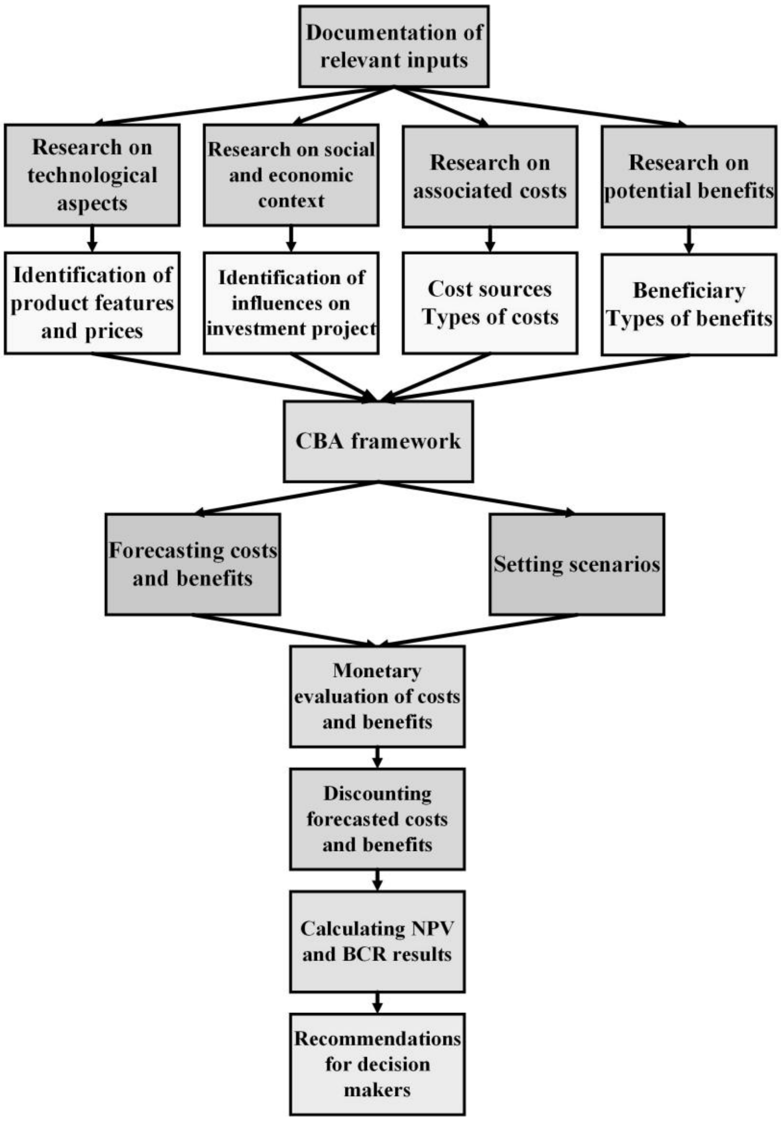


**Figure 1.** CBA Flow Chart

*Note: NPV = Net Present Value; BCR = Benefit Cost Ratio*

From our point of view, six stages have been completed, which are essentially the main issues to be addressed in the CBA, namely: collecting and analysing data on the evolution of the number of vehicles, on the one hand, and the number of fatalities and severe injuries in road accidents in the EU, on the other hand, in the last decade; identifying and forecasting the costs associated with the implementation of eCall technology, on the 2021–2030 analysis horizon; identifying and forecasting the benefits generated by the implementation of the technology; establishing the scenarios on which the analysis will be built; monetary evaluation of costs and benefits; analysis of results and formulation of recommendations.

Regarding the data used, in order to perform pertinent and relevant analyses in any field, we need quality information, obtained by applying unitary methodologies that are standardized and applicable on a large scale. The standardization in the reporting of data regarding the number of fatalities and severe injuries, for example, has the role of helping to provide the necessary framework for analysing the impact that the implementation of eCall In Vehicle System (IVS) technology at the European Union level can have. However, it is more difficult to have the same 'discipline' regarding the reporting of the number of new vehicles purchased in a year, or the number of vehicles by age categories etc. In order to ensure coherence in the CBA approach, only Eurostat data, or data provided by relevant entities at European level was used.

However, we notice a negative aspect, which, unfortunately, is not specific only to the field considered. We refer to the extremely large gap between the data availability and the time when various studies and analyses are performed, as is the case of the present research. We consider that an interval of 2–3 years between the two moments of time can slightly alter the relevance of the results of a cost-benefit analysis. In this situation, the last year with complete data on the number of fatalities and vehicles in use is 2019, and for the number of severe injuries in road accidents it is 2018.

**The Forecast of Passenger Vehicles and Costs**

To begin with, we will address some issues related to the passenger vehicle fleet in the EU Member States. Then, some correlations will be established between the pace of eCall IVS technology implementation and the size of the impact generated on the decrease in the number of deaths and severe injuries, resulting from serious road accidents. The following indicators are taken into consideration: the number of passenger vehicles in circulation, or the passenger vehicle fleet (Table 1), the average age of the vehicle fleet (Table 2 and Figure 2) and the growth rate of the number of passenger vehicles in use (Figure 3), which represent the basis for forecasting the number of vehicles on the analysis horizon. In the case of these indicators, as in the case of those related to health, there are long delays in the availability of data. The last year with definite data is 2018, but we also present some provisional data for 2019 and 2020.

The evolution of the number of passenger vehicles was strongly affected by the COVID-19 pandemic, throughout 2020 (ACEA, 2021).

It is estimated that the number of new vehicles, registered in 2020, contracted by about 25 % compared to 2019 (ACEA, 2021). If we refer to the vehicles in circulation (Table 1), we notice that in the period 2009–2020 their number increased by almost 18 %, which means an average of 1.5 % per year. As there are still no clear reports for vehicles traveling on EU27 + UK roads in 2020, the value has been approximated, starting from the declining pace of newly registered vehicles.

Regarding the evolution of the average age of the passenger vehicle fleet, the data shows that it has increased almost continuously in the analysed interval, with one exception (2018). Thus, the average age of the passenger vehicle fleet increased from 8.6 years in 2009, to over 11 years in 2019 and 2020, respectively by almost 35 %, which shows continuous aging. The phenomenon has two main causes: the increase of the quality of the vehicles, which allows longer use; the slow pace of buying new vehicles, both due to their rising price and the lack of financial resources to purchase a new vehicle, especially in Eastern European countries.

The detailed situation by country (except for the data for Bulgaria, Cyprus and Malta) for 2019 is shown in Figure 2. The average indicator is 11.5 years in 2019. In the group of countries with an average passenger vehicle fleet age less than or equal to 10 years we find 8 countries, respectively Luxembourg, United Kingdom, Austria, Ireland, Denmark Belgium, Germany, and Sweden.

In the segment of countries with a fleet age of 16 years or more, we include Greece, Romania, Estonia, and Lithuania. In the case of other countries, the average age of passenger vehicle fleet is in the range of over 10 years (France with 10.2 years), up to a maximum of 15 years (Czechia with 14.9 years).

However, in the bottom ranked countries, the value of the indicator (16 years and over) is almost twice higher than the average value in 2009.

For the 2015-2020 periods, we notice the steady decrease in the increasing index, so that the growth rate of the number of passenger vehicles in use decreased almost to the level recorded in 2010, compared to the previous year (an increasing index of 1.21 in 2010, compared with 2009). We note that, in absolute values, the passenger vehicle fleet increased constantly throughout the analysed time period.

The duration targeted by the Cost Benefit Analysis (CBA) is 10 years, respectively 2021–2030, starting from the idea that at European Commission level the goal is to reduce the number of deaths resulting from road accidents by 50 % in the mentioned period (Carson *et al.*, 2020).

The forecast of the number of vehicles that will be equipped on the analysis horizon in the interval established for the CBA considers several main aspects, which will be further detailed.

The transition period for the UK's withdrawal from the EU ended on 31 December 2020 (when the United Kingdom became a non-member country). For the realization of the CBA, the data for EU27 + UK is taken into account, because: most of the historical data is available for EU28. The attempt to now separate the statistical data for the EU27 and the UK so that the two can be treated as separate entities may affect the accuracy and relevance of the analysis; although, formally, EU road safety legislation no longer applies in the UK, it is hard to believe that from 1 January 2021 the legislative framework is completely different in the UK. As a result of global decision-makers' efforts, most road safety regulations (including indicators, data collection and reporting etc.) are the same, almost everywhere in the world.

Table 1

**EU27 + UK Passenger Vehicle Fleet, in 2009–2020 (Million Units)**

| **Year** | **2009** | **2010** | **2011** | **2012** | **2013** | **2014** |
|---|---|---|---|---|---|---|
| Passenger cars | 238.7 | 241.6 | 244.5 | 246.8 | 248.9 | 251.4 |
| **Year** | **2015** | **2016** | **2017** | **2018** | **2019** | **2020*** |
| Passenger cars | 257.9 | 263.4 | 268.8 | 273.4 | 277.9 | 281.3 |

*Provisional data

*Source: ACEA, Vehicle in use Europe, January 2021; ACEA, the Automobile Industry Pocket Guide 2015–2021.*

Table 2

**Average Age of the EU27 + UK Passenger Vehicle Fleet (Years)**

| **Year** | **2009** | **2010** | **2011** | **2012** | **2013** | **2014** |
|---|---|---|---|---|---|---|
| Average age | 8.6 | 8.9 | 9.1 | 9.3 | 10.3 | 10.5 |
| **Year** | **2015** | **2016** | **2017** | **2018** | **2019*** | **2020*** |
| Average age | 10.7 | 11.0 | 11.1 | 10.8 | 11.5 | >11.5 |

*Provisional data

*Source: ACEA, the Automobile Industry Pocket Guide 2015–2021.*

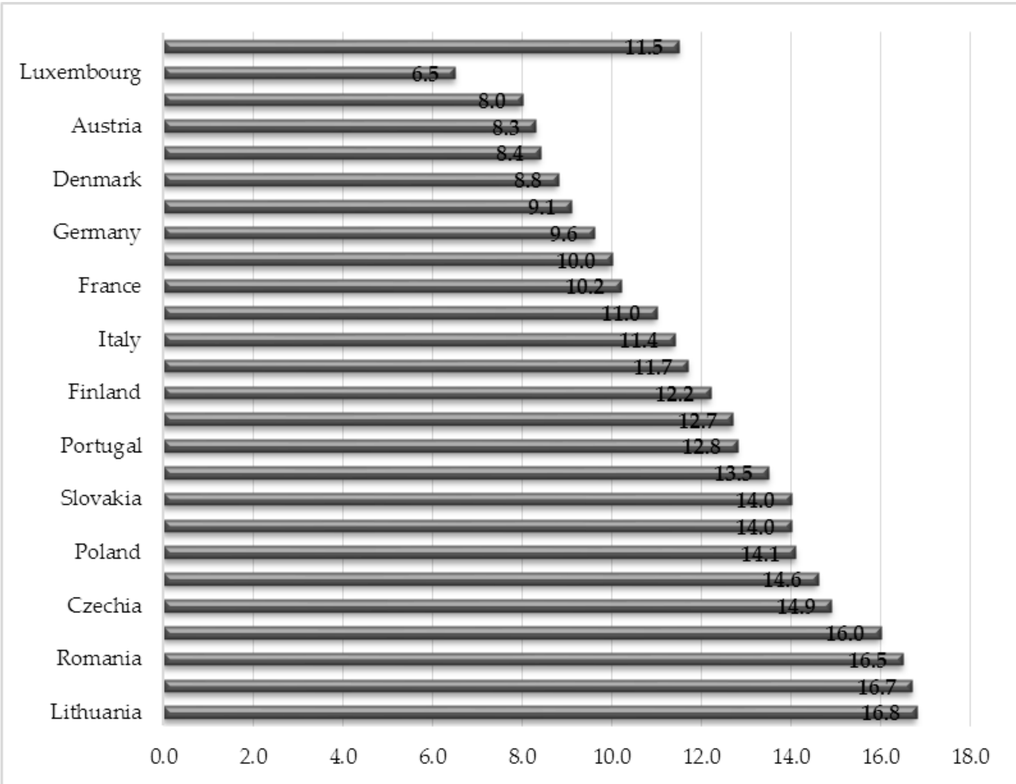


**Figure 2.** Average Age of the Passenger Vehicle Fleet by Countries (EU27 + UK) in 2019 (Years)

*Source: ACEA, Vehicle in use Europe, January 2021. No data for Bulgaria, Cyprus, and Malta.*

In this analysis, only the passenger vehicle segment is considered, for several reasons. On the one hand, this segment has the largest share in the total number of vehicles (Table 3), respectively 87.3 % in EU27 + UK and 86.1 % in Europe (ACEA, 2021). On the other hand, according to the latest data available for EU27 + UK (EC, Annual Accident Report 2018), 46 % of road fatalities (in 30 days after the crash, and includes drivers and passengers in motor vehicles, people on bicycles, and pedestrians) are caused by passenger vehicles (cars and taxis).

According to recent analyses, despite the contraction in passenger vehicle sales in 2020, the behavior of individuals has been influenced by the COVID-19 pandemic (Vitale *et al.*, 2020), because, out of a desire to be more protected, they prefer the safety of their own means of transport, rather than public transportation.

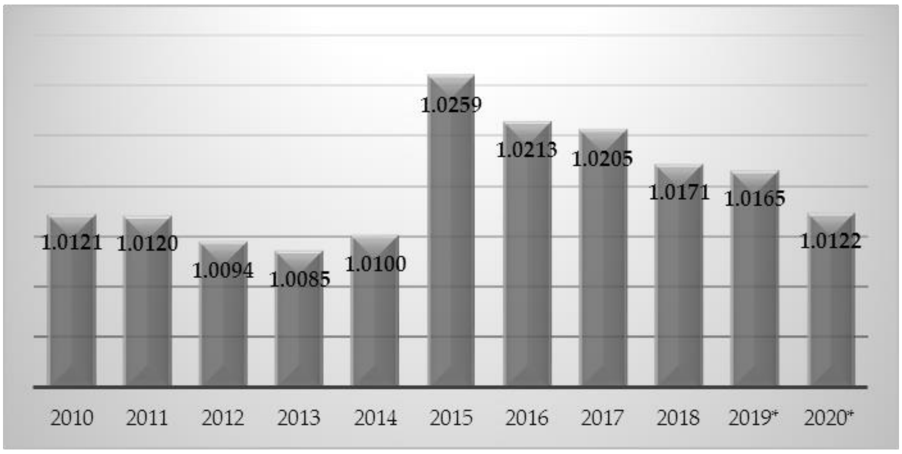


**Figure 3.** Increasing Index of the Passenger Vehicle Fleet (EU27 + UK), 2010–2020

*Source: ACEA, Vehicle in use Europe, January 2021; ACEA, The Automobile Industry Pocket Guide 2015–2021.*
**Provisional data for 2019 and 2020.*

In this regard, we mention the recent trends in preference towards one's own car as means of transportation revealed by surveys conducted in countries such as France (79 %), US (74 %), UK (69 %) and South Korea (63 %) etc. (Vitale *et al.,* 2020).

Therefore, even if the pace of sales of new vehicles (equipped with eCall at the factory) has slowed down, it is certain that very old vehicles will continue to be taken out of service and replaced with new ones; people will want to buy new, more efficient vehicles.

In addition, the passenger vehicles segment older than April 2018 segment (when it became mandatory to equip new M1 and N1 vehicles with the eCall device) remains consistent and of great interest for the objective considered by this analysis.

The annual growth rate of the passenger vehicle fleet, which will be considered in the analysis horizon, is 1 %, respectively an increasing index of 1.01 (Table 4). The value is lower both compared to the increasing index in 2020 compared to 2019 (1.0122) and compared to the annual renewal rate (1,017), considered in similar analyses, performed previously (Zirra *et al.,* 2020). The reason for this choice is generated by the uncertainty regarding the evolution of the passenger vehicle fleet on the analysis horizon, including here the newly purchased vehicles. We refer here to the impact caused by the uncertainty regarding the level of future revenues, both for companies and for individuals, against the background of the economic crisis generated by the COVID-19 pandemic.

The basic value for calculating the annual number of passenger vehicles in use in the 2021–2030 period is the one published for 2020, respectively 281.3 million units (ACEA, 2021).

Table 3

**Weight of Passenger Vehicles and Light Commercial Vehicles in Total Motor Vehicles in 2019**

| Vehicle category | Area | Number | Weight in total motor vehicles (%) |
|---|---|---|---|
| Passenger vehicles | EU27 + UK | 277,895,501 | 87.3 |
| | Europe | 342,268,333 | **86.1** |
| Light commercial vehicles | EU27 + UK | 32,638,675 | 10.3 |
| | Europe | 42,007,675 | **10.6** |
| Others | EU27 + UK | 24,770,908 | 2.4 |
| | Europe | 30,195,304 | **3.3** |

*Source: Calculations based on ACEA Report, January 2021.*

Table 4

**EU27 + UK Passenger Vehicle Fleet, in 2021–2030 (Million Units)**

| Year | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 |
|---|---|---|---|---|---|---|---|---|---|---|
| Passenger cars | 284.1 | 287.0 | 289.8 | 292.7 | 295.6 | 298.6 | 301.6 | 304.6 | 307.7 | 310.7 |

*Source: Own calculations, based on ACEA, Vehicle in use Europe, January 2021.*

The total cost of implementing eCall technology is not just about equipping passenger vehicles. The adoption of the technology for the entire fleet of passenger vehicles circulating on European roads is addressed to both new vehicles, which are equipped from the factory, and to those older than 3 years, so equipped after-market.

The segment of vehicles that are in use and older than three years is consistent. This is observed from the constant increase of the average age of the passenger vehicle fleet in the 2009–2020 period (Table 2), as well as from the Eurostat data for 2009–2018 (Eurostat, 28 March 2020), according to which the share of passenger vehicles older than 2 years in 2018 (Figure 4) is 87 % (considering that the average renewal rate mentioned above is 1,017, the share of vehicles older than three years is likely around 85 %).

The annual cost of equipping vehicles with the eCall IVS device will result from multiplying the unit price by the number of vehicles that will be equipped each year.

When evaluating the costs of installing eCall IVS devices, the financial efforts of after-market service providers for passenger vehicle owners may also be considered. This implies adapting their offer, in the sense of increasing the installation capacity of the devices on board the vehicles that are in use. But, at least for now, no financial data can be obtained from this segment of companies, in a way that would allow the value of these costs to be considered in substantiating this analysis.

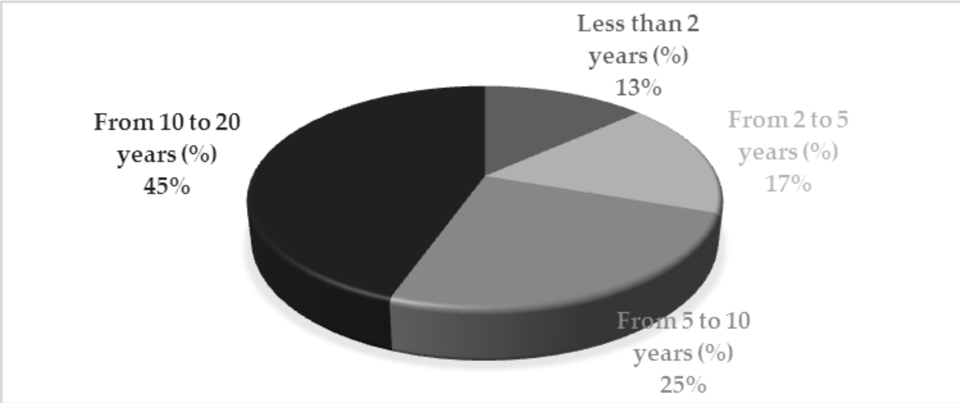


**Figure 4.** The Weight of Passenger Cars by Age of Vehicles, 2018

*Note: without reported data for number of passenger cars by age from Bulgaria, Greece, and Slovakia.*

*Source: Own calculations based on Eurostat, 28 March 2020.*

Another category of costs that should be mentioned is the proper equipping of Public Safety Answering Points (PSAPs) (including software) and to the training / instruction of personnel, so that these essential for rescue operations entities have the ability to properly manage the new category of 112 calls (HeERO, 2015, p. 69–73). These costs were estimated in 2013 at a level of 1.1 million Euros per Member State (Proposal COM / 2013/0315 final - 2013/0166, approved by Decision No 585/2014 / EU of 15 May 2014).

Given that important steps have already been taken with regard to the interoperability of the 112-emergency service at European level (which has been under way since 2005) and the adoption of eCall technology on board passenger vehicles, we cannot include this category of expenses on the forecast horizon. An additional reason would be the fact that no definite data are known on the level or degree of modernization of PSAPs in the Member States, in line with the pace of progress in the field of information and communication technology.

### The Forecast of eCall Implementation Benefits

When performing a CBA there are two main components. On the one hand, it is the component of the costs associated with an investment approach, which must be identified, evaluated, and quantified from a monetary point of view. On the other hand, we have the benefit component, which in turn must go through the same steps, mentioned earlier for costs.

If in terms of costs the process is relatively easier to achieve, monetary assessment of benefits is more complicated. Moreover, the higher the amplitude of the investment, the greater the territorial expansion and the expected effects, especially the social impact, the harder the identification and quantification of all the benefits generated becomes.

Usually, when we think of an investment that is made at company level, the benefits are expressed by a higher turnover, a higher profit, a higher market share than those obtained before the investment. In the case of this CBA, the benefits are not expressed in financial benefits but in the reduction of costs, which is generated by the implementation of eCall IVS technology on an extended scale. This reduction of costs means savings made by reducing the number of fatalities and severe injuries resulting from serious road accidents. Therefore, in order to forecast the benefits on the analysis horizon, we have in mind several aspects, which will be highlighted further.

The installation of the device on board all vehicles will make an important contribution to the efficiency of rescue operations from at least three perspectives. First, we refer to the reduction of the intervention time, by quickly calling the emergency service 112. Second, it is about the more exact location of the accident site and about the availability of essential information about the vehicles involved, the participants in the trip etc. Third, we consider a better preparation of the intervention, both through the equipment and machinery moved to the accident site, and through a better allocation of qualified personnel (medical and non-medical).

With all passenger vehicles equipped so far with eCall technology, to which those equipped on the forecast horizon will be added (either from manufacturing or after-market), it is estimated that the contribution to reducing the number of fatalities and severe injuries will be significant.

There is several impact assessments conducted on this topic. According to the initial proposal (approved by Decision No 585/2014 / EU of 15 May 2014): the impact on reducing the number of fatalities is in the range of 1 % - 10 % (this value is influenced by several factors, such as the quality of transport infrastructure and the emergency system, population density and, implicitly, traffic etc.); the impact on reducing the gravity of severe injuries is between 2 % and 15 %.

According to other studies, such as E-MERGE / STORM Germany, National Evidences, France, and National Evidences, USA (calculations based on Berg Insight, 2007): the impact on reducing fatalities is between 5 % and 15 %; the effect on reducing severe injuries is between 10 % and 15 %. Starting from the previous intervals, for the present analysis we will consider that, for the situation in which all passenger vehicles will be equipped with eCall IVS devices until the end of the forecast interval, the number of fatalities will be reduced annually by 10 %, and the number of severe injuries by 12 %. Chosen values were calculated as an average of the data published in various specialized studies, such as those already mentioned.

Calculating the benefits of implementing large-scale eCall IVS technology is extremely difficult. There are several main elements on which the identification and evaluation of benefits is based. These are mentioned in profile studies conducted by experts in this field, and some of the most important will be mentioned below.

The first element is that, in order to ensure the uniformity of analyses and statistical records, standardized definitions are applied (Table 5) and used globally to quantify the effects of road accidents resulting in injuries or deaths (van der Vlegel, 2020).

At European Union level, starting with 2014, a new way of collecting data is applied, based on the classification system used in the medical field, called Abbreviated Injury Scale (AIS). It is worth mentioning that old definitions of fatality, severe injury and slight injury are more detailed by applying the new measurement and classification scale, and the analyses that can be performed benefit from more relevant information (CE Delft, 2019, p. 39).

Table 5

**Concepts Used to Define the Effects of Transport Accidents**

| AIS scale | | Example | Concepts | Old definition |
|---|---|---|---|---|
| **AIS 1** | Minor | Sprained ankle | Slight injury | A person who sustained an injury as a result of the accident but does not fall under the definition of serious injury. |
| **AIS 2** | Moderate | Closed fracture | | |
| **AIS 3** | Serious | Open fracture | Serious injury | A person who sustained an injury as a result of the accident and who was hospitalized for a period of more than 24 hours. |
| **AIS 4** | Severe | Amputation | | |
| **AIS 5** | Critical | Rupture liver with tissue loss | | |
| **AIS 6** | Maximum | Extreme or fatal injury | Fatality | Any person killed immediately or dying within 30 days as a result of an injury sustained as a result of an accident. |

*Source: CE Delft, 2019, p. 39; UNECE, 2020.*

Transport operations (passengers and freight) are costly (they actually make up the external cost of road transport). They can be classified into several categories, depending on the generated impact, such as costs generated by accidents, air pollution, noise, roadblocks, damage to natural habitat etc. (Table 6).

The largest share of transport operations costs are the costs generated by accidents (37 %) and costs related to traffic congestion (almost 35 %). This is largely due to road traffic accidents and the quality of the road infrastructure (responsible for many of the accidents, especially in countries with poorly developed road infrastructure, either in road size or quality).

Table 6

**Annual External Cost of Road Passenger Transport by Passenger Vehicles**

| Cost type | Billion Euro/year | Cost type | Billion Euro/year |
|---|---|---|---|
| Accidents | 210.2 | Congestion | 196.1 |
| Air Pollution | 33.4 | Well-to-Tank | 18.13 |
| Climate | 55.6 | Habitat damage | 25.9 |
| Noise | 26.2 | | |
| **Total** | **565.4** | | |

*Source: CE Delft (complete overview of country data), 2019.*

When referring to road accidents, there are several categories of costs that can be considered (Corazza *et al.*, 2016).

On the one hand, we mention the classification of these costs into two main groups: outsourced costs, associated with the operations carried out by various entities involved in rescue operations, such as fire brigades, police, or those providing emergency medical services; internalized costs, associated with the field of insurance, covering the field of accidents, destruction of property due to accidents etc. and which are not taken into account when evaluating the benefits of installing eCall technology.

On the other hand, we consider the classification according to which (Schoeters *et al.*, 2017; EC Delft, 2019) there are six cost categories (Table 7) associated with the impact generated by road accidents, quantified in injured persons and fatalities. In addition, we remind that, for the realization of the CBA, only the outsourced costs are included in the total cost of road accidents, by type of casualty.

Another aspect worth emphasizing is that the basis for calculating the level of external cost of accidents, by cost elements, per casualty type (Table 7), is one of the indicators used globally for the evaluation of human health, respectively the Value of Statistical Life (VSL). VSL is part of the group of indicators that express the value of years of life that were lost or spent in poor health due to an accident (for example).

Table 7

**The Components of External Cost per Casualty Type, Average EU28 (Euro/Unit)**

| Type of cost | Definition | Externalized cost per casualty type | |
|---|---|---|---|
| Human costs | The monetary expression of the suffering that a person injured in a road accident must endure (of which externalized 100 %). | Fatalities | 2,907,921 |
| | | Serious injuries | 464,844 |
| | | Slight injuries | 35,757 |
| Medical costs | The value of medical care (treatments, medicines, medical staff etc.) offered in specialized institutions, such as hospitals, recovery centres etc. (of which externalized 50 %). | Fatalities | 2,722 |
| | | Serious injuries | 8,380 |
| | | Slight injuries | 721 |
| Administrative costs | The monetary value of the operations carried out by the specialized services that intervene at the accident site (of which externalized 30 %). | Fatalities | 1,909 |
| | | Serious injuries | 1,312 |
| | | Slight injuries | 564 |
| Production losses | Monetary expression of production losses, generated by the temporary or permanent incapacity of the injured person, including the costs necessary to replace the person (of which externalized 50 %). | Fatalities | 361,358 |
| | | Serious injuries | 24,055 |
| | | Slight injuries | 1,472 |
| Material costs | The value of the goods destroyed in the accident, respectively vehicles, street furniture, road infrastructure, goods in vehicles (of which internalized 100 %). | Fatalities | 0 |
| | | Serious injuries | 0 |
| | | Slight injuries | 0 |
| Other costs | Amount of expenses generated by the impossibility of using the damaged vehicle, burial (if applicable), traffic jams (of which internalized 100 %) | Fatalities | 0 |
| | | Serious injuries | 0 |
| | | Slight injuries | 0 |
| **Total** | | **Fatalities** | **3,273,909** |
| | | **Serious injuries** | **498,591** |
| | | **Slight injuries** | **38,514** |

*Source: CE Delft, 2019, p. 194–195.*

There are extremely large differences that exist between countries (CE Delft, complete overview of country data, 2019), regarding these costs (for example, the minimum cost of a fatality is evaluated at 1,728. 478 Euro / casualty in Bulgaria, and the maximum value is 6,491,289 Euro / casualty in Luxembourg). For this reason, we will use the average values (Table 7) of these costs at EU28 level to assess the benefits that can be generated from the installation of eCall technology in passenger vehicles circulating in the European Union.

In the category of benefits, we can include the reductions of costs generated by pollution, or road congestion, because studies present data on the relationship between installing eCall on board vehicles and reducing these types of costs (Schulz *et al.*, 2019, p. 44–46).

The calculation of the monetary value of the forecasted benefits considers three main aspects. First, the installation of eCall devices on board vehicles aims to help reduce the severity of the consequences of road accidents. More specifically, a potential death is reduced in severity, becoming a severe injury, thus generating savings of 2,775,318 Euro (3,273,909–498,591) for each case, and a severe injury becomes a slight injury, resulting in savings of 460,077 Euro (498,591–38,514).

Second, the cost reductions as a result of the impact on the number and duration of traffic jams (traffic jams or congestion) caused by serious road accidents, which result in deaths or serious injuries, are also considered when evaluating the benefits.

According to specialized studies (Schulz *et al.*, 2019, p. 44–46), the costs generated by traffic congestion caused by road accidents amount to 19,263 Euro / casualty in case of death, respectively 6,213 Euro / casualty in case the accident results in a severe injury or a slight injury. Therefore, similar to the previous aspect, we can consider that if a potential death is reduced in severity at the level of a severe injury, savings of 13,050 Euros (19,263–6,213) can be generated for each case.

Third, if we refer to air pollution caused by road traffic in Europe, we can consider that part of this category of external costs of transport is due to pollution caused by road congestion, which occurs when accidents with serious consequences occur.

According to the data already presented. The cost of air pollution amounts to 33.4 billion Euro / year (CE Delft, 2019). For the current analysis, we can include a reduction of some of the costs caused by air pollution in the benefits category, starting from the idea that by streamlining rescue operations, favoured by the implementation of eCall, road congestion and, consequently, pollution will be reduced.

Therefore, depending on the scenario, we will consider a reduction of this category of costs with values between 1 % and 3 % per year.

### Establishing Scenarios

Any investment approach, especially one on such a large scale, must consider at least three scenarios, regarding the evolution of the investment over a long period of time (in our case 10 years, respectively 2021–2030). In order to establish the scenarios for the elaboration of this cost-benefit analysis, it is necessary to consider some main aspects. Some are related to the size and pace of cost evolution, and others are related to the associated benefits.

On one hand, we refer to the fleet of passenger vehicles traveling on European roads, and to the pace of equipping them with eCall technology based on 112 (we will identify and evaluate the costs associated with this process on this basis), and on the other hand, we refer to the impact that the device would have on reducing the negative consequences of road accidents.

The scenarios considered have five elements:

- The annual pace of equipping passenger vehicles with the eCall IVS device;
- The impact on reducing the number of fatalities resulting from road accidents on European roads;
- The impact on reducing the number of severe injuries;
- The effect on pollution reduction;
- The influence on the costs generated by road congestions.

For the first element, the forecast of the number of vehicles in use on the analysis horizon presented in Table 4 will be considered. In the case of the following two elements (Figure 5 and Figure 6), respectively fatalities and severe injuries, we consider the latest statistics provided by the European Transport Safety Council (ETSC) in June 2020 (Carson *et al.*, 2020). A correction coefficient of 1.25 will be applied to the values regarding the evolution of the number of severe injuries, due to the presence of non-reporting situations of some road accidents (Ecoplan, 2002; HEATCO, 2006; Ecoplan & Infras, 2014; CE Delft, 2019). In the case of slight injuries, the proposed correction coefficient is 2, but this category of road accident effects is not considered when outlining the scenarios in this analysis.

The evolution of the number of severe injuries in road accidents produced in the EU27 + UK (Figure 5) in the 2010-2018 period does not show very large variations from one year to another (2018 being the last year in which we find data reported for most countries). However, we find a peak in 2011, when the number reported was close to 280,000 cases and a minimum in 2013, when the number fell below 260,000 cases.

For the number of fatalities, the reporting interval with complete data is 2010–2019 (Figure 6). In the case of this indicator, the evolution is with a predominantly decreasing trend. Thus, the indicator decreased by 22.17 % in 2019 compared to 2010, which means a decrease at an average of 2.2 % per year.

At European level, this rate of decline is unsatisfactory because it is much too slow. Moreover, the ‘Vision Zero’ target for 2050 at European level (EC, 2020), respectively no fatalities and severe injuries on European roads, seems, at least for the time being, an increasingly distant goal.

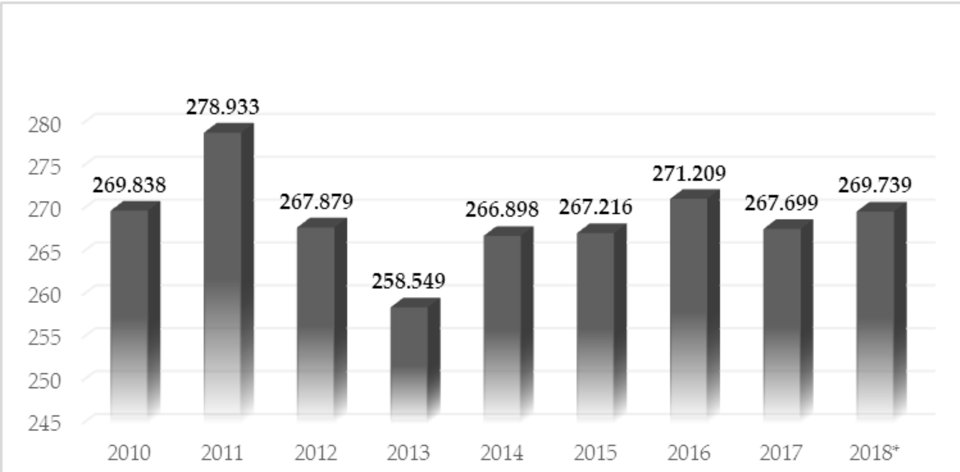


**Figure 5.** Number of Severe Injuries in Road Accidents in EU27+UK, 2010–2018

*Note: the values presented in ETSC report do not include data from Finland (2012–2018) and Italy (2010–2018), because they were not transmitted. *In the case of France, Ireland and Slovakia, the values for 2018 have been taken over from 2017, in order to ensure a relative coherence of the data series for 2010–2018.*

*Source: Carson et al., 2020.*

ETSC PIN Report (Carson *et al.*, 2020) shows that there are very big differences between countries, in terms of rhythm in the decrease of the number of fatalities in road accidents on European roads, in the period 2010–2019.

The gap between the country with the sharpest decline (Greece, with -44.44 %) and the one with the slowest rate of decline (Malta, where in fact the indicator has not decreased but, on the contrary, has increased by 6.67 %) is 51.11 percentage points.

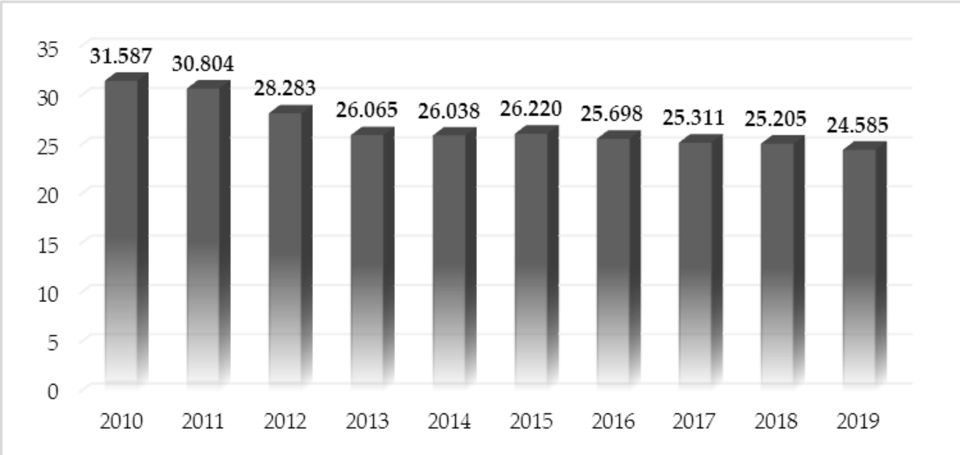


**Figure 6.** Number of Fatalities in Road Accidents in EU27+UK, 2010–2019

*Source: Carson et al., 2020.*

Therefore, the setting of scenarios is based on the following values of the indicators considered:

1. The evolution of the number of passenger vehicles that will be equipped with the eCall device annually (a share of the passenger vehicles fleet - Table 4).

2. The impact of equipping vehicles on reducing the number of severe injuries will be established starting from the level reached in 2018 (269,739 cases), this being the most recent value included in the ETSC PIN Report 2020 - Figure 5.

3. The impact on reducing the number of fatalities will be established starting from the value of this indicator for 2019 (24,585 cases), also included in the ETSC PIN Report 2020–Figure 6.

4. In order to establish the forecasted impact for the three scenarios, respectively Basic Scenario (BS) - do nothing (10 % of the passenger vehicles will be equipped at the end of the 10-year forecast period), Voluntarily Scenario (VS) - do minimum (50 % of the passenger vehicles will be equipped), and Regulatory Scenario (RS) - do something (all the passenger vehicles will be equipped), we will take the aforementioned data from the previously mentioned documents and studies into account (Decision No 585/2014 / EU of 15 May 2014; E-MERGE / STORM Germany; National Evidences, France; National Evidences, USA).

All aspects that characterize the scenarios and that will then be used in the monetary evaluation of costs and benefits are summarized in Table 8.

Table 8

**Scenarios' Description (% per year)**

| Scenario | Vehicle equipment rate | Severe injures decreasing rate | Fatalities decreasing rate | Pollution costs decreasing rate | Impact on congestion costs |
|---|---|---|---|---|---|
| Basic | 1 | 4 | 2 | 1 | Cost reduction is directly proportional to the fatalities decreasing rate |
| Voluntarily | 5 | 8 | 6 | 2 | |
| Regulatory | 10 | 12 | 10 | 3 | |

*Source: own assumptions.*

We would like to specify that the number of vehicles equipped annually with the eCall device depends on the forecast regarding the evolution of the passenger vehicles fleet on 2021–2030.

In terms of the impact on the cost reduction generated by the decrease in the number of fatalities and severe injuries, the same volume of benefits will be considered in each forecast year. The principle from which we started is a very simple one. On the one hand, a vehicle, once equipped, will generate effects throughout its life. On the other hand, road accidents will continue to occur, whether or not the vehicles are equipped with eCall devices, generating the negative effects we all know.

### Monetary Evaluation of the Costs and Benefits Generated by the Implementation of eCall Technology in EU Passenger Vehicles

There are various opinions on the unit cost of an eCall IVS device. In the case of this analysis, the monetary assessment of the cost of installing the eCall device (Table 9) is based on the consideration of an initial unit price of 100 Euros.

This value was chosen on the basis of the results of research on the adoption of eCall technology, carried out at the level of road vehicle owners, which, among other things, revealed that most of them would agree to purchase and use such a device, for a price between 80 and 100 Euro / unit (Perju-Mitran *et al.*, 2020, p. 19).

Table 9

**Monetary Evaluation of Annual Costs (AC)**

| Year | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Basic Scenario (BS)** | | | | | | | | | | | |
| EV | 2.84 | 2.87 | 2.90 | 2.93 | 2.96 | 2.99 | 3.02 | 3.05 | 3.08 | 3.11 | 29.72 |
| AC (P1) | 284.1 | 287 | 289.8 | 292.7 | 295.6 | 298.6 | 301.6 | 304.6 | 307.7 | 310.7 | 2.972,4 |
| AC (P2) | 227.3 | 229.6 | 231.8 | 234.2 | 236.5 | 238.9 | 241.3 | 243.7 | 246.2 | 248.6 | 2,377.9 |
| AC (P3) | 213.1 | 215.3 | 217.4 | 219.5 | 221.7 | 224.0 | 226.2 | 228.5 | 230.8 | 233.0 | 2,229.3 |
| **Voluntarily Scenario (VS)** | | | | | | | | | | | |
| EV | 14.21 | 14.35 | 14.49 | 14.64 | 14.78 | 14.93 | 15.08 | 15.23 | 15.39 | 15.54 | 148.62 |
| AC (P1) | 1,420.5 | 1,435 | 1,449 | 1,463.5 | 1,478 | 1,493 | 1,508 | 1,523 | 1,538.5 | 1,553.5 | 14,862 |
| AC (P2) | 1,136.4 | 1,148 | 1,159.2 | 1,170.8 | 1,182.4 | 1,194.4 | 1,206.4 | 1,218.4 | 1,230.8 | 1,242.8 | 11,889.6 |
| AC (P3) | 1,065.4 | 1,076.3 | 1,086.8 | 1,097.6 | 1,108.5 | 1,119.8 | 1,131 | 1,142.3 | 1,153.9 | 1,165.1 | 11,146.5 |
| **Regulatory Scenario (RS)** | | | | | | | | | | | |
| EV | 28.41 | 28.7 | 28.98 | 29.27 | 29.56 | 29.86 | 30.16 | 30.46 | 30.77 | 31.07 | 297.24 |
| AC (P1) | 2,841 | 2,870 | 2,898 | 2,927 | 2,956 | 2,986 | 3,016 | 3,046 | 3,077 | 3,107 | 29,724 |
| AC (P2) | 2,272.8 | 2,296 | 2,318.4 | 2,341.6 | 2,364.8 | 2,388.8 | 2,412.8 | 2,436.8 | 2,461.6 | 2,485.6 | 23,779.2 |
| AC (P3) | 2,130.8 | 2,152.5 | 2,173.5 | 2,195.3 | 2,217 | 2,239.5 | 2,262 | 2,284.5 | 2,307.8 | 2,330.3 | 22,293 |

*Notes: equipped vehicles (EV) in Mill Units; annual costs in Mill Euro; unit price in Euro, P1 = 100, P2 = 80, and P3 = 75.*

*Source: own calculations, based on previous assumptions and Table 4.*

Therefore, the annual cost (AC) of equipping passenger vehicles with the eCall device will result from multiplying the number of vehicles equipped each year with the unit price / cost of the eCall device. Depending on the resulting values, the calculations were extended to lower unit prices, respectively 80 and 75 Euro / unit.

The monetary evaluation of the benefits of installing the eCall device starts from the impact of this technology on reducing various cost categories. A summary of the evaluation process, on the three scenarios, is presented in Table 10.

Table 10

**Monetary Evaluation of Annual Benefits (AB)**

| Scenario | Casualty type | Costs category | Unit value (Euro) | Number of cases | Total (Euro) |
|---|---|---|---|---|---|
| Basic | Fatality | External costs | 2,775,318 | 492 | 1,365,456,456 |
| | | Congestion costs | 13,050 | 492 | 6,420,600 |
| | Severe injury | External costs | 460,077 | 10,790 | 4,964,230,830 |
| | Pollution costs generated by relevant accidents | | | | 334,000,000 |
| | **Total AB** | | | | **6,670,107,886** |
| Voluntarily | Fatality | External costs | 2,775,318 | 1,475 | 4,093,594,050 |
| | | Congestion costs | 13,050 | 1,475 | 19,248,750 |
| | Severe injury | External costs | 460,077 | 21,579 | 9,928,001,583 |
| | Pollution costs generated by relevant accidents* | | | | 668,000,000 |
| | **Total AB** | | | | **14,708,844,383** |
| Regulatory | Fatality | External costs | 2,775,318 | 2,459 | 6,824,506,962 |
| | | Congestion costs | 13,050 | 2,459 | 32,089,950 |
| | Severe injury | External costs | 460,077 | 32,369 | 14,892,232,413 |
| | Pollution costs generated by relevant accidents* | | | | 1,002,000,000 |
| | **Total AB** | | | | **22,750,829,325** |

*Note: *relevant accidents refer to road accidents resulting in fatalities and severe injuries.*

*Source: own calculations, based on previous assumptions and presented data.*

Given the high level of uncertainty regarding the direct relationship between the installation of the eCall device in passenger vehicles traveling on European roads and the impact on reducing the financial impact of road accidents relevant to this analysis, we consider that only 10% of annual benefits expressed in Table 10 will be associated with the positive effects of eCall (667 Mill Euro per year for BS; 1,470.9 Mill Euro for VS, and 2,275.1 Mill Euro for RS).

In addition, in order to increase the relevance of the results, the costs were calculated for two price options (P1 = 100 Euro / unit and P2 = 80 Euro / unit).

Finally, the results of the analysis were obtained using the discounted values of annual costs and benefits for the calculation of indicators (The Net Present Value - NPV and The Cost Benefit Ratio - CBR). An annual discounted rate (a %) of 5 % was applied, for which the related discount factors, $z = (1 + a)^{-h}$, presented in Table 11 were calculated.

The choice of discounted rate was based on the recommendations of the EU *Guide to Cost-Benefit Analysis on Investment Projects* (p. 42), which proposes the use of a rate of at least 4 % per year.

Table 11

**Discounting Factor Calculated for a=5% per Year**

| Year | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 |
|---|---|---|---|---|---|---|---|---|---|---|
| $z = (1 + a)^{-h}$ | 0,952 | 0,907 | 0,864 | 0,823 | 0,784 | 0,746 | 0,711 | 0,677 | 0,645 | 0,614 |

The discounted values of annual benefits and costs, for the forecast period 2021–2030, on the three scenarios, are presented in Table 12. The last column shows the cumulative value of benefits and costs, which was later used at NPV and CBR calculation.

Table 12

**Discounted Annual Values of Benefits (DAB) and Costs (DAC) (Mill Euro/Year)**

| Year | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Basic Scenario (BS)** | | | | | | | | | | | |
| DAB | 635 | 605 | 576.3 | 549 | 522.9 | 497.6 | 474.2 | 451.6 | 430.2 | 409.5 | 5,151.3 |
| DAC (P1) | 270.5 | 260.3 | 250.4 | 240.9 | 231.8 | 222.8 | 214.4 | 206.2 | 198.5 | 190.8 | 2,286.4 |
| DAC (P2) | 216.4 | 208.2 | 200.3 | 192.7 | 185.4 | 178.2 | 171.6 | 165 | 158.8 | 152.6 | 1,829.2 |
| DAC (P3) | 202.8 | 195.2 | 187.8 | 180.7 | 173.8 | 167.1 | 160.8 | 154.7 | 148.8 | 143.1 | 1,714.8 |
| **Voluntarily Scenario (VS)** | | | | | | | | | | | |
| DAB | 1,400.3 | 1,334.1 | 1,270.8 | 1,210.5 | 1,153.2 | 1,097.3 | 1,045.8 | 995.8 | 948.7 | 903.1 | 11,359.6 |
| DAC (P1) | 1,352.3 | 1,301.5 | 1,251.9 | 1,204.5 | 1,158.8 | 1,113.8 | 1,072.2 | 1,031.1 | 992.3 | 953.8 | 11,432.2 |
| DAC (P2) | 1,081.9 | 1,041.2 | 1,001.5 | 963.6 | 927.0 | 891.0 | 857.8 | 824.9 | 793.9 | 763.1 | 9,145.8 |
| DAC (P3) | 1,014.2 | 976.2 | 939 | 903.3 | 869.1 | 835.3 | 804.1 | 773.3 | 744.2 | 715.4 | 8,574.2 |
| **Regulatory Scenario (RS)** | | | | | | | | | | | |
| DAB | 2,165.9 | 2,063.5 | 1,965.7 | 1,872.4 | 1,783.7 | 1,697.2 | 1,617.6 | 1,540.2 | 1,467.4 | 1,396.9 | 17,570.5 |
| DAC (P1) | 2,704.6 | 2,603.1 | 2,503.9 | 2,408.9 | 2,317.5 | 2,227.6 | 2,144.4 | 2,062.1 | 1,984.7 | 1,907.7 | 22,864.5 |
| DAC (P2) | 2,163.7 | 2,082.5 | 2,003.1 | 1,927.1 | 1,854.0 | 1,782.0 | 1,715.5 | 1,649.7 | 1,587.7 | 1,526.2 | 18,291.6 |
| DAC (P3) | 2,028.5 | 1,952.3 | 1,877.9 | 1,806.7 | 1,738.1 | 1,670.7 | 1,608.3 | 1,546.6 | 1,488.5 | 1,430.8 | 17,148.3 |

*Notes: equipped vehicles in Mill Units; annual costs in Mill Euro; unit price in Euro, P1 = 100, P2 = 80, and P3 = 75.*

*Source: own calculations, based on previous assumptions and Tables 9 and 10.*

At first glance, we notice that for the price option of the device P1= 100 Euro/unit, only the first scenario is viable, and at P2= 80 Euro/unit, the cumulative benefits exceed the cumulative costs only for the BS and VS scenarios.

However, for a price lower than 80 Euro / unit, all 3 scenarios are viable (as we can see for example the Annual costs calculated for P3= 75 Euro/unit).

Either way, the reduction in the unit price of an eCall device is predictable. Increasing the volume of production to be able to equip all passenger vehicles entails significant economies of scale, so that the price will no longer be an impediment in the decision to install and use such a device in the vehicle used for road transport.

**Discussions on Results – the Opportunity of Installing eCall in Passenger Vehicles**

The final goal of the cost-benefit analysis is to establish the viability of an investment approach. There are a number of indicators that can be calculated in order to complete the evaluation process. Those of interest for the analysis are the Net Present Value (NPV) and the Benefits Cost Ratio (BCR). The first indicator shows the surplus of benefits or net benefits cumulated on the forecast horizon (2021–2030), which remain after covering the costs generated by equipping passenger vehicles with the eCall device. The condition for accepting a project based on this indicator is that the NPV has a positive value. The second indicator is the ratio between the discounted value of the cumulated benefits and the discounted value of the cumulated costs, calculated for the 2021–2030 period. The condition that BCR must comply with is to have a value higher than 1, so that the project can be considered opportune.

The calculation formulas applied for calculating the indicators are:

$$NPV = \sum_{h=1}^{n} DAB_h - \sum_{h=1}^{n} DAC_h, \quad (1)$$

Where h is the year for which the DAB and DAC were calculated and *n* represents the prognosis horizon of 10 years, as it was foreseen.

$$BCR = \frac{\sum_{h=1}^{n} DAB_h}{\sum_{h=1}^{n} DAC_h}, \quad (2)$$

The numerator represents the cumulated benefits, and the denominator represents the cumulated costs in the 10 years of forecast. The values of the results obtained for the two indicators, for the 3 scenarios, on the 3 price options, can be found in Table 13.

At first sight, the results obtained show that there is an inverse relationship between the price of the device and the conditions which NPV and BCR must comply with. The higher the unit price, the lower the value of NPV and BCR. This means that only the first scenario could be considered appropriate for all three price options, namely the equipping of new passenger vehicles. A second observation refers to the fact that the option of voluntarily equipping vehicles with the eCall device becomes cost-effective as the price decreases. Thus, any incentive regarding the elaboration of a constructive solution of the device through which its unit price should fall below 100 Euro will make this scenario become opportune (especially since the value of BCR is 0.99, which shows again that the financial effort can be fully covered with only minimal effort on the part of the manufacturers, respectively of the entities that equip the after-market vehicles).

Table 13

**NPV and BCR, Associated to Each Scenario**

| Scenario | NPV (Mill Euro) | BCR | Comments |
|---|---|---|---|
| **Basic Scenario (BS)** | | | |
| Calculations for P1 | 2,864.9 | 2.25 | NPV > 0; BCR > 1 |
| Calculations for P2 | 3,322.1 | 2.82 | NPV > 0; BCR > 1 |
| Calculations for P3 | 3,436.5 | 3.00 | NPV > 0; BCR > 1 |
| **Voluntarily Scenario (VS)** | | | |
| Calculations for P1 | -72.6 | 0.99 | NPV < 0; BCR < 1 |
| Calculations for P2 | 2,213.8 | 1.24 | NPV > 0; BCR > 1 |
| Calculations for P3 | 2,785.4 | 1.33 | NPV > 0; BCR > 1 |
| **Regulatory Scenario (RS)** | | | |
| Calculations for P1 | -5,294 | 0.77 | NPV < 0; BCR < 1 |
| Calculations for P2 | -721.1 | 0.96 | NPV < 0; BCR < 1 |
| Calculations for P3 | 422.2 | 1.03 | NPV > 0; BCR > 1 |

*Note: unit price, P1 = 100 Euro, P2 = 80 Euro, and P3 = 75 Euro.*

*Source: own calculations, based on Table 13*

The third aspect refers to the last scenario, respectively to the regulated equipment of passenger vehicles with the eCall device. According to the obtained results, this option seems the least efficient; however efficiency is not the first aspect that is pursued by the implementation of eCall on a large scale. In this project, as in any type of project that aims to improve the lives of individuals, the positive impact on the affected entities prevails. We refer here to the impact on increasing the safety of road traffic participants in Europe, the positive effects on the natural environment, reducing road congestion caused by serious accidents, streamlining rescue operations, and improving the work of organizations involved in these operations.

Therefore, as long as the benefits cover the costs (which would be very easy to accomplish for all scenarios, by focusing efforts on making and installing the device at the lowest possible cost, without affecting its quality and functionality), this investment approach can be considered.

It is normal for such an effort, with an impact on a European scale, to require the allocation of substantial resources. To the same extent, the benefits that can be obtained have the ability to provide satisfaction on multiple levels, such as: individually, by improving the safety of road users, especially after a serious accident; socially, by reducing the negative consequences of road accidents, at the expense of reducing the severity of the impact on all affected people, directly or indirectly (giving them an extra chance to survive, or return to a normal life, with the least possible long-term effects); economically, by achieving consistent savings, due to the reduction of costs associated with the effort to intervene at the accident site, the reduction of intervention time, the reduction of the negative impact on the environment and on other road users etc.

Some voices state that CBA is not very suitable for capturing intangible aspects related to the benefits of a project (Beria *et al.,* 2012, p. 138–139). In our opinion also, the CBA is insufficient because it approaches the implementation of eCall in passenger vehicles in general, without going into details about the production of devices, their marketing and installation. However, the analysis did not even aim at a detailed evaluation, from a financial point of view, of this European initiative.

Also, CBA is not approved as a research methodology per se, which is correct. However, we must accept that the whole part of the CBA's preliminary documentation is diligent research of all the elements that contribute to the drawing up of the investment approach, to the establishment of the context and to the identification of the associated costs and potential benefits generated by its implementation.

Another aspect that represents a limitation of this type of CBA refers to the fact that it operates with reference values, which are often conventionally established (Damart, 2007; Persky, 2001; Boardman *et al.*, 2018), like the value of human life. As shown in this study, there are great disparities between European countries regarding this indicator, so the choice of which value should constitute the basis for calculations was not easy.

The results show that regulation of eCall implementation in all passenger vehicles is both timely and necessary. This is all the more so as about 90 % of passenger transport is carried out using road infrastructure, and of its total 81.8 % with passenger vehicles, and 8.5 % with busses and coaches (EC, Statistical Pocketbook 2020).

Readers may wonder why we decided to approach this topic, namely the development of a cost-benefit analysis for a technology that began to develop more than 10 years ago. Although the eCall technology has been promoted by the ITS Directive since 2010 (ITS Directive 2010/40 / EU), the study published by the European Commission since 2008, attached to the Impact assessment on the introduction of eCall service in all new type-approved vehicles in Europe, including liability / legal issues (Francsics *et al.*, 2009), and, later, in the UK 2014, published in eCall UK 2013 Review and Appraisal Final Report, considered only the costs and benefits of the eCall technology for their implementation on new M1 and N1 cars.

The novelty brought by the CBA study carried out within the sAFE project consists in extending the potential vehicles equipped with IVS to all categories of vehicles (as a result of the recommendations and technical solutions from the iHeERO 2015–2017 project), as well as for the vehicles in use (sAFE project 2018–2021).

The long duration of implementation of the eCall technology (2010–2018) was caused by two main circumstances. The first refers to the need to update the PSAP infrastructure, regarding the following aspects: the possibility of MSD reception and calling the signalling vehicle (the deadline for compliance being November 30, 2017; until then, signalling a road accident was possible only by voice call); the implementation of eCall discriminant for mobile networks (MNO), to prioritize the voice call made by PSAP for the signalled vehicle (November 30, 2017). The second regards the conformity of the vehicle manufacturers, for the new models from category M1 and N1, which should include a certified IVS.

Therefore, we appreciate that the extension of the categories and condition of the vehicles considered for the CBA developed in sAFE project and the consideration of the expenses already made by PSAPs through the European projects HeERO1 and 2, iHeERO and sAFE (already completed) provided the premises to achieve a new CBA, which led to results that are relevant to the current period.

## Conclusions

The aim pursued by conducting the analysis was to approach the introduction of the eCall IVS for aftermarket passenger vehicles from a cost-benefit standpoint. This has allowed the effectiveness of the investment to be determined in economic, financial, and social terms. An aspect of a particular interest considered in the current study was analysing from a cost-benefit point-of-view the possibility of bridging the gap between new manufactured passenger vehicles that, according to the European Law, will be equipped with eCall IVS devices, and the already existing passenger vehicles fleet, with a view of retrofitting it with such safety systems.

As human life is invaluable, actions such as defence, care, keeping it in good health and assuring its safety by applying high quality standards, imply significant costs which must be properly analysed, weighed, and managed appropriately by regulatory and legislative bodies. Assessment of the introduction of the eCall in-vehicle system from a cost-benefit point of view was carried out under an analytic research approach using statistical data. The results can support decisions regarding future implementation for the aftermarket passenger vehicle segment, which is a prerequisite to increased road traffic safety.

In addition to this, the cost-benefit approach of eCall IVSs implementation in the EU passenger vehicles, offers new perspective on the opportunity of installing eCall IVSs in all passenger vehicles. The obtained results emphasize the advantages of implementing eCall IVS devices and provide a clearer perspective to decision makers on adoption circumstances.

Another conclusion that has emerged from the conducted study and has been brought forward to the contractor, the European Commission, is that the CBA must be used in conjunction with other methodologies, such as multi-criteria analysis. As such, the tangible and intangible elements generated by the implementation of such a large project or legislative initiative are considered.

Finally, the transport domain is vital for both the growth and development of an economy, and for the beneficiaries of this category of services. These beneficiaries can be companies, public authorities, or individual citizens. Any approach that contributes to increasing the safety of road traffic participants must be supported and encouraged. Initially, the benefits may only cover the costs or may in certain cases be lower than the costs, but road traffic safety must remain a priority.

Future research directions in this field are focused on several aspects. First, the implementation of the eCall devices on other types of road vehicles, together with a cost-benefit approach to other types of technologies that have the potential to help increase transport safety. Second, a territorial extension of the analyses and even a hybrid approach encompassing several research methodologies to be integrated in order to increase the relevance and usefulness of the results. Third, although the devised study targets the fleet of passenger vehicles traveling on European roads, this study also represents a useful tool for analysing other types of road vehicles, due to its generalization capability.

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