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Adopted cost-benefit analysis approach

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Consortium - List of partners

Partner No	Short name	Name	Country
1	UIC	International Union of Railways	France
2	VTT	VTT Technical Research Centre of Finland Ltd	Finland
3	NTNU	Norwegian University of Science and Technology	Norway
4	IFSTTAR	French institute of science and technology for transport, development and networks	France
5	FFE	Fundación Ferrocarriles Españoles	Spain
6	CERTH-HIT	Centre for Research and Technology Hellas - Hellenic Institute of Transport	Greece
7	TRAINOSE	Trainose Transport – Passenger and Freight Transportation Services SA	Greece
8	INTADER	Intermodal Transportation and Logistics Research Association	Turkey
9	CEREMA	Centre for Studies and Expertise on Risks, Environment, Mobility, and Urban and Country planning	France
10	GLS	Geoloc Systems	France
11	RWTH	Rheinisch-Westfaelische Technische Hochschule Aachen University	Germany
12	UNIROMA3	University of Roma Tre	Italy
13	COMM	Commsignia Ltd	Hungary
14	IRU	International Road Transport Union - Projects ASBL	Belgium
15	SNCF	SNCF	France
16	DLR	German Aerospace Center	Germany
17	UTBM	University of Technology of Belfort-Montbéliard	France

Executive summary

This deliverable is dedicated to the discussion of the various aspects that need to be considered to assess the SAFER-LC solutions in terms of cost-benefit ratio. The Cost-Benefit Analysis (CBA) methodology that shall be applied in the following steps of the project has to take into account, in one hand, all the benefits that can be derived from the developed solution and on the other hand, the various costs in terms of implementation, operation and maintenance. It will integrate the various Key Performance Indicators (KPI) defined in WP4 for the evaluation of the SAFER-LC measures. Moreover, the methodology will serve as a basis for a comprehensive analysis that will be performed for each solution, ensuring that the infrastructure is examined as a whole integrating both the railway and road sides, and that all economical, societal and environmental aspects are considered.

In practice, the business models that will be elaborated inT5.2 shall consider the various factors to take into account while performing a CBA. Relevant CBA models are described in this deliverable. They shall give valuable pointers that allow for guiding the involved stakeholders making appropriate choices towards managing safety at LCs.

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1. INTRODUCTION

The main objective of the SAFER-LC project is to improve safety and minimise risks at and around level crossings (LCs) by developing a fully integrated cross-modal set of innovative solutions and tools for the proactive management and design of LC infrastructure. These tools will enable:

- road and rail decision makers to achieve better coherence between both modes,
- effective ways to detect potentially dangerous situations leading to collisions at LCs as early as possible,
- prevention of incidents at LCs through innovative design and predictive maintenance methods,
- mitigation of consequences of incidents/disruptions due to accidents or other critical events.

The main output of the SAFER-LC project is a toolbox which will be accessible through a user-friendly interface which will integrate all the project results and solutions to help both rail and road stakeholders to improve safety at LCs.

The objectives of WP5 are to perform a Cost Benefit Analysis (CBA) and provide final recommendations for further implementation. Cost-Benefit analyses will evaluate the measured benefits and the implementation and operation/maintenance costs of the provision of the safety systems at level crossing in order to facilitate the development of Business Models for the deployment of the services. The application of CBA as part of a holistic risk management process can be used to decide which option or combination of options gives the best value for the infrastructure manager / railway undertaking.

This first step consists in analysing existing practices of Cost Benefit Analysis related to safety in railway sectors. Then, in collaboration with the involved partners a harmonised approach (D5.1) will be suggested based on the results of WP4.

Deliverable D5.1 aims to discuss the various aspects to be considered to derive CBA for the assessment of safety measures. Such aspects consider the economic, social and environmental incidence of the measures. Besides D5.1 will give pointers regarding the important factors to be considered for developing business models (T5.2).

Perform CBA to assess some envisaged solutions is an essential point insofar as any measure monopolising resources shall be strongly justified since these resources could be allocated to other purposes. Indeed, the assessment of the project outcomes appreciably depends a lot on the degree of uncertainty, which directly influence the decision-making as for the realisation of a project. Besides, it is essential to distinguish the different points of view in a CBA because a cost for a person can be a benefit for another one. Thus, the CBA will be ensured through learning from existing economic evaluation frameworks by knowing that it is likely to evolve over time, according to progress in transport railway appraisal in our case.

1.1. Acronyms

LC	Level crossing
IM	Infrastructure Manager
POC	Proof Of Concept
RU	Railway Undertaking
RAMS	Reliability, Availability, Maintainability and Safety
RINF	ERA Register of Infrastructure
SDB	UIC Safety Database
SIL	Safety Integrity Level
BCR / CBR	Benefit to Cost Ratio / Cost Benefit Ratio
CBA	Cost Benefit Analysis
CEA	Cost Effectiveness Analysis
IRR	Internal Rate of Return
HEATCO	Harmonised European Approaches for Transport Costing and Project Assessment
NPV	Net Present Value
KPI	Key Performance indicator

1.2. Definitions

In this section, we introduce some basic definitions that will be useful in the sequel to discuss the various issues related to Cost-Benefit Analysis.

Advanced approach zone	At a Level Crossing, this is the zone, before the Level Crossing is announced by traffic signs. This means anything far away up until 240m before the level crossing.
Approach zone	At a Level Crossing, this is the zone, where road users receive (traditional road-side) information about the type of the level crossing and its status. The road user also perceives in this area the environmental situation of the level crossing and takes a decision whether he passes or stops.
Non-recovery zone	Given a certain speed of the road user, the non-recovery zone starts with the point where the vehicle driver must have decided to stop - braking later will not lead to stand still before the level crossing. This depends on the vehicle speed and can be some 50m long if driving fast and on slippery road surface.
Hazard zone	At a Level Crossing, the road section between the barriers – or, if no barriers are present – between the St Andrews Crosses. The hazard zone must be cleared at activation of the Level Crossing
Clearance zone	The clearance zone is, from the perspective of an approaching road user, an area of the opposite side of the Level Crossing. The clearance zone describes the space necessary for the road user (vehicle) to occupy once he has entirely left the

	hazard zone. The clearance zone is as long as the longest truck (20m), no stationing and no takeover is allowed in this zone.
Fatality	Death within 30 days for causes arising from the accident.
Serious injury	Casualties who require hospital treatment and have lasting injuries, but who do not die within the recording period for a fatality.
Slight injury	Casualties whose injuries do not require hospital treatment or, if they do, the effect of the injury quickly subsides.
Damage-only accident	Accident without casualties.

2. METHODOLOGY

The aim of this WP5 is to perform a cost-benefit analysis and provide final recommendations for future international standards in rail and road environment for safer level crossings. This WP will then output a concise set of recommendations on technical specifications and human processes, as well as organisational and legal frameworks required to implement the elaborated innovative solutions. The established recommendations are also to be fed into the relevant standardisation framework.

Depending on the available data, Cost-Benefit and/or Cost-Effectiveness analyses will be developed using the “measured” benefits, implementation, operation and maintenance costs, in order to facilitate the development of Business Models (T5.2) for the deployment of the solutions suggested by Safer-LC project. Multi-criteria analyses will also be considered to take into account not only economical, but also social and environmental benefits of the solutions. This analysis will be conducted in a comprehensive way to ensure that the infrastructure is examined as a whole.

WP5 will be partly based on the data collected in the demonstration phase (WP4) as well as on the results of the questionnaire regarding CBA that was distributed to the participants during the third project meeting in March. The analysis of all the gathered answers to this questionnaire are provided as an appendix to this deliverable.

The application of CBA as part of a holistic risk management process can be used to decide what option or combination of options gives the best value for the railway/road infrastructure manager / operator.
This first step consists in analysing existing practices of Cost Benefit Analysis related to safety, particularly in the railway sector. Then, in collaboration with the involved partners a harmonised approach will be suggested while considering the results of WP4.

Analysis of relevant projects

The first step of WP5 was to analyse existing practices of Cost Benefit Analysis related to safety, particularly in the railway sector.

In the following paragraphs, we give a few examples of projects which have investigated issues related to CBA in the transport sector.

- HEATCO (FP6): It was one of the most recent project that attempted to produce monetary unit values for use in the CBA. This project has dealt with producing values for safety, environment, congestion and travel time savings for all EU countries at that time (EU-25). The FP6 research project HEATCO - Developing Harmonised European Approaches for Transport Costing and Project Assessment- has developed a proposal for harmonised guidelines for transport project appraisal [2].

- RESTRAIL (FP7) project aimed at reducing the number of collision of persons entering unduly on railway property coupled with lower costs resulting from these accidents / incidents, in terms of the needless loss of life, injuries (including agents and rail travelers), of materials damages (rolling stock, infrastructure), of interruption of transportation service and emergency services mobilised, etc., by providing rail authorities with existing evidences, current knowledge as well as results of analyses of costs / benefits of measures or combination of measures that (potentially) decrease the occurrence of trespassing [3, 4].

- ROSA: Rail Optimisation Safety Analysis (ROSA) is a Franco-German project that aimed to establish a safety analysis of the overall railway system based on the two major European railways. Indeed, the main idea is to identify the possible consequences resulting from the apportionment of the global safety targets. A Cost benefit analysis (CBA) of common safety targets (CST) apportionment was performed within this project [5, 6].

- SELCAT: The SELCAT (Safer European Level Crossing Appraisal and Technology) a FP6 project which aim is to provide an overview about existing and planned European level crossing research and the actual risk on European level crossings. The application of cost-benefit analysis methods was conducted in the third work package of the project to demonstrate the suitability for a cost optimisation of the necessary risk reduction measures for various level-crossing types considering all RAMS factors (Reliability, Availability, Maintainability and Safety). [7, 8, 9]

- VERUITS (Improving the safety and mobility of vulnerable road users through ITS application) an EU-sponsored project assessed the safety and mobility impacts of ITS applications for Vulnerable Road Users. The project identified how the usability and efficiency of ITS applications can be improved and recommended actions to be taken at a policy level to accelerate the deployment of such ITS solutions [10].

- MORIPAN (developing risk models for level crossings) aims to develop means to support decision-making related to safety at LCs. Namely, a set of risk models has been elaborated to highlight the impact of various factors on the risk level at LCs. In addition, the relationship between the impacting factors and the consequences in terms of accidents, casualties, economical losses were scrutinised and formalised within dedicated models. A central aspect in MORIPAN was the ability to quantify the risk incurred at LC as well as the weight and relationships between causes and consequences [11, 12, 13].

3. ECONOMIC ASPECTS OF SAFETY AT LCS

In this section, we will discuss some main notions that we need to tackle in the framework of our CBA analysis, in particular the economic aspects in relation with safety at LCs.

The economic evaluation estimates the expected benefits and anticipated costs of measures associated with varying degrees of reduction in risk, using monetary criteria which are amenable to quantitative economic analysis. Several types of economic analysis techniques can be used for risk evaluation; the following techniques are most suitable for economic evaluation of risk reduction alternatives at level crossing.

3.1. Cost-Benefit Analysis (CBA)

Cost-Benefit Analysis (CBA) is a systematic process for calculating and comparing the benefits and costs of several projects/criteria/decisions or government policy. A CBA has two main purposes:

- To determine if it is a judicious investment/decision (justification/feasibility).
- To provide a reference for comparing projects/criteria/decisions.

It involves comparing the total expected cost of each option against the total expected benefits, to see whether the benefits outweigh the costs, and by how much. In fact, Cost-Benefit Analysis offers a basis for a rational decision-making and is based on a variety of methods allowing for:

- Identifying alternatives.
- Defining alternatives in a way that allows fair comparison.
- Adjusting for occurrence of costs and benefits at different times.
- Calculating monetary values for things that are not usually expressed in money.
- Coping with uncertainty in the data.
- Summing up a complex pattern of costs and benefits to guide decision-making.

It is essential to keep in memory that the results of the CBA can vary appreciably according to the working hypotheses, which is why it is important to complete the appreciation of the project by an analysis of sensibility which aims at checking in which way the profitability of the project is affected by variations of the considered variables. Depending on the context, such a sensibility analysis may lead to reconsider the output of the CBA.

The results can also be checked thanks to three indicators of profitability which are the Net Present Value (NPV), the Internal Rate of Return (IRR) and the Cost Benefit Ratio (CBR**)** or a combination of them [5, 6]:

- The Net Present Value and the Internal Rate of Return: When all the costs and the benefits have been assigned the same value, the net present value can be computed. A positive net present value means that an investment is profitable in terms of return. In the same optics as a financial analysis, the appraiser will calculate the net present economic value by using the following formula [5, 6]:

$$NPV = (A_0 - C_0) + (A_1 - C_1) / (1 + r) + (A_2 - C_2) / (1 + r)^2 + \dots (A_n - C_n) / (1 + r)^n$$

where:

A_i: all the awaited advantages for the "i"th period,

C_i: all the costs to be covered during the same "i"th period,

r: a rate that allows for updating all the costs and the profits according to the reference year defined in this case as the year 0. As a general rule, the updating rate varies between 3% and 10%, but the advised rate is 4%, which corresponds to the rate of return on the invested capital on long-term financial markets.

n: represents the total duration of the project operation/use

- Internal Rate of Return (IRR): is another measure often applied in CBA. The IRR is the discount rate that equates the present value of the costs with the present value of benefits associated with a project. Always, by analogy with the financial analysis, the internal rate of return represents the "r" value which fulfils the following relation:

$$(A_0 - C_0) + (A_1 - C_1) / (1 + r) + (A_2 - C_2) / (1 + r)^2 + \dots (A_n - C_n) / (1 + r)^n = 0$$

As for the advantages and the costs of a project which cannot be the object of a systematic valuation, the analysis will be completed by a deeper analysis of non-monetary effects linked to the realisation of the project. The internal rate of return has to be higher than the interest costs against which the capital for the investment is borrowed. Hence:

If IRR > cost of capital, the project is attractive (beneficial) for the society.

If IRR < cost of capital, the project is not attractive for the society.

- A last measure that is sometimes used to express the outcome of a CBA is the Cost/Benefit ratio (CBR). The CBR is a simple measure of profitability. The ratio simply divides the discounted benefits by the discounted costs.

$$CBR = \Sigma Ct / \Sigma Bt$$

Where B_t is the present value of the cash inflows

C_t is the present value of the cash outflows

If CBR < 1, the discounted benefits are higher than the discounted costs, and the project is attractive for the society:
If CBR > 1, the project is not attractive for the society.

In case of more than one alternative, the general consequence of the three measures mentioned above is that the project with the highest IRR or the lowest C/B ratio has the highest attractiveness from a socio-economic point of view. As far as possible, cost-benefit analysis puts both costs and benefits into monetary terms so that they can be compared directly. Costs and benefits occurring at different time periods need to be set on a comparable basis. Normally, they should be expressed in 'real terms'. At the price levels prevailing in the year, the analysis is carried out because inflation simply raises the values of all costs and benefits of future years by a given percentage. Importantly, all estimates of costs and benefits, even those that relate to well-known market resources or goods are subject to uncertainty and risk. Future costs and benefits cannot be forecast precisely. In some cases, the uncertainties and risks are particularly high. In these cases, the recommended procedure is first to make the best average estimates of each cost and benefit and to forecast the average net social benefit or net present value (NPV) that is likely to occur given the range of risks and uncertainties. Then, it is interesting to assess another rate, the Cost Benefit Rate (CBR) [5] that is the ratio of the benefits expressed in monetary terms, related to its costs expressed in monetary terms. The efficiency of the project/decision may be measured according to the CBR value (Table 1).

Table 1: Interpretation of CBR values

CBR	Ratio
< 0.1	Extremely favourable
0.1 ... 0.5	Favourable
0.5 ... 2	Well-balanced
2 ... 5	Unfavourable
> 5	Extremely unfavourable

One major difficulty in CBA is that the costs, disbenefits and benefits should be translated into their equivalent monetary value before the cost-benefit ratios can be estimated out. However, in the case of level crossing, it is very difficult to estimate and reach agreement on the economic impacts of benefits and disbenefits for projects intending to put in place controls for risk reduction at LC. Furthermore, a viewpoint must be established (usually after a debate between different stakeholders and groups) prior to the economic evaluation. The viewpoint finally adopted will determine the estimates of costs, benefits and disbenefits. Various techniques for making quantitative estimates can be used including revealed preferences and stated preferences methods.

3.2. Cost-effectiveness analysis (CEA)

A CEA is a multi-step process, namely after defining the policy of interest, an analyst conducts a cost assessment and an effectiveness assessment for each alternative measure for implementing the policy, and then integrates the results of his assessment into a decisional analysis [3, 4]. In general, CEA is most relevant when different policy measures yield the same effectiveness, but at different costs. Cost-effectiveness analysis (CEA) is a kind of economic analysis that compares the relative costs and outcomes (effects) of two or more courses of actions. Cost-effectiveness analysis is closely related to cost-benefit analysis in that both represent economic evaluation of alternative resource use and measure costs in the same way. However, cost-benefit analysis is used to address only those types of alternatives where the outcomes can be measured in terms of their monetary values. In other terms, CEA differs from CBA in that benefits are expressed in physical units (e.g. in the LC context, the number of lives to be saved) rather than in monetary units. Costs, however, are expressed in monetary terms as in CBA. CEA is useful in areas such as health, accident safety and education where it is often easier to quantify benefits in physical terms than to value them in monetary units. CEA is useful most often when the benefits of a risk reduction scenario are difficult to quantify in monetary terms, but decision-makers wish to know which option will achieve social benefits or government objectives most cost effectively. One limitation of CEA is that it applies only to situations where all the proposed risk control alternatives are intended to meet the same physical objective.

3.3. Adopted CBA approach

In fact, making the CEA and CBA of different safety measures comparable requires relating both the assessed performance and the costs of implementing the measure to a certain time reference.
On one hand, cost benefit analysis (CBA) is an important part of the cycle of understanding and quantifying risk, modelling and monetarising its effects and the cost of reducing it, and then applying expert judgment to decide which option to adopt. On the other hand, Cost-Effectiveness Analysis (CEA) compares the projected costs for a range of proposed risk control alternatives, all intended to meet the same objective [4].

Cost-benefit Analysis is the preferred method for evaluating the economic performance of new safety technologies for society. However, there are a number of issues which indicate that the results of an economic cost-benefit analysis should not be considered as the only necessary information for decision-makers considering whether to promote a certain technology or not.

3.4. Life cost as a factor in the cost-benefit analysis

Cost-benefit analysis is a prescriptive technique that is performed for the purpose of informing policy makers about what they ought to do. It is based on welfare economics and requires all policy impacts to be stated in monetary terms. Nevertheless, assigning a monetary value to human life (lifesaving or to quality of life) is sometimes considered meaningless and ethically wrong.

According to (ERA 2015), the Value of Preventing a Casualty (VPC) is composed of [1]:

1) Value of safety per se: Willingness to Pay (WTP) values based on stated preference studies carried out in the Member State for which they are applied.

2) Direct and indirect economic costs: cost values appraised in the Member State, composed of:

- medical and rehabilitation costs,
- legal court cost, cost for police, private crash investigations, emergency services and administrative costs of insurance,
- production losses: value to society of goods and services that could have been produced by the person if the accident had not occurred.

The values applied in the national frameworks vary considerably across countries. For example, the values used for a fatality lie between approx. €127.000 and approx. €3,348,000 and great differences between regions can be observed. The following table, borrowed from ERA (2015) updated the values proposed in the HEATCO to base year 2010, provides the estimated values for Fatalities, serious injuries and slight injuries avoided for each European country (Table 2).

Table 2. Cost of fatalities and injuries in European countries

Country	Fatality	Severe injury	Slight injury
Austria	2,395,000	327,000	25,800
Belgium	2,178,000	330,400	21,300

Bulgaria	984,000	127,900	9,800
Croatia	1,333,000	173,300	13,300
Cyprus	1,234,000	163,100	11,900
Czech Republic	1,446,000	194,300	14,100
Denmark	2,364,000	292,600	22,900
Estonia	1,163,000	155,800	11,200
Finland	2,213,000	294,300	22,000
France	2,070,000	289,200	21,600
Germany	2,220,000	307,100	24,800
Greece	1,518,000	198,400	15,100
Hungary	1,225,000	164,400	11,900
Ireland	2,412,000	305,600	23,300
Italy	1,916,000	246,200	18,800
Latvia	1,034,000	140,000	10,000
Lithuania	1,061,000	144,900	10,500
Luxembourg	3,323,000	517,700	31,200
Malta	2,122,000	269,500	20,100
Netherlands	2,388,000	316,400	25,500
Norway	3,438,000	482,300	34,600
Poland	1,168,000	156,700	11,300
Portugal	1,505,000	201,100	13,800
Romania	1,048,000	136,200	10,400
Slovakia	1,593,000	219,700	15,700
Slovenia	1,989,000	258,300	18,900
Spain	1,913,000	237,800	17,900
Sweden	2,240,000	328,700	23,500
Switzerland	2,770,000	379,800	29,200
United Kingdom	2,170,000	280,300	22,200
EU average	**1,870,000**	**243,100**	**18,700**

Note that since these values refer to 2010, they should not be used as given but updated annually with GDP per capita values. They should be taken from the EUROSTAT database of EU statistics [1].

The significant differences in the values used for the countries in the EU raise the question of whether to use country-specific values or EU-averaged values [7]. The impact of the choice among country (specific and EU-averaged values) is explained as follows:

a) Country specific values:

- The results of the cost-benefit analysis will be more acceptable and easier to understand for domestic stakeholders when the values used derive directly from the national context;
- On the other hand, specific unit values may not exist in some cases or be of poor quality for individual countries within the EU and the valuation of identical impacts using different local values may be considered to be morally indefensible (e.g. differences in the values of human lives or values of reduced fatalities between countries may not be acceptable to decision-makers);
- Another disadvantage results from the lack of good quality data covering in some EU Member States;

b) EU-averaged values:

- A set of common EU values for individual impacts might simplify the appraisal process and increase transparency;
- It may be more politically acceptable on the basis of perceived equity;
- On the other hand, they do not fully reflect differences in terms of preferences and resource/labour costs;
- In addition, they are in conflict with the values, which are supplied in some countries by national ministers.

In the framework of SAFER-LC, we advocate for considering country-specific values as much as possible, to provide a more accurate analysis. In fact, it is important for decision-makers to have realistic values that are relevant for their proper context so as to help them making appropriate decisions.

3.5. Values of time to estimate cost of delays

In the context of the SAFER-LC project, and as long as the required data is available, the cost related to delays induced by LC accident can be estimated in line with the EC Directive 2009/149/EC, which estimates costs of delays for an accident based on the information of its actual duration as follows:

Value of Time (VT) refers to the monetary value of delays incurred by users of rail transport (passengers and freight customers) as a consequence of accidents or incidents. It is proposed to be calculated using the following formula (from ERA 2015) [1]:

VT = monetary value of travel time savings

Value of time for a passenger of a train (an hour):

*VTP = [VT of work passengers] * [Average percentage of work passengers per year] + [VT of non-work passengers] * [Average percentage of non-work passengers per year]*

VT measured in € per passenger per hour

Value of time for a freight train (an hour)

*VTF = [VT of freight trains] * [(Tonne-Km)/(Freight Train-Km)]*

VT is measured in € per freight tonne per hour

Average number of tonnes of goods carried per train in one year = (Tonne-Km) / (Freight Train-Km)

CM = Cost of 1 minute of delay of a train

Passenger train: CMP = K1(VTP/60) * [(Passenger-Km) / (Passenger Train-Km)]*
Average number of passengers per train in one year = (Passenger-Km) / (Passenger Train-Km)
Freight train: CMF = K2 (VTF/60)*

Here, factors K1 and K2 are between the value of time and the value of delay, as estimated by preference studies, to take into account the fact that the time lost as a result of delays is obviously perceived way more negatively than normal travel time.

Cost of delays upon the occurrence of an accident = CMP * (Minutes of delay of passenger trains) + CMF * (Minutes of delay of freight trains)

Work-passengers are those travelling for their professional activities excluding commuting passengers (cf. HETCO project) (Commuters are not classified as work passengers.)

The following methods are advised for calculating the VT:

- "Cost saving" for work passengers and commercial goods traffic
- "Willingness to pay" for non-work passengers

HEATCO project provides an overview of these methodologies:

- National values should be used whenever possible; if such values are not available, the values provided by the HEATCO project may be used:
- The Value of Time (VT) of work passengers is measured in € per passenger and hour and is reported in Table 5, column "Work (business)"
- [VT of non-work passengers] is approximately 1/3 of the values reported in Table 5, column "Work(business)"
- [VT of freight trains] is measured in € per freight/tonne per hour and is reported in Table 6.
- As explained above, factors K1 = 2.5 and K2 = 2.15, between VT and the value of delay are to be taken into account to reflect the fact that the time lost as a result of delays is perceived more negatively than normal travel time.

It should be noted that the values shown are at market prices (PPP) in € for 2010.

It is straight forward to recall that these values should not be used as given but updated annually with GDP per capita values. Moreover, the values are to be updated by Member States annually by linear increase of the growth of Gross Domestic Product (GDP) per capita (reference year 2010).

Table 3: Work passenger trips – VT *(2002 in € per passenger per hour)*

Country	Work
Austria	28.40
Belgium	27.44
Cyprus	21.08
Czech Republic	14.27
Denmark	31.54

Estonia	12.82
Finland	28.15
France	27.70
Germany	27.86
Greece	19.42
Hungary	13.52
Ireland	29.87
Italy	25.63
Latvia	11.73
Lithuania	11.58
Luxembourg	38.02
Malta	18.64
Netherlands	28.00
Poland	12.87
Portugal	19.34
Slovakia	12.36
Slovenia	18.80
Spain	22.34
Sweden	30.30
United Kingdom	29.02
EU (25 Countries)	23.82

Table 4: Freight trips VT (2002 in € per freight/tonne per hour)

Country	Per tonne of freight carried	
	Road	**Rail**
Austria	3.37	1.38
Belgium	3.29	1.35
Cyprus	2.73	1.12
Czech Republic	2.06	0.84
Denmark	3.63	1.49
Estonia	1.90	0.78
Finland	3.34	1.37
France	3.32	1.36
Germany	3.34	1.37
Greece	2.55	1.05
Hungary	1.99	0.82

Ireland	3.48	1.43
Italy	3.14	1.30
Latvia	1.78	0.73
Lithuania	1.76	0.72
Luxembourg	4.14	1.70
Malta	2.52	1.04
Netherlands	3.35	1.38
Poland	1.92	0.78
Portugal	2.58	1.06
Slovakia	1.86	0.77
Slovenia	2.51	1.03
Spain	2.84	1.17
Sweden	3.53	1.45
United Kingdom	3.42	1.40
EU (25 Countries)	**2.98**	**1.22**

3.6. Cost of damages to the environment

The cost of damages to the environment refers to the costs that are to be met by railway and road operators /Infrastructure Managers, to restore a damaged area following a railway accident. The main cases that belong to this category are [1]:

- Pollution of an area by liquid, solid or gas release of goods.
- Material damages to an area (e.g. trees pulled down by rolling stock in motion)
- Fires in an area inside or outside the railway premises (e.g. fires of trees caused by rolling stock in motion).

In general, the area harmed can be considered being equal to the area needed for the transport infrastructure including a 5m zone on both sides of the infrastructure, with a depth of pollution assumed to be about 20cm. The costs are then expressed in EUR per m^3 of soil/water polluted at price level 2008 (Table 5).

Table 5. Cost in EUR per m^3 of soil/water polluted (2008).

Country	**Value (in 2008)**
Austria	45.71
Belgium	43.55
Bulgaria	6.20
Channel Tunnel	40.04
Czech Republic	19.96

Germany	40.58
Denmark	57.71
Estonia	16.45
Greece	27.91
Spain	32.22
Finland	47.06
France	40.58
Croatia	14.56
Hungary	14.16
Ireland	54.61
Italy	35.46
Lithuania	13.08
Luxembourg	108.94
Latvia	13.62
Netherlands	48.81
Norway	86.56
Poland	12.81
Portugal	21.84
Romania	8.76
Sweden	48.67
Slovenia	24.81
Slovakia	16.04
Switzerland	60.00
United Kingdom	39.51

Note that these values should not be used as given but updated annually with GDP per capita values. They should be taken from the EUROSTAT database of EU statistics.

3.7. Cost of material damage

Under this category, the significant damage to rolling stock, track, other installations or environment means implies a damage equivalent to €150 000 or more (ERA 2015) [1]. The cost of material damage to rolling stock or infrastructure includes the cost of providing new rolling stock or infrastructure, with the same functionalities and technical parameters as the one which was damaged beyond repair, and the cost of restoring repairable rolling stock or infrastructure to its pre-accident state. Both are to be estimated by Railway Undertakings/Infrastructure Managers on the basis of their experience. It also includes costs related to leasing rolling stock, as a consequence of non-availability due to damaged vehicles.

4. FACTORS TO DETERMINE RISKY LC

SAFER-LC's deliverable D1.3 produced a danger index calculation to decide which kind of protection is needed for a given LC. Such an index is useful to have some indicators of the risk level at a LC. The danger index is mainly based on the traffic density (both road and railways traffic), visibility from both sides of the road and other parameters, such as the maximum railway speed, angle of the crossing, slope of the road, etc.

To determine the danger index of a LC, the following formula is used:

$$P=\frac{T\cdot V}{4\sin\varphi}\cdot\left(\frac{1}{F_1}+\frac{1}{F_2}+\frac{1}{F_3}+\frac{1}{F_4}\right)\cdot(1+b)$$

Where:

T is the number of trains within the 12 hours with higher railway traffic density.

V is the number of road vehicles within the 12 hours with higher road traffic density.

F_1, F_2, F_3 and F_4 are the visibility factors related to the 4 approaching zones.

4sinφ is the crossing angle between track and road.

b is a parameter that reflects additional features that can increase the risk while crossing the LC (slopes, etc.), as discussed in the following.

For calculating visibility factor, both left and right sides visible track, from an observer located 15 meters away from the closest rail for unpaved roads or placed 30 meters away for paved roads, shall be considered (distance d in Figure 1)

The formula to calculate visibility factors is:

$$F_i = \frac{\sum l_i}{5\cdot v}$$

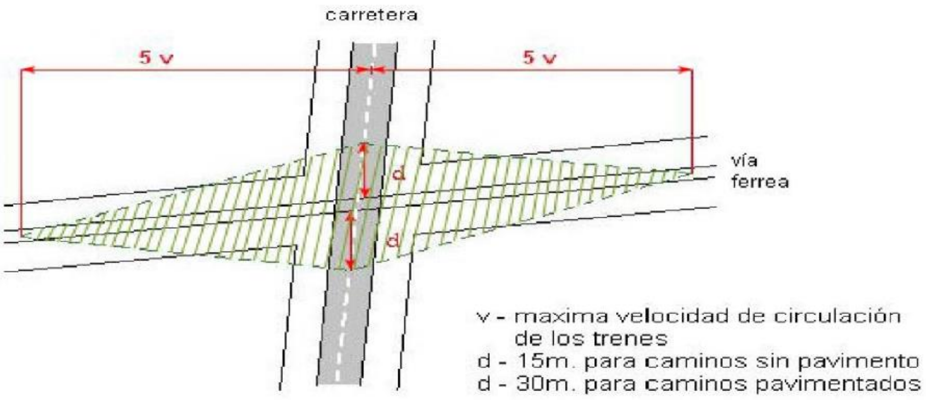

Figure 1. Distances diagram for calculating danger index

Where:

v is the train speed in km/h,

d is the length of visible track up to a distance equivalent to 5·v for each one of the 4 directions. So, if there is no obstacle, visibility will be equal to 1. The value of parameter b can be determined on the basis of the following table.

Table 6: b index

Total slopes	**Up to 8% on both sides**	0,30
Up to 4% on one side	0,15	
Narrow crossing	0,10	
Lateral roads leading to LC road within 20 m from LC	0,15	
Multiple lane road	Two lanes	0,10
Three lanes	0,20	
Four or more lanes	0,30	
Sun reflection	0,15	

Once the danger index P is calculated, the protection type for LC can be established according to the following rules (Ci Liang, 2018):

- If P < 12.000: LC shall be protected with fixed signages.
- If 12.000 ≤ P < 50.000: LC shall be protected with active sound and light warning.
- If 150.000 ≥ P ≥ 50.000: LC shall be protected with barriers.
- If P ≥ 150.000, is recommended to build an overpass/underpass

5. EFFECTS WHICH USUALLY ARE NOT MONETARISED

When it comes to implement a given solution, besides the various aspects discussed above for which a monetarisation is possible, a set of further effects cannot be (objectively) monetarised. Here below is a non-exhaustive list of such aspects that may apply depending on solution/system to assess.

- Ease in terms of implementation;
- Ease in terms of use;
- Reputation of railways;
- Effects on the environment;
- Customer satisfaction with the railway safety;
- Capacity performance;
- The possibilities of by-passing the system;
- Maturity degree of the technology
- Privacy issues regarding the collected data
- Effects on the surrounding / other stakeholders
- Availability of the solution (used components)
- Certification procedures (necessary delays, etc.)
- Impact on the LC operation (closing duration, etc.)
- Acceptability by users.

6. HARMONISED CBA FOR SAFER-LC

The cost benefit analysis (CBA) is a tool to assist decision making and allows for highlighting the best alternative in economic terms. Theoretically, such an analysis aspires to estimate the payoff of a project from the whole community point of view by quantifying the willingness-to-pay (WTP) or the willingness-to-accept (WTA). The WTP - or the WTA - is the stated amount that an individual is willing to pay - or to accept - in compensation for a loss or a diminution of its utility. When this amount cannot be determined, tutelary values are used, such as a pre-determined value of human lives.

One of the difficulties of building a harmonised calculation scheme for cost benefit analysis is to ensure that all the railway undertakings and infrastructure managers (IMs) in Europe have the same safety requirements. In fact, when the levels of safety requirements stringency are different, they may be under different levels of pressure, their safety targets differ from each other’s, and consequently their WTP and WTA can be quite dissimilar which directly impacts the CBA.

6.1. Analysis of the quantitative risk

The objective of this analysis is to evaluate the risks at LCs to help rail and road stakeholders to deploy the most suitable safety measures at LCs. Based on the frequency of different types of LCs in EU’s railway network and the European LC accident statistics, this analysis will take into account both passive LCs and actively protected LCs with automatic barriers (half or double barriers).

The decision on the level of protection for a LC is typically done following a method called the danger index used by some railway networks, as discussed in a previous section.

Deliverable D1.2 produced an in-depth review of level crossing (LC) accident data collected from seven countries, namely Greece, Finland, France, Italy, Norway, Spain and Turkey. Some of the main factors affecting the occurrence of LC accidents identified in D1.2 are the following:

- Breakdown of a vehicle in the crossing zone of the LC
- Vehicle abandoned at LC
- Vehicle driver violating the closed (half)barriers, by making zigzag
- Excessive speed which does not allow a vehicle driver to stop before the crossing zone
- Non-observation of road signage
- Overtaking the queueing traffic
- Limited visibility due to glare from the sun
- Loss of control (vehicles or bicycles)
- Vehicle stopped too close from the railway track.

The goal behind quantitatively assessing the risk is to determine the risk reduction which can be reached by the implementation of a given solution. For this purpose, the initial and the incurred risk must be quantified both early on.

6.2. Estimation of the risk reduction factor

In order to evaluate the risk reduction potential, the initial risk must be considered. For the assumed level crossing type, the statistics of railways from a given year (Y0) or an average considering a period of N years, can be taken as a reference.

Overall, the reference shall be fixed according to the solution investigated in the CBA and the range of its deployment. For instance, if we focus on the reduction in terms of number of collisions at a given LC due to the installation of a given solution, it is likely that considered one given year Y0 as a reference would not be appropriate. Indeed, collisions at LCs are rare events from a statistical point of view, therefore taking the number of collisions that have occurred at the considered LC in Y0 as a basis will not offer a representative sample for the reference. On the contrary, if the solution is deployed on a wide range (important number of LCs), considering a given year Y0 as a reference can be convenient.

Table 7: Statistics of accidents in country in Y0

Accidents in the country on number of LC-s in Y0	Starting risk (Absolute numbers)	Ratio per 1 accident (%)
No. of accidents	x	
No. of fatalities	x	x
No. of serious injuries	x	x
No. of light injuries	x	x

D4.2 of SAFER-LC proposed quantitative estimates of the effects of safety measures in terms of, for example, annual reductions in the numbers of level crossing accidents or cost reduction of material damages caused by LC accidents. It is well known that it is hardly possible to give reliable estimates of avoided accidents in small scale pilot tests. However, it is desirable to try to give some estimates on the effect (on annual numbers of level crossing accidents and related fatalities and injuries) if the measure is to be implemented on a large scale (e.g. covering all potential implementation locations).

As explained earlier in this report, the determination of the effect of using a new safety measure has to be carefully thought with regards to the evaluated criteria and the range of LCs on which the solution is deployed. In particular, the challenge of focusing on yearly number of accidents is that typically several years of study are needed to have a sufficient number of accidents for the analysis.

In addition, the identification of differences in accident frequencies between the before and after periods cannot be systematically associated only to the implemented safety measure, since it can be attributed to other external factors as well. Hence, alternative indicators are needed to evaluate the effect of safety measures with the aim to avoid the influence of unknown variables. In addition, these alternative indicators provide support in reaching the quantitative estimates of effectiveness of the piloted safety measure. Risky behaviours, for example, are easy to identify and are more frequent than accidents, providing more data for evaluating the effectiveness of safety measures. Using the number of scenarios related to risky behaviours recorded during a sufficiently long observation period con be convenient for extrapolating a more general impact of accident occurrence.

Moreover, as human errors are considered to be the main cause of level crossing accidents, the analysis of inadequate behaviour of drivers of road vehicles is an important issue (cf. Deliverable D1.1 of SAFER-LC). In the SELCAT project a taxonomy of human errors made by road vehicle drivers was made. Overall, the analysis has shown that we can consider 3 types of road vehicle drivers with inadequate behaviour [table 9]:

- Type 1 represents the road vehicles whose drivers violate the level crossing warning system deliberately or non-deliberately. Here are falling the drivers who make zigzags and those who violate the warning lights by ignorance, distraction, or due to another reason such as, for instance, sun dazzle.
- Type 2 represents road vehicles which enter the danger zone at the time when there are no warning lights activated but is forced to stop without having the possibility to clear completely before 2 minutes elapse. This type represents all the road vehicles stacked in the danger zone due to a traffic jam at the exit zone of the LC or a technical reason e.g. grounding.
- Type 3 represents the road vehicles whose drivers enter the danger zone deliberately despite activated warning lights. Such drivers do not intend to leave the level crossing e.g. with the intention to commit a suicide.

Table 8: Road vehicle types and their risk contribution (SELCAT, 2008)

Road vehicle Type	Cause	Cause Risk Contribution	Total cause type Risk Contribution
Type 1	Zigzagging	33.5%	67%
	Visibility	17%	
	Second train arrives	16%	
	Sun dazzle	0.5%	
Type 2	Grounding	13.5%	29.5%
	Adhesion	8.5%	
	Blocking Back	7.5%	
Type3	Suicide or Vandalism	3.5%	3.5%

For the sake of illustration let us consider the case of a safety measure based on obstacle detection. If a timely alert is sent to the train and operation centre once an obstacle is detected at the danger zone and under the assumption that the solution is 100% reliable (this feature could be tested using pilot sites for example), it can be stated that the installation of the safety measure on level crossing is able to reduce the risk approximately by 30%. This corresponds to the proportion of accidents caused by road vehicles which enter the danger zone before a train reached the activating zone of the level crossing (Type 2) and remain stucked in this zone, mostly due to traffic jam at the exit zone of the LC. The risk of accidents caused by road vehicles of type 3 can also be partially eliminated, however due to the very small proportion of this kind of events (assumed in this example), there is no significant difference of the safety benefits among the investigated technologies. This is supported by the fact that the proposed technological solutions of the obstacle detection are not able to prevent accidents caused by road vehicles of Type 1 (67%).

6.3. KPI for safety

SAFER-LC Deliverable D4.2 provides an evaluation framework for testing the developed measures for increasing safety at level crossings at different simulators and pilot sites. This report also describes which parameters should be measured, how these will be measured, and which pilot or simulator is able to provide these data. Namely, D4.2 determines a list of Key Performance Indicators (KPI) to be evaluated and cluster them into five categories: “Safety”, “Traffic”, “Human behaviour”, “Technical” and “Business”. For each category, a generic set of relevant parameters has been identified. These parameters have been contrasted to the capabilities of the simulators and pilot sites in order to determine where the different parameters can be measured.

The KPI category “Safety” focuses on indicators which describe the amount of actual accidents around a level crossing (KPIs grouped under group ‘Collisions’) as well as indicators which reflect the accident risk at a level crossing (KPIs grouped under groups ‘Surrogate safety measures’ and ‘Kinematic indicators’). Indicators which reflect the accident risk contain aspects regarding movement of traffic participants as well as reliability of a safety measure.

The KPI category “Traffic” focuses on indicators regarding the influence of a safety measure on road and railway traffic. Namely, effects on movement of individuals as well as groups of vehicles (cars and trains) are considered.

The KPI category “Human behaviour” focuses on behaviour of traffic participants. The category contains indicators regarding the effect of safety measures on the visual and hearing perception of relevant information as well as indicators regarding the effects of a safety measure on road users’ observable behaviour.

This list of performance indicators related to human behaviour is a general introduction to useful measures of the appropriateness of traffic participants’ information processing and behaviour. Since maladaptive behaviour of road traffic participants is the central reason for accidents at level crossings, the topic of assessing human behaviour in the context of level crossings will be broadened in a detailed methodological framework. This assessment tool will be the subject of the SAFER-LC Deliverable D2.2 (Test version of the “Human factor" methodological framework and application guide for testing). Such a framework should also be taken into account to develop the business models (T5.2) to assess the benefits/disbenefits of the SAFER-LC measures in terms of human behavior.

The “Technical” KPI category focuses on indicators regarding operational processes and the maintainability of the safety measure. Operational process-related KPI focuses on the technical behaviour of the LC and the safety measure. The KPI on maintainability focuses on the frequency of failure and time needed to repair the identified failure in the LC and/or in the implemented safety measure.

Finally, the “Business” KPI focuses on indicators concerning financial effort required to realise, maintain, enhance and recycle a safety measure. The category contains capital as well as operational expenditure (including maintenance).

Exhaustive tables listing the various items of the 5 KPI categories which are provided in D4.2.

7. CBA BASED CBR APPROACH

This section aims at discussing the CBA harmonised approach that shall be used to evaluate the safety measures to be developed within SAFER-LC. The CBA advocated approach can be characterised using four main categories of variables, as explained below:

- The incurred costs: cost evaluation has to take into account not only the monetary expenditures but also the social costs generated by the project. For instance, the real cost of hiring a ground placed, without expenses, at the disposal by a public institution to a user, since this will divest the users of this resource.
- The benefits foreseen: both the strictly economic effects and the social incidences of the safety measures must be considered. For instance, the reduction of congestion resulting from the installation of the developed solution, or the change in terms of operational rules.
- Time: as no investment is characterised by a lifespan, it is important to spread the analysis over the entire period concerned by the future of the project. Each of the years for which the solution will be deployed has to be taken into account. It is necessary to underline that the time is limited itself by the life cycle of the investment (equal to "n" years). In general, it should roughly be considered as 20 years for infrastructure projects and 10 years for productive investments.
- The up-dating rate: The costs and the advantages being distributed over the time, it is essential to update the values in order to be able to globalise the calculated values.

In practice a CBA can be performed based on different kind of analyses which would take into account economic, social and environmental aspects.

7.1. Economic analysis

The aim of the economic analysis is to evaluate the cost-benefit ratio based on costs of purchase, operation and maintenance to implement a safety measure and the benefits offered by this measure expressed monetary value. If we consider:

- ΔB = efficiency of a measure (assessment of potential risk-reduction and monitoring of the risk evolution),
- ΔC = the costs of a measure,
- $\Delta C / \Delta B$ = cost-benefit ratio (CBR),

Then, the probability for a new safety measure to be accepted is as shown in table 9.

Table 9: Probability of acceptance of a new safety measure

ΔB / ΔC	Ratio
< 0.1	Extremely Favourable
0.1 ... 0.5	Favourable
0.5 ... 2	Well-balanced
2 ... 5	Unfavourable
> 5	Extremely Unfavourable

7.1.1. Costs

The economic costs to be considered integrate a set of cost categories that are listed in Table 10.

Table 10: Safety measure costs calculation for the chosen case

Cost of the equipment implementation	Cost (€)
Safety measure equipment costs	
▪ Installation cost ▪ Training and education cost (staff) ▪ Operational cost ▪ Maintenance cost ▪ False Alarm (if any) - delay time ▪ No detection (if any) - consequences ▪ Renewal cost (if any) ▪ Development costs ▪ Testing, commissioning and standardisation costs ▪ Solution certification cost (solution on rail side) ▪ Legal framework adaptation ▪ Depreciation cost ▪ Legal responsibility in case of malfunction ▪ Recycling cost	
Total per 1 LC	
Total per number of Risky LC-s (ΔC)	Total per LC x Number of risky LC

7.1.2. Benefits

In order to evaluate the benefits of a given safety measure, the monetary values of reduced risk, integrating the lives and injuries saved, the material and environmental damages avoided as well as the accident/incident delays prevented/reduced thanks to the implementation of the measure.

Table 11: Life costs in monetary values.

	Fatalities	**Serious injuries**	**Light injuries**
Costs - VPC in €	x	x	x
Cost material damage	x	x	x
Cost environment damage	x	x	x
Cost of delay	x	x	x

The benefits evaluation has to be based on the number of prevented accidents and reduced accident consequences obtained by the quantitative risk evaluation. Furthermore, these benefits have to be calculated while taking into account the whole equipment life cycle.

Table 12. Monetary benefit calculation from prevented accidents

	Ratio per 1 accident (%)	**Absolute numbers**	**Fin. Cost per unit (€)**	**Total cost (€)**
Accidents prevented				
Fatalities prevented				
Serious injuries prevented				
Light injuries prevented				
Delay saved				
Total saved per year				
Total saved in life cycle (ΔB)				

7.2. Social analysis

The aim of the social analysis is to identify factors related to the social impact of the considered measure. In general, such factors cannot be monetarised in a straightforward way; nevertheless, they can have a big influence on real revenue of the investment. In the case of LCs, as the human factor plays a major role in the occurrence of accidents the social aspect of any technological change should be carefully taken into account. In particular, since LC accidents can be "spectacular", they generally give rise to large media coverage. Therefore, deploying safety measures at LCs can help people feel safer at LCs while improving the image of railway transport itself. In addition, the society may understand better some taxes if those are specifically used to improve people safety.

However, the installation of new safety measures may also lead, for instance, to the prolongation of level crossing closure times which would have a negative impact on road users (for instance in terms of obstacle detection). It could also trigger an increasing number of violations of rules which would have a negative impact on road safety). In fact, the presence of a new technology aiming at improving safety at level crossings (for instance obstacle detection) could, on the contrary, lead road users to rely too much on the updated level crossing facilities. As a consequence, they could be tempted to violate the road side warnings more often. Such kind of "risk compensation" could have a negative influence on the cost-benefit ratio since the safety measure is not able to prevent accidents caused by deliberate violations of signs by road users. That is why the implementation of a new safety measure need to also reduce the residual operational risk.

7.3. Some recommendations regarding the implementation of a CBA

The process to deploy a CBA to elaborate business models (T5.2) should consider a difference-based reasoning for the various cost and benefit parameters that are relevant to assess. Such process must be implemented in order to determine the positive and negative impacts of the considered measure through a pre/post reasoning.

In practice, for a given measure, the process to deploy a CBA can be composed into a set of steps as discussed below. For the sake of illustration, we will consider the obstacle detection solution to give some examples.

1- Determine the various relevant economic costs and determine the related KPI from the 5 categories mentioned above, while referring to the KPI tables of D4.2. For the obstacle detection solution for instance, the costs are related to the development, testing, qualification, installation, operation and maintenance. But these costs can also include delays in case the closure cycle is extended due to the installation of the obstacle detection system.

- Then, for each of the identified items, determine how to measure the "value" while considering a WITHOUT/WITH reasoning.

2- Determine the various relevant economic benefits and determine the related KPI from the 5 categories mentioned above, while referring to the KPI tables of D4.2. For the case of obstacle detection, this would relate to the lives/injuries saved as well as the material/ecological damages avoided.

- Then, for each of the identified items, determine how to measure the “value” while considering a WITHOUT/WITH reasoning.

3- Determine the various relevant social costs and determine the related KPI from the 5 categories mentioned above, while referring to the KPI tables of D4.2. For the case of obstacle detection, this could be, for instance, related to the discomfort caused by the extended LC closure duration due to the installation of the detection obstacle solution.

- Then, for each of the identified items, determine how to measure the “value” while considering a WITHOUT/WITH reasoning.

4- Determine the various relevant social benefits and determine the related KPI from the 5 categories mentioned above, while referring to the KPI tables of D4.2. For the case of obstacle detection, this could also be linked to the reputation of railway safety.

- Then, for each of the identified items, determine how to measure the “value” while considering a WITHOUT/WITH reasoning.

5- Ultimately, determine the CBR ratio of the measure by summing-up the whole costs on one hand, and the whole benefits on the other hand. Discuss the relevance of the considered measure based on the results obtained and the various external factors that may also have an impact on the profitability of the measure (sensibility analysis, etc.).

Another important aspect to consider is the actual practicability and relevance of a CBA in some cases. In fact, if the implementation of a CBA analysis is often advocated, in some cases not enough data can be found to implement it as such since converting all the effects of a new solution into monetary values can seem awkward, unrealistic and not reliable, if not purely impossible. Therefore, in T5.2 a CEA could be performed with the various parameters to assess valued through “qualitative” scores instead of reasoning in pure monetary values. The overall rating of the solution assessed can then be expressed in a qualitative way too.

8. CONCLUSIONS AND RECOMMENDATIONS

In this deliverable, we discussed the various issues related to the implementation of a CBA/CEA to assess the various SAFER-LC measures. In particular, this document provides different pieces of information that need to be considered in T5.2 for the development of business models to deploy the solutions proposed by the SAFER-LC project.

In what follows, we list the various items that must also be considered for the examination of the SAFER-LC measures. Namely, we first determine the various aspects that impact safety and operation at LCs, and we then list the solution-related aspects that need to be considered in the CBA.

Priorities regarding **road user human factor**:

- Attention:
    - Inattentiveness of the users: Pedestrians/cyclists with headphones or using smartphones, road drivers using smartphones or GPS
    - Non-observation of the road signage and rail tracks by road users or pedestrians
- Understanding: Special focus on lack of signage or too many signage at LCs and the special needs of impaired people.
- Behaviour: Special focus on excessive speed of road vehicles and deliberate violations at active LCs

Priorities regarding **LC design**:

- Design of the LC: Curves before and after the LC, bumps, slopes and high declivity should be avoided/tackled; difficult especially for buses and trucks
- Location of the LCs: LC located, for example, too close to a road crossing or at proximity to commercial centres could generate long waiting queue at the LC (and could also cause so called blocking back effect)
- Protection of the LC based on a risk evaluation
- Easy access through and around LC or under the barriers for pedestrians/cyclists

Priorities regarding **railway operations**:

- Vehicle stuck on the level crossing
- Long-time of LCs closure
- Failure on rail devices: detection of train, LC control system, barriers, etc.

Priorities regarding **innovative solutions** resulting from the above priorities:

- Risk assessment: Risks at LCs shall be regularly monitored to adapt the safety measures at LC
- Communication
    - Road users shall be informed about a LC he/she is approaching
    - Road users shall be informed about a train approaching at the LC
    - The train driver shall be informed in advance about obstacles at the level crossing
    - The train shall brake when an object is detected in the hazard zone of the LC

- Maintenance
    - All subsystems of the level crossing shall be inspected, maintained and repaired according to the regulations.
    - IM shall be alerted in case of failure occurrence or foreseen failures
    - The train driver shall be informed in advance about failures of the LC
- Design of the LC
    - Road users shall be protected by technical means from entering the hazard zone if a train is approaching
    - The level crossing activation period shall be as short as possible in order to maximise fluidity and avoid impatience of awaiting road users
    - All traffic signs and similar communication for information and warning shall be unambiguous, easily understood and giving clear (positive) instructions for a road user paying moderate attention
    - The design of the LC shall be adapted for all types of vehicles
- Cost-effective safety measures shall be preferred

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10. ANNEXES

Annex 1 – Questionnaire on CBA (WP5 Workshop – March 27th, 2018)

About CEA/CBA

Which method is appropriate for SFER-LC? Why?

The answers are quite mixed: 54% for CBA against 46% for CEA.

Although some participants think that CBA would be more precise since more quantitative, the argument regarding data availability to perform CBA is put forward, so as many participants think that it is more realistic to achieve CEA. Another evoked aspect in favour of CEA is regarding the quantification of some factors such as, for instance, safety.

About values of life

Country specific values or EU-averaged values?

Please give 2 arguments for your proposal:

65% EU-averaged value vs. 35% country-specific value

- The arguments in favour of EU-average value are mainly :

** simplicity in performing CEA/CBA*

** as SAFER-LC is a European project, we should consider EU-averaged values*

** fairness: cost of life should be the same*

** country specific values could be considered for sensitivity analysis*

- The arguments in favour of country specific value are mainly:

** better accuracy of the CBA/CEA analysis*

** discrepancy in terms of costs of saving lives (hospitalisation), etc.* ** usefulness of the analysis results in different countries*.
Accident cost (property, etc.)
Which are the five main elements to be considered in the accident cost? *The main accident costs that have been highlighted are:* *- infrastructure damage (track, overhead power supply, LC equipment)* *- rolling stock damage* *- involved road vehicles* *- repairing works* *- emergency services* *- delays* *- other property damages (near-by buildings, roads, green spaces)* *- posttraumatic stress* *- reputation/image damages* *- ecological cost* *- lawsuit compensation fees* *- insurance*
Values of delays (passenger, freight)
Do we need to integrate the impact in terms of delay for neighbors' lines? *Most of participants (90%) consider that we should integrate the cost in terms of delay to neighbors' lines so as to make a comprehensive CBA/CEA analysis. However, many participants highlighted the fact that the evaluation of such a delay would not be easy, while some recommend making rough estimation of this cost.* *The 10% participants that do not recommend to integrate such delays argue that this would be complicated since finding relevant data regarding these delays would not be easy.*

Slight injuries
To be included Yes / No *60% answered No, against 40% for yes* *Arguments in favour of "Yes": accuracy of the CBA/CEA analysis* *Arguments in favour of "No": not enough reliable data available. In particular often slight injuries are not reported appropriately*
Factors to determine risky LC (FB, HB Road signal and unprotected)
Factor K = ɱ x n_{acc} / 10^3 ɱ = number of trains x number of road vehicles (over one year) n_{acc} is the number of incidents (knocked barriers) and of accidents over 10 years. (2) Expert's judgment *Please indicate 2 more factors to be considered.* *The main factors indicated by the participants are:* *- exposure* *- profile* *- visibility* *- railway speed* *- road speed* *- traffic moment* *- type of the LC* *- environmental factors* *- Type of traffic: local/tourist road users, type of crossing road vehicles*

weather specific conditions *- traffic fluctuation* *- frequency of inappropriate behavior (hard to get this information)*
Cost of Safer-lc measures
Are there any more main costs to be considered for a given measure? *- Equipment* *- Installation cost* *- Training and education cost (staff)* *- Operational cost* *- Maintenance cost* *– False Alarm (if any)- delay time* *- Renewal cost saving (if any)* *- ...* *The new costs raised by the participants are:* *- development costs* *- testing, commissioning and standardisation costs* *- solution certification cost (solution on rail side)* *- legal framework adaptation* *- depreciation cost* *- legal responsibility in case of malfunction* *- recycling cost* *Which duration (10, 15 or 20 years) is more appropriate for economic evaluation of suggested measures* *Not many participants addressed this question, but some answers advocate to consider different durations and make comparison, while other recommend to adapt the duration to the life duration of the solution (technological or not)*
Effects which usually are not monetarised Accident
Are there any more effects to be considered for a given measure?

- Easy issues of implementation; *- Easy issues of use;* *- Competitiveness of the European Railway industry;* *- Effects on the environment;* *- Customer satisfaction with the safety system;* *- Capacity performance;* *- The possibilities of by-passing the system;* *- Maturity degree of the technology* *The other aspects evoked are:* *- privacy issues regarding the collected data* *- effects on the surrounding / other stakeholders* *- availability of the solution (used components)* *- certification procedures (duration necessary, etc.)* *- LC closing time after the solution has been installed* *- acceptability by users*.
Social analysis and ethical issues of sfer-lc solution
Identify the benefits and disbenefits for given solution? *The positive aspects raised by the participants are mainly:* *- fostering quality of life* *- improve safety* *- help mobility* *The negative aspects raised by the participants are mainly:* *- the disturbance caused to neighborhood: noise, etc.*

- privacy issues (vide recording, data logging, etc.) *- accessibility of disabled persons* *- discrimination: protecting some users better than others especially for some technological based solutions (mobile apps)* *- risk to decrease road user awareness about danger (obstacle detection for instance)*.
10. Other projects
Is there any other project that could be useful for the CBA analysis that will be made within SAFER-LC? *- Co-Gustucs (ITS communication solutions)* *- Compass4D (ITS communication solutions)* *- CAPITAL (ITS communication solutions), ongoing project* *- AEOLIX (ITS communication solutions), ongoing project* *- MORIPAN* *- PRORAD smart mobile cameras* *- Expert group of safety at level crossings of the UN-ECE (cf. website)*