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Deliverable D5.3

Business Models for safer LC innovative solutions

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Consortium - List of partners

Partner No	Short name	Name	Country
1	UIC	International Union of Railways	France
2	VTT	Teknologian tutkimuskeskus VTT Oy	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	NeoGLS	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

The European project SAFER-LC (*Safer level crossing by integrating and optimizing road-rail infrastructure management and design*) aimed to introduce innovative ways to minimise the risk of LC accidents and hence improve safety in road and rail transport. The activities carried out included the development and piloting of low-cost innovative LC safety measures. An innovation can either be deployed and result in benefits for the society or stay on a paper, and this is the reason that an organisational business model with clearly defined roles and products is required. A clear roadmap for the after-project life of the developed solution make the innovation self-sustained and profitable and can bring benefits to the society. The added value outcome of a successful exploitation of the SAFER-LC solutions can be twofold; the partners can exploit the results of the research for their own benefit and the society can benefit from the same innovation e.g. via reduced number of LC fatalities and accidents. The Business Model and the detailed Cost-Benefit Analysis (CBA) are key elements that are required to convince the stakeholders about the worthiness of some solutions. Especially for safety measures where there is a lack of profitability it is an imperative to point out the benefits of the safety solutions and the practices that can result from a successful implementation (we do not examine demand oriented commercial products and this can make things more complicated). The current document examines the views of the consortium on further exploitation of the tested safety solutions, analyses the benefits of their implementation for the society, and proposes an organisational structure – business model for the SAFER-LC solutions.

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1. INTRODUCTION

1.1. Objectives of SAFER-LC project

The main objective of the SAFER-LC project (Safer level crossing by integrating and optimising road-rail infrastructure management and design) 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 new design of level-crossing infrastructure. These tools will enable:

i. Road and rail decision makers to achieve better coherence between both modes,

ii. Effective ways to detect potentially dangerous situations leading to collisions at LCs as early as possible,

iii. The prevention of incidents and accidents at level crossing through innovative design and predictive maintenance methods, and

iv. The mitigation of the 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 while integrating all the project results and solutions to help both road and rail stakeholders to improve safety at level crossings.

The project focuses both on technical solutions and on human processes to adapt infrastructure designs to road user needs and to enhance coordination and cooperation between different stakeholders from different land transportation modes. The challenge is also to demonstrate the acceptance of the proposed solutions by both road and rail users and to implement the solutions cost-efficiently.

Within the project, the objective of Work Package 5 (WP5) is to examine the economic viability and efficiency of the different solutions trialled within the SAFER-LC project. WP5 introduced the Cost-Benefit Analysis approach and provided recommendations for future international standards in road and rail environment for safer LCs. This deliverable (D5.3) focusses on the application of the CBA and the development of SAFER-LC business models for the deployment of the safety solutions suggested earlier in the SAFER-LC project.

1.2. Purpose of this deliverable

This deliverable reports the work conducted in Task 5.2 of WP5. It is considered as a continuation of the previous deliverable D5.1 (El-Koursi & Ghazel, 2018) produced in WP5, which introduced the Cost-Benefit Analysis (CBA) approach for the SAFER-LC solutions. The current document will be used as a basis for the deliverable D5.4 regarding the recommendations and guidelines and the analysis will be used at the SAFER-LC Toolbox for the categorisation of the solutions.

This current deliverable will apply the CBA by exploiting the information on deployment costs of the solutions from the questionnaire developed in the context of this deliverable (see Annex B for details). Each pilot site leader replied to this questionnaire and the benefits were obtained both from this questionnaire and from WP4 (Silla et al., 2019). The next step suggested the best solutions for deployment and proposed the Business Model with an organisational structure for the solutions developed. A business scenario explaining views of the users is elaborated in the case of our partner TRAINOSE.

For starting the analysis, a clear understanding of the solutions and their added value was needed. The name ‘solutions’ refers to the SAFER-LC safety measures (as referred in WP4). However, in WP5, it is more preferable to discuss about customer-oriented solutions in the attempt to define a potential product out of it.

This deliverable collects the main results obtained from the evaluation of the safety solutions piloted within the SAFER-LC project. An additional questionnaire was directed to pilot test leaders to collect information on benefits of these solutions as well as on costs regarding the development, installation, operation and maintenance of the solutions. Furthermore, this additional online survey was conducted to collect views of the partners in regard to the exploitation aspects and the commercialisation of the tested solutions. The results of this online questionnaire are presented in chapter 2 of this deliverable.

Moreover, this deliverable reports the results from the CBA applied on the piloted safety solutions. The results are of high importance when choosing the business scenarios and the proposed business models. Several business model techniques and business models are presented after a thorough literature review and the most applicable and useful were elaborated and applied to estimate the potential and requirements for the SAFER-LC solutions.

Lastly, this deliverable suggests the business models that can be realistically applied to ensure a sustainable exploitation of the SAFER-LC solutions.

1.3. Interactions with other activities within the project

Task 5.2 was initially planned to be dedicated purely on the “Business Models to deploy the SAFER-LC solutions”. However, it was agreed between the Task 5.1 and Task 5.2 leaders to include the application of the CBA in deliverable D5.3 as the timing was better and the results would be easier to obtain after the end of piloting instead of the first months of the project (when evaluation results were missing). This development allowed Task 5.2 to create a clear story replying firstly to the question: is the solution worth deployment – is it beneficial for the users and for the society? The second question this deliverable deals with is: How the solution can work in the real world taken business potential into consideration? Business models will set the ground for the future actions to be followed in order to deploy the SAFER-LC solutions.

To respond to the above questions, this deliverable uses the outputs of deliverable D4.4 (Silla et al., 2019) in order to evaluate the benefits for the CBA, and deliverable D4.3 (Carrese et al., 2019) to better understand the tested solutions and the design and conditions of pilot-testing. The work being done in WP1 was also of great importance for the development and enrichment of WP5 activities, especially for the introduction of the necessary bibliography and the status quo concerning the level crossings in Europe and around the world.

Figure 1 presents the interactions of this deliverable with the other project documents.

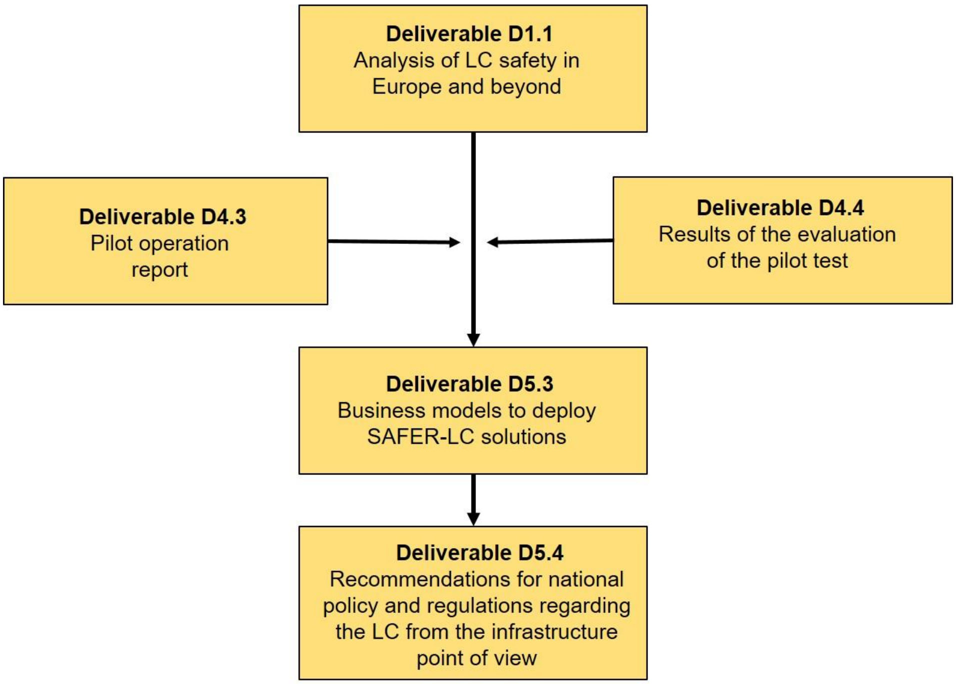

Figure 1: *Main interactions of D5.3 with other documents within the project.*

1.4. **Structure of the document**

After the Introduction of the current deliverable, the second chapter is dedicated to the results from the online survey on the exploitation of piloted SAFER-LC solutions. Chapter 3 includes the application of the SAFER-LC Cost-Benefit Analysis whose approach and methodology was introduced and described in Deliverable D5.1 (El-Koursi & Ghazel, 2018). Chapter 4 will present the proposed business model for the SAFER-LC solutions and chapter 5 will describe some selected business cases that can approach reality as close as possible at this stage, while taking into consideration the needs and desires of the businesses and partners of the SAFER-LC consortium. Finally, in chapter 6 some general conclusions and recommendations will be elaborated exploring the potential of SAFER-LC solutions in the market.

1.5. Abbreviations and terms

Table 1: *Abbreviations and terms.*

Abbreviation	Description
BCR	Benefit – Cost Ratio
BM	Business Model
BMC	Business Model Canvas
BMT	Business Model Technique or Tool
CBA	Cost-Benefit Analysis
CBR	Cost – Benefit Ratio
CEN	European Committee for Standardization
C-ITS	Cooperative Intelligent Transport Systems
EC	European Commission
ETSI	European Telecommunications Standards Institute
IRR	Internal Rate of Return
ITS	Intelligent Transport Systems
KPI	Key Performance Indicator
LC/LCs	Level Crossing / Level Crossings
NPV	Net Present Value
RSU	Restricted Stock Unit
SDO	Standard Development Organizations
SDS	Smart Detection System
TRL	Technology Readiness Level
WP	Work Package

2. THE SAFER-LC ONLINE SURVEY

2.1. Online survey on the SAFER-LC exploitation

During the course of the project, an online survey was developed in order to obtain the general views of the SAFER-LC consortium on the potential exploitation of the safety solutions tested within the project, and more specifically on the Business Model aspects to be analysed within this deliverable. The survey included aspects such as the objectives, the required resources, the main benefits and the value proposition regarding the piloted safety solutions (see Annex A for more details).

The partners were asked to estimate the benefits of their solutions for the society. In addition, the SAFER-LC Business Model was introduced to the partners with the help of Business Model Canvas. Specifically, the question “what happens next?” was broken down to the following three questions:

- What did the consortium achieve during the project-life and the pilot-tests and how can we make the next steps?
- Is it worthy to invest to the piloted solutions?
- What will the organisational structure be in case of an exploitation scheme and how is this going to be sustainable/profitable?

The online survey was focused on the general perception of partners on the future exploitation steps and there was no need for analysis related to each specific solution – several solutions can be exploited but we need a strategy for all at this stage. In this chapter, we are going to present the answers to the various questions in the survey.

During the SAFER-LC pilot testing, eight different sites implemented 21 solutions in simulator and real-life environments. ***Table 2.*** *List of piloted safety measures presented in this document, by pilot site.*Table 2 presents the solutions considered during the online survey. The survey was directed to all pilot test leaders and at least one partner engaged to each of the pilot sites responded to the survey. In total, 12 responses were gathered from ten different consortium partners. The SAFER-LC solutions will be presented as a whole at this point; thus, it is not necessary to separately analyse the responses per solution.

Table 2. *List of piloted safety measures presented in this document, by pilot site.*

Pilot site	Safety measures
Driving simulator of DLR	• Blinking lights drawing driver attention • Improved train visibility using lights • Noise-producing pavement • Sign ‘Look for train’
Two simulation environments (VTT)	• V2X messaging system between automated vehicles (AVs) and passive LCs
Aachen test site (multiple partners)	• Smart detection system • Early detection and hazard information • Smart communication system 1 • Smart communication system 2 • Monitoring and remote maintenance
CEREMA Rouen (CEREMA&NTNU)	• Monitoring and remote maintenance
Thessaloniki living lab (CERTH-HIT & DLR)	• In-vehicle train and LC proximity warning
Real rail environment (VTT)	• Additional warning light system at front of the locomotive
Real rail environment (DLR)	• Blinking amber light with train symbol • Written letters on ground

In questions three and four of the survey, the partners responded on which of the solutions have been taken into consideration during the framework of this questionnaire and the respective characteristics of the pilot sites. The majority of the rest of the questions have the greater goal of capturing the general scope of the partners on the SAFER-LC solutions and not each of them separately.

The first three questions (questions 3 to 5) refer to the identification of the respondents in a qualitative way (characteristics of test sites, piloted solutions and objectives) while towards the end of the questionnaire, the willingness of the partners to continue working on the developed solutions, the expectations from the market and the stakeholders were to be assessed.

The first questions were targeting to profile the respondents and understand their point of view while responding to the rest of the questions. A coverage of participants from as many solutions as possible was desirable. The 12 respondents have been engaged with the piloted solutions (in some cases solutions might be referred more than once or respondents can represent multiple ones).

2.2. **Survey results**

Hereunder, the results from the consortium's online survey on business aspects are presented. The online survey helped us in order to build a sound business model for the SAFER-LC solutions which can be found in chapter 4.3.

Questions 1–5:

The characteristics of the test sites were described by the respondents as following:

- Active LC with high vehicle traffic
- Research facilities
- Urban area LC
- Mock-up of a level crossing installed in the RWTH premises: video sensor, processing power and Roadside units
- Fixed-base driving simulator
- Driving Simulator to test measures to enhance safety in a virtual Environment
- Tests to be implemented at several level crossings in the western suburbs of the city, under real life conditions. LC characteristics vary (active, passive, with barriers, etc)
- Tests are made by using a rental locomotive at some suitable place
- Installation of C-ITS equipment on a LC and a vehicle and deployment of C-ITS software in order to warn end-users of dangers

The main objectives and characteristics of the piloted safety solutions were described by the following way:

- Objectives: Safer Level Crossings - fatalities and injuries avoided - less environmental damages - Infrastructure damages - Traffic delays - Rescue service costs avoided
- The measure is thought to increase the detectability of the LC and the carefulness of the drivers
- Additional flashing warning light to train front. Light is activated automatically when train approach level crossing. Objective is to draw road user's attention to the flashing
- It introduces a mobile application developed to enhance road user safety around level crossings
- The main aim is to automatically detect potentially dangerous situations at level crossing. Scenarios are played on the test site
- Aim: to prevent road-rail collisions at passive LC. Characteristics: Road sign on advance to LC (either independent or combined with LC signage) giving explicit instruction to road users to visually check the rails for a train before crossing a passive LC
- Especially at passive railway Level crossings road traffic participants often do not spend enough visual attention to detect an approaching train. Oscillating light attached to the front and side of the locomotive will enhance the conspicuity of the train and therefore reduce the risk of accidents at passive LC
- Two lights located in the left and right periphery of the level crossing. Lights start blinking when a car passes an in-road sensor on approach to the LC. The light sources appear in the periphery of the driver's visual field. The salient blinking lights trigger an automatic and effortless visual orientation reaction of the driver towards the peripheral regions of the level crossing that require visual scanning to detect a train (exogenous capture of attention, physiological mechanism)

- The solution introduces a mobile application developed to enhance road user safety around level crossings. The app can be installed on any common mobile device like a smartphone or tablet, and it alerts users about the presence of a LC through a pop-up window and a short audio alert, whenever they approach a LC. The warning also includes an estimated time of arrival for the case of an incoming train.
- System activates additional warning lights installed on the front of the locomotive at predefined distance before level crossing. Lights give short and powerful light bursts. Aim is that road users pay attention to these bursts and notify that train is approaching
- See if C-ITS technology is adapted to provide security at level crossings

Question 6: Continuation of collaboration

Figure 2 refers to the question: *"As a partner of SAFER-LC would you envisage to keep working with other partners of the consortium after the end of the project to implement some of the solutions developed and tested within the project?".* The majority of the respondents (75%) expressed a positive view ('Yes, definitely') on the future collaboration for the implementation of one (or more) SAFER-LC solutions. Two out of 12 replied that they did not know and only one out of 12 respondents replied negatively. This result is considered as very positive.

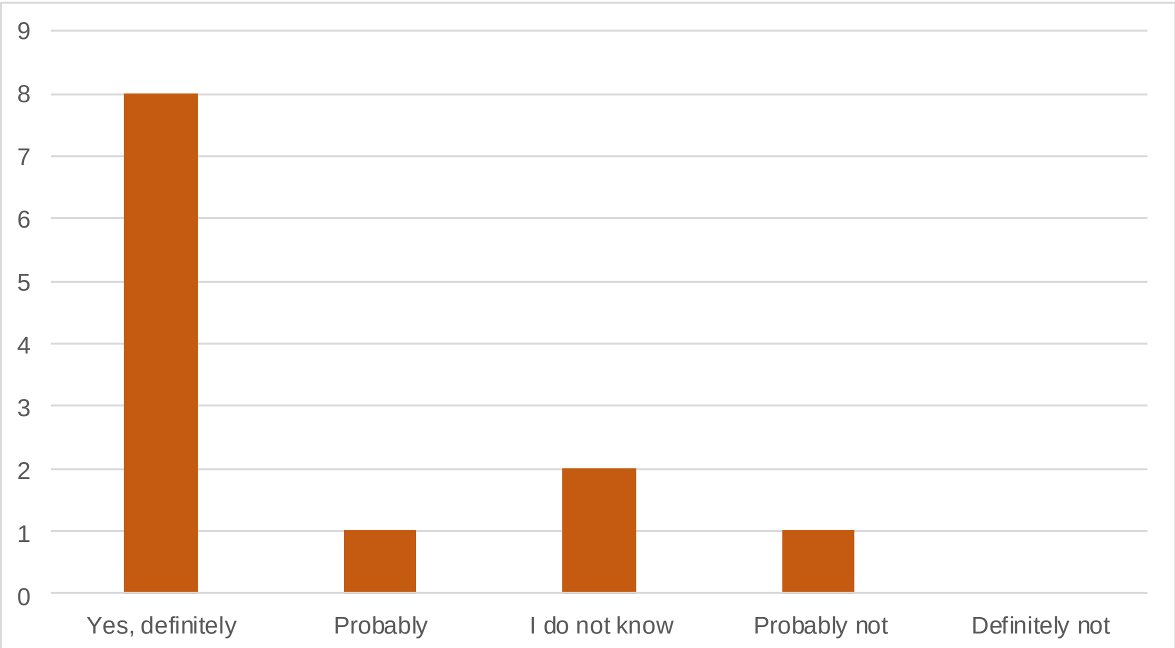

Figure 2: *Collaboration continuation after project-life.*

Question 7: Partners for market introduction

"*According to you, what would be the most suitable type of partners to introduce the solution tested in the "market"?*" In this question, the responses are different from rail infrastructure companies or rail operators to road authorities and other public authorities. The understanding of the partners on who the future customer is not clearly defined.
• Rail infrastructure companies, IT companies, Rail operators to provide the data, road construction companies etc. • The infrastructure managers • Train electronics manufacturer • Railway companies • The two SMEs, NeoGLS and Commsignia could introduce this kind of solution in the market (in close collaboration with railway companies) • Any party responsible for securing level crossings, either on public (e.g. communities, countries, railway operators) or private (e.g. producing / manufacturing companies) grounds • Any party responsible for securing level crossings, either on public (e.g. communities, countries, railway operators) or private (e.g. producing / manufacturing companies) grounds • Manufacturers of locomotives like Siemens, Bombardier, Alstom, Thales (...) in combination with an interested rail traffic Provider • Service and content providers for the automotive sector. Probably also railway operators, infrastructure managers and logistic companies. • Road authority • Company, which is focused to provide equipment to the rail environment. • Organisations in link with railway companies or directly railway companies.

Question 8: Steps needed for market introduction

"According to your expertise, what would be the steps to follow after the testing phase to introduce the solution to the market and implement it in the real world? (e.g. R&D, product development, production planning [process, capacity] and control, communications, sales support…)"
• Further research and fine tuning of the solutions, market development, product development, business model development, market analysis, risk assessment and risk mitigation plan, business plan development and business plan execution. • Communications • R&D phase to design power electronics to drive LED units as well as design of the light beam reflector. Possible integration with main headlight units. • The solution is already implemented. An awareness campaign would be interesting

- Before introducing in the real world, a deep evaluation is needed to have definitive results of the system. It could consist on installing the system on a level crossing and let it work for a long while and then verify what is happening. It is an intermediate step. We are not at the level of putting it on the market. Another project on implementation could be useful
- Mostly communications (production, sales etc. can be integrated easily in the existing road sign "industry")
- product development, production planning and control, communications, sales
- Product development, field research of usefulness, demonstration of usefulness by a small-scale series, for example by implementing it at trains of an industrial railway line.
- Scale up of the service to a national level including all LCs and all trains in Greece. Inclusion of other professional fleets (more taxis, buses and coaches as well as vans and trucks).
- Test in real LC and product development
- Redesign the hardware to fulfil the rail environment specifications and lower the production cost. Redesigning of the software to selected platform and develop the user interface for maintaining the system.
- Introduction of non-standard, experimental solutions to SDOs (Standard Development Organizations) in an attempt to fine-tune and harmonize them with existing solutions.
- To test in real conditions on an operated level crossing open to road traffic.

Question 9: Required resources

"*What would be the key resources needed to produce, sell, set-up, operate and maintain the solution tested? (Typical equipment required, nature of the workforce…)*"

The responses also here differ depending on the needs of each pilot-site leader.

- Regarding the solutions: IT solutions: IT personnel, GPS location hardware etc. Infrastructure solutions: Infrastructure production, technical equipment
- The solutions are besides applicable
- Skilled engineers
- GPS installed in cars and trains
- Standard C-ITS communications equipment installed on-board of road vehicles and trains, as well as in roadside and LC infrastructure. Equipment and workforce comparable to that in producing, setting up, and maintaining existing road signs
- Equipment and workforce comparable to that in producing, setting up, operating and maintaining normal traffic light systems
- You would need high quality LED - lights, a good GPS Sensor to detect the Train Position relative to a Level crossing. You could assemble a small series in a Workshop equipped for electrical engineering work. You need engineers to assemble and install the Systems.
- Servers able to facilitate more level crossings and support more application users. Ideally, the service requires historical and real-time spatio-temporal data from more

operating trains. There is a need for an initial effort in setting up the back-office, defining the LC areas and collecting historical data (skills needed: knowledge and experience in spatio-temporal data analysis and machine learning), but after this set up the resources needed are significantly lower, mostly for maintaining the solution.

- Production can be given to the subcontractor, salesman, some engineers to do the service and repair support etc. Operation is automatic, but some maintenance of the level crossing database is required.
- Hardware and software must be adapted and maintained. The system must be operational 24/7.

Question 10: Type of market introduction

"*In your opinion, could the solution tested have the potential to be introduced in the market as a stand-alone product or should it be part of a broader set of solutions? Please specify briefly why*".

Most respondents defined the respective solutions as potential stand-alone products.

- Broader set for the majority of the solutions
- It can be used as stand alone
- Could be aftermarket product or OEM solution in new locomotives.
- It could work as a stand-alone product.
- The system is not a standalone solution. In its industrial version, the solution is included in the global managing chain of the railway companies (control centre, trains, cars, level crossing, emergency services....)
- Could be used as stand-alone product because it strongly increases the probability of road users looking for a train by itself. (Still, there is nothing against combining it with other measures.)
- It can be a stand-alone system, if it is designed as an expansion or an upgrade for regular trains. If not, the system should become part of train manufacturing.
- Indeed, the solution tested could be introduced as a standalone product. As a mobile app, it operates individually on any mobile device (smartphone or tablet), thus no other products/solutions are needed to accompany it.
- it will be may be an answer that we will have at the end of the tests
- Standalone. Operation is not dependent to any other solution. For easy maintenance Wi-Fi hotspots are required at depots or stations to download updates to level crossing database automatically.
- Communication solutions belong to the broader C-ITS ecosystem.
- It could be a stand-alone product but it would be even more efficient if it is completed with the video system.

Question 11: Main benefits to customers

"*What are the main benefits of the tested solution(s) for the customers? What critical problems are being solved for them?*"
• Safety, provision of information to the drivers • The measure is thought to increase the detectability of the LC and the carefulness of the drivers so that they can become aware of the LC, slow down and stop at safe distance when the LC is closed. • Decreased accidents • Accidents in LC's, fatalities and costs from damages. • More safety, over accidents mitigation, quicker incidents and accidents management thanks to images • Effective reduction of accident risk at passive LCs with small financial effort • Safety of level crossing will be enhanced - no delays because of accidents at passive LC • Safer driving in the surroundings of a LC. The application warns users about the existence of a LC in the direction they are heading, and also about the proximity of trains. Often people do not trust the safety measures provided by each LC protection, for example the closing of the barriers. By providing real time information to the drivers about when (exactly) the train will arrive, it kind of forces them to trust and respect the barriers and any other protection offered. • it will be may be an answer that we will have at the end of the tests • Decrease level crossing accidents where road user fails to pay attention to approaching train. • Validation of compliance and performance of standard C-ITS communication solutions in the LC environment. • Reduce accidents at a level crossing both for vehicle drivers, pedestrians and train drivers

Question 12: Value proposition

"*According to you, what is the unique value proposition (or obvious advantage) of the solution tested in comparison to other solutions available on the market?*"
• Safety of road and rail transport • It is a cheap solution and easy to apply • Solution utilise GPS and LED technology. Automated operation. • It is very cheap and easy to work. • It is a smart detection which could avoid accidents and warn the operators. But again, the system must be evaluated more intensively. The comparison with other systems is not obvious • The system works without requiring any previous knowledge or wilful effort from the road user as it uses an innate attentional mechanism. Moreover, it works independent of railway operations and therefore does not require railway-specific safety Validation. It is low-cost.

- Compared to regular safety systems to upgrade passive LCs the solution appears much cheaper. If you attach the oscillating light system on one train, it will be active at all LCs that the train passes. The system is Independent of a single infrastructural environment of an LC.
- The integration of trains in the intelligent Co-operative Transport Systems. It is the first smart application that offers safety warnings regarding LCs to users. In addition, the system can be easily expanded to scale up to more LCs of any type (protected, unprotected etc.) with relatively low costs for drivers.
- it will be may be an answer that we will have at the end of the tests
- Because it is installed to the locomotive, amount of the devices is less than amount of level crossings. It also operates both passive and active crossings as well as any arbitrary point along the rail network.
- It relies on standard C-ITS communications solutions adapted to the specific LC requirements.
- Reliability

Question 13: Usefulness of solutions

The majority of the consortium members (eight out of eleven) responded positively – that they would be benefited from the solution as end-users (Figure 3). Only two negative responses were reported and one as 'I do not know'.

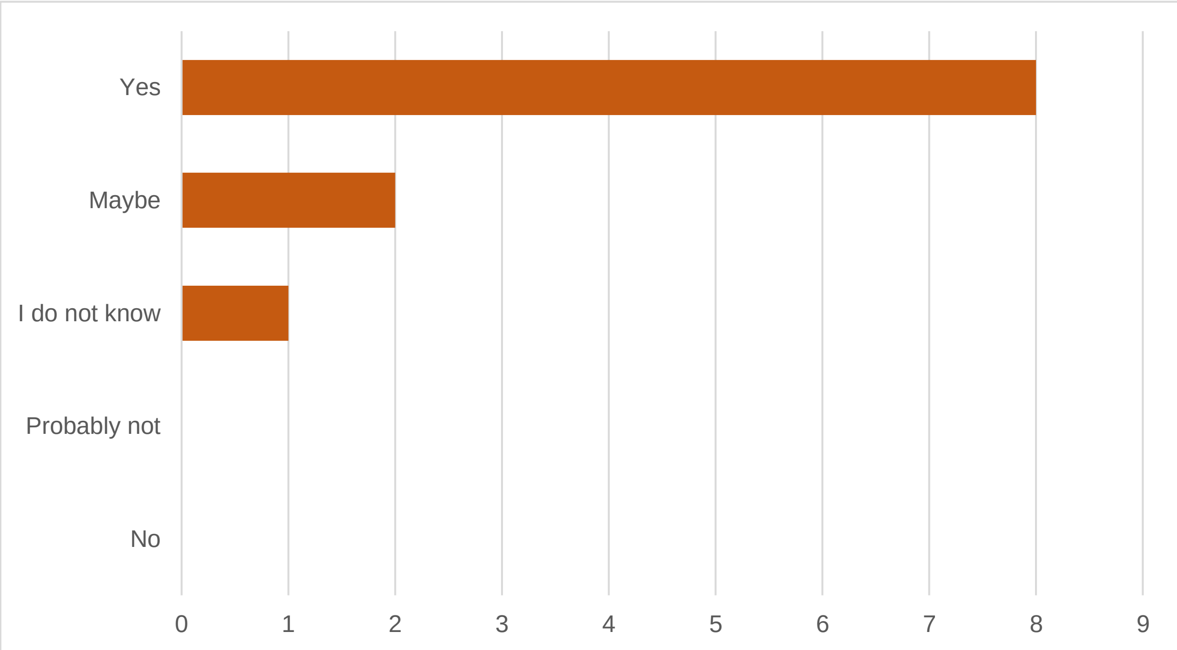

Figure 3: *Partners benefited from the SAFER-LC solutions.*

Question 14: Possibilities to be positioned as standards

Figure 4 shows that the majority of respondents considered that their solution could position itself as a standard in the sector.

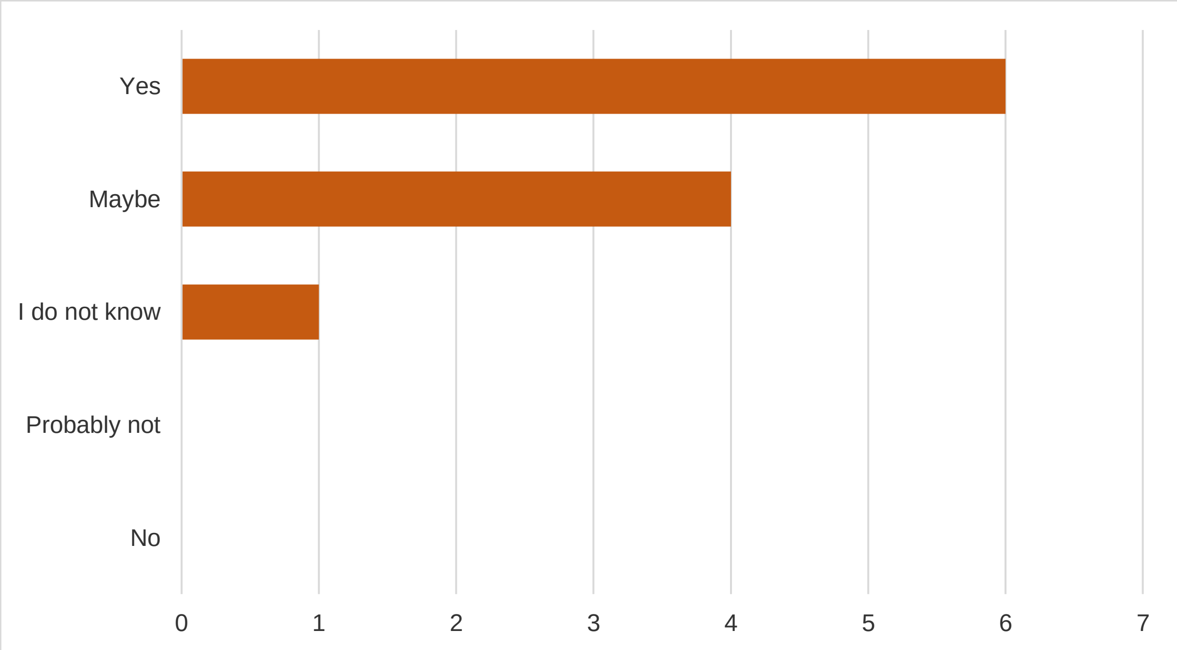

Figure 4: *"Could the solution tested position itself as a standard in the sector?"*

Question 15: Possibilities to become obsolete

Figure 5 shows that the results related to solutions becoming obsolete in near future were more negative (only two responded 'yes'), which can be translated as more time required for the solutions to become obsolete.

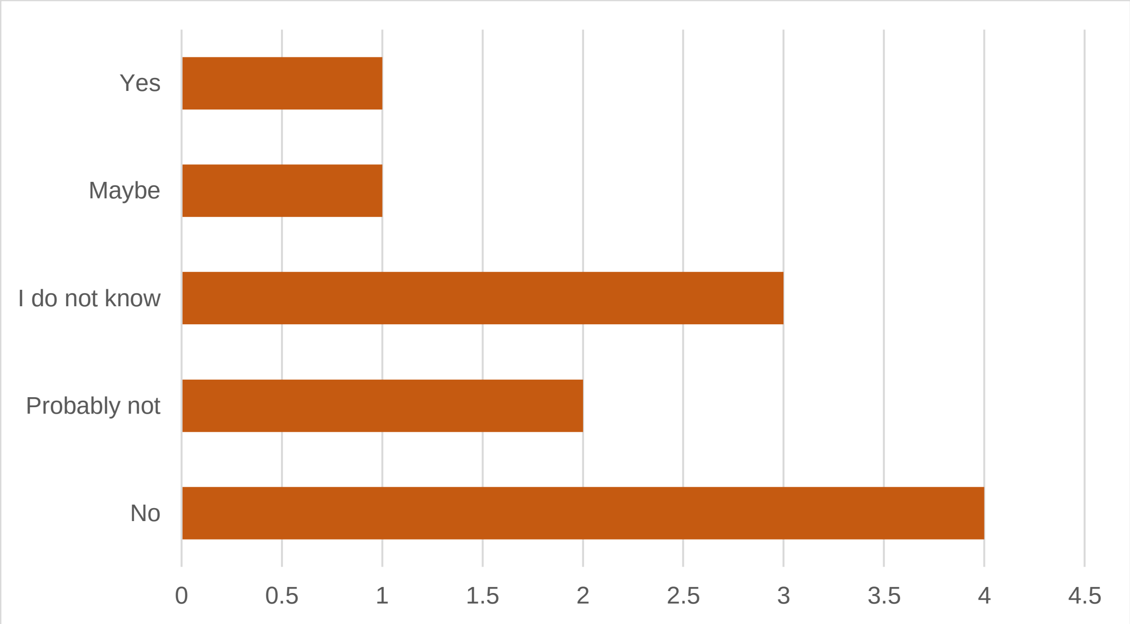

Figure 5: *"Could the solution tested become obsolete soon?"*

Question 16: Targeted market

"*What would be the size of the targeted market? Local, national, continental or global?*"

The majority of the partners targets a global market for the SAFER-LC solutions. Seven out of the eleven responses estimated that the size of the targeted market would be globally oriented. The rest responses included regional, national and continental level.

- Regional, national or European
- Global (3 responses)
- Global because it is a solution that could work in every train fleet.
- Continental. In the global number of level crossings (LC). In France we have 15 000 LC
- Global (applicable in any country and region with passive LCs)
- Global --> The technical principle of oscillating light on locomotives should be set as a safety standard for all trains that will be manufactured in the future. It should be started in Europe and then spread.
- Global. The user only needs a mobile device to use the app while no infrastructure is needed at the LCs.
- National
- At each country a potential market is amount of locomotives and rail equipment which drive rail sections where level crossings are. Therefore, high speed trains are probably excluded. Eg. Finland 670, Germany 16892

Question 17: Type of customers

"*What type of customers do you foresee for the solution tested?*" There is no clear outcome in question 17, but almost all the respondents included rail-oriented companies - entities as customers.
• Rail operators, infrastructure managers, road infrastructure managers, regional, national governments, European investment schemes etc. • infrastructure managers • Train operators and manufacturers. • Railway operators, truck companies, bus fleets. • Two levels of clients: end users and railway transport operators • Any party responsible for assuring level crossing safety, either on public (e.g. communities, countries, railway operators) or private (e.g. producing / manufacturing companies) grounds • Rail traffic providers that buy trains or want to retrofit trains will be the primary customers. The light rail industry might as well benefit from the solution. • Initially professional fleets, and later on all technology-friendly drivers. • Road managers or rail managers • Rail companies • Level crossing managers meaning railway managers

Question 18: Main beneficiaries

In this question, the consortium members were asked to estimate the stakeholders who would benefit the most out of the solutions tested and to rank them from 1 to 7. Public authorities and road operators were estimated to be benefited the most. On the contrary, road users, rail users, rail infrastructure managers and rail operators were estimated to be benefited the least.

In Figure 6*: **Weighed results of main beneficiaries***, the main beneficiaries from the SAFER-LC solutions have been presented in a weighed way. We followed a weighing of the responses from 1 to 7 in order to sort the main beneficiaries.

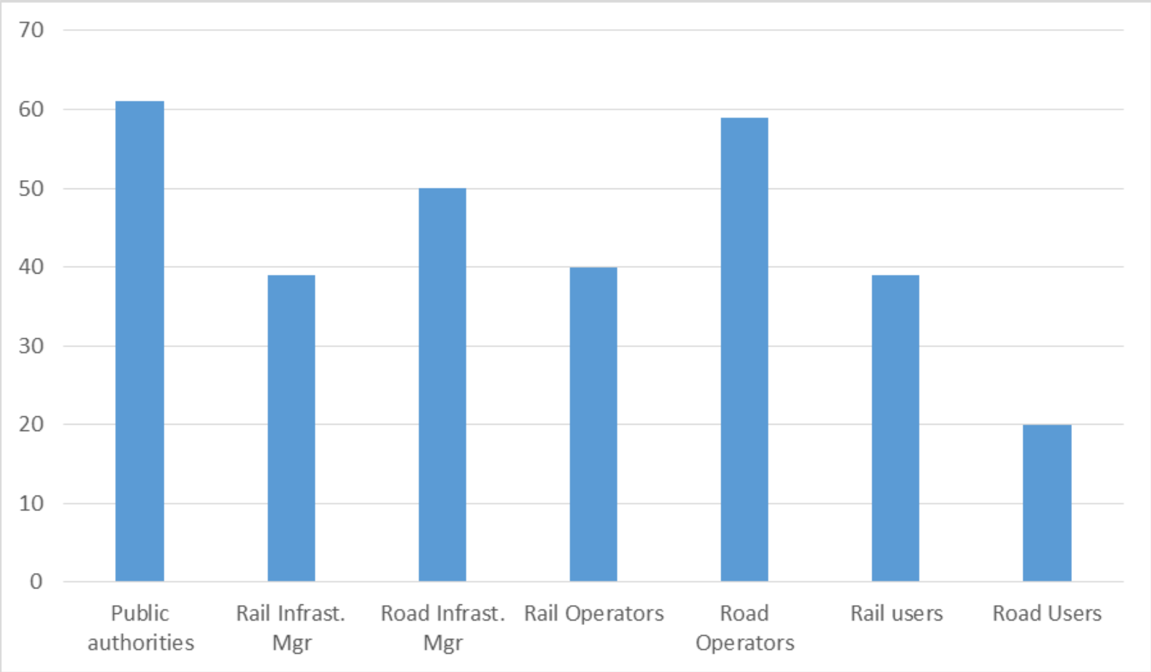

Figure 6: *Weighed results of main beneficiaries.*

Question 19: Main stakeholders to implement the solutions

Question 19 asks the respondents – consortium members to rank from 1 to 7 the likeliness that the main stakeholders can implement the solution tested. The responses from public authorities to infrastructure managers vary significantly. The specific questions are in regard to all the pilot-sites and the goal is to capture the general stakeholder view on implementation potential.

Figure 7 presents the main stakeholder categories in a weighed way. We followed a weighing of the responses from 1 to 7 in order to sort the stakeholders that benefited the most.

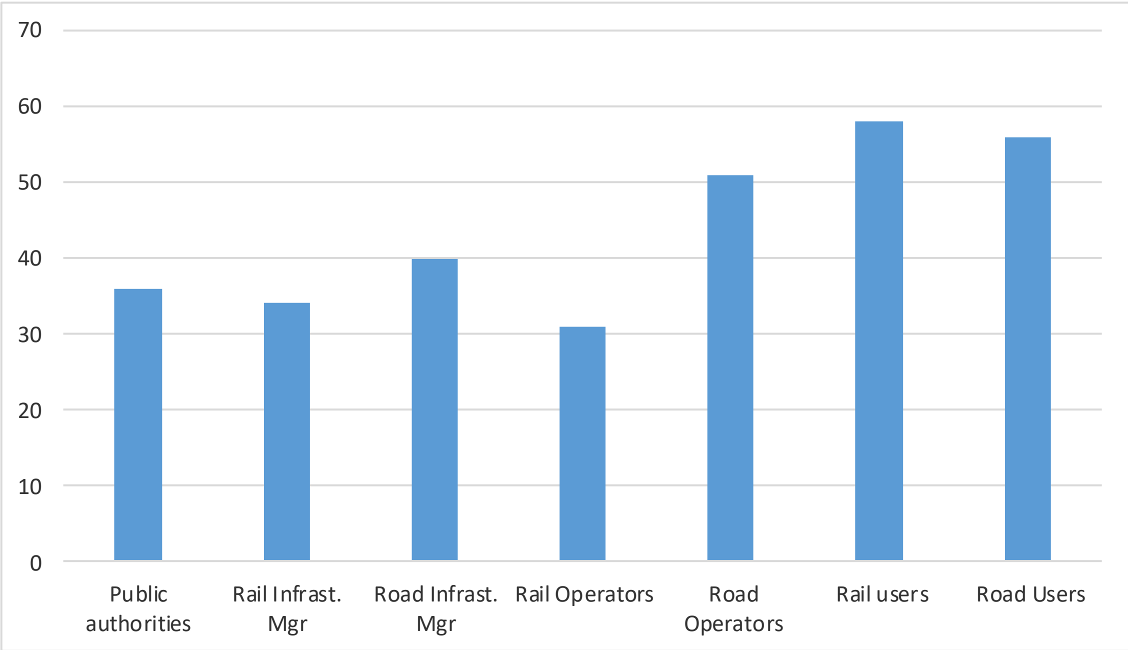

Figure 7: *Weighed results on main stakeholders for implementation.*

Question 20: Type of relationship with customers

"*What kind of relationship you would expect to have with the customers of the solution tested? (E.g. purely transactional, long-term, personal assistance, co-creation, switching costs…) If possible, please explain briefly:*" A long-term customer relationship is clearly indicated by the project partners.
• Long-term • Personal assistance • Transactional, support service • Long-term assistance • Long-term personal assistance • grantor of a license of the patent --> long term transactional partnership • A research Partner, accompanying the market introduction and helping to prove the effectiveness with appropriate research methods. • It is expected to form a close, long time relationship with customers. The app would benefit from customer feedback and users are expected to use it forever, as long as they drive. In addition, it would be better to have it as part of a suite of services together with other cooperative ITS services and not as a stand-alone service. The feedback provided would be used to further expand and update the app. • Any • Transactional. Product is bought and installed. • Close relationship through assistance and maintenance contracts

Question 21: Loyalty of potential customers

The respondents were asked in regard to their beliefs on the loyalty / captivity of the potential customers of the solution tested. Almost half of the respondents (n=5) replied 'I do not know', while the same percentage responded 'Yes' or 'Maybe' (Figure 8).

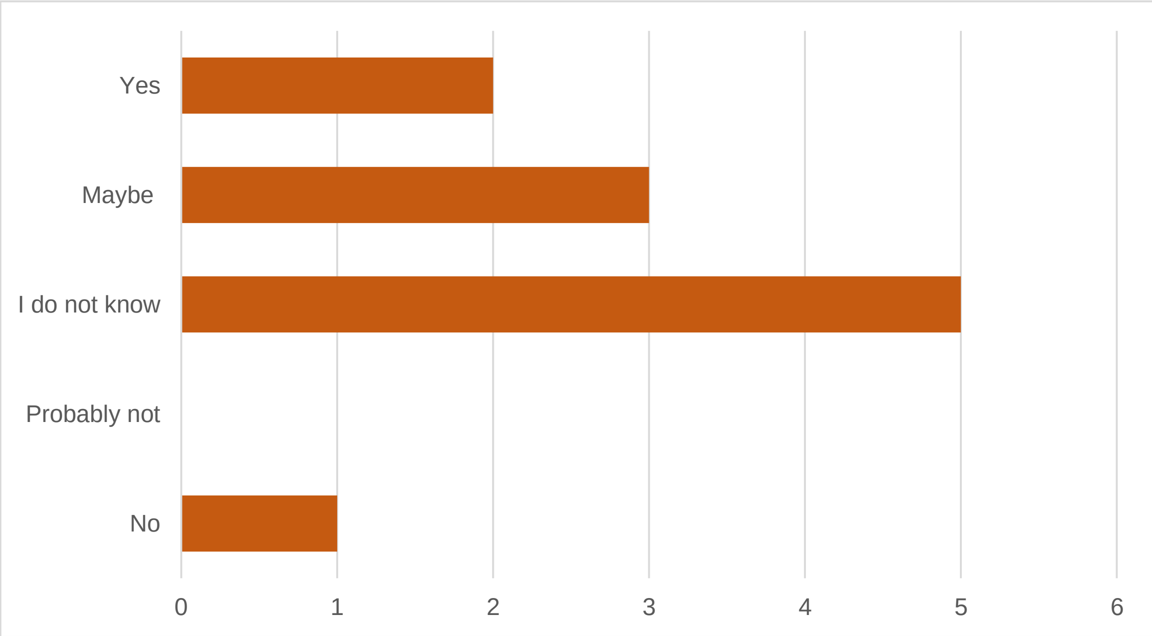

Figure 8: *Loyalty of the potential customers.*

Question 22: Categorisation of solutions

In Figure 9, the majority of the respondents categorised the SAFER-LC as B2B solutions.

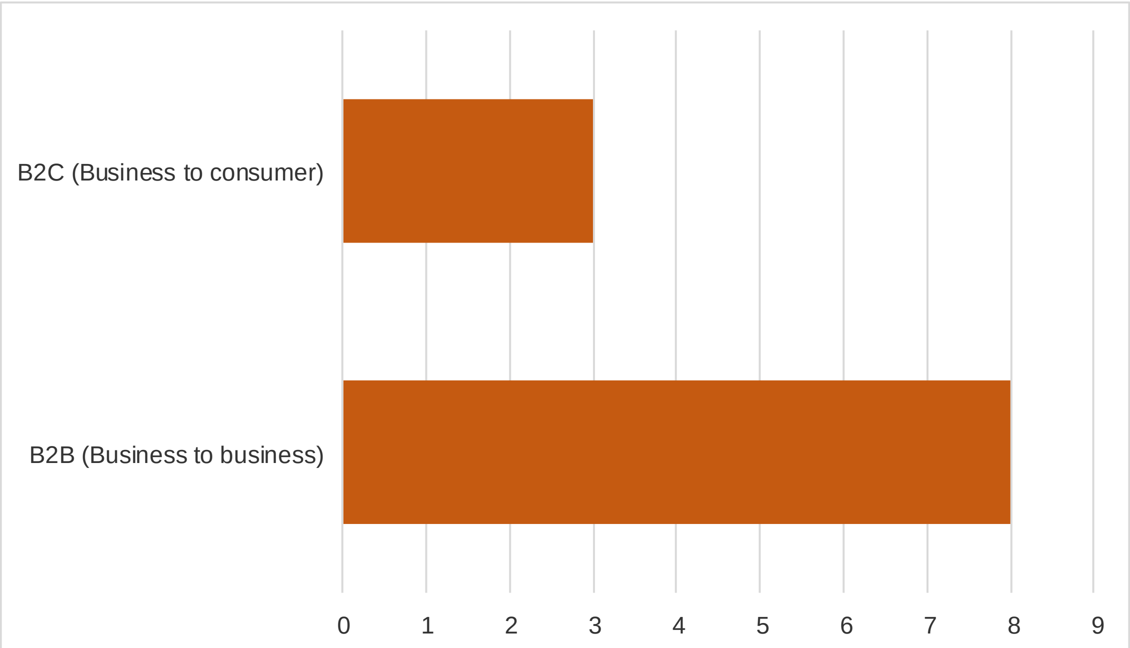

Figure 9*: How would you categorise the solution tested?*

Question 23: Distribution channels

According to the replies that there is a relative lack of knowledge regarding the distribution channels utilised for selling the SAFER-LC solutions. Specifically, six out of eleven respondents were not aware of them. It is of great importance to define the channels that will be targeted in case the SAFER-LC solutions are going to be commercially exploited.

Question 24: Strategy for market introduction

Only two partners indicated that they have already defined the 'go to market' strategy for the piloted solutions. Other (n=9) replied 'No' to this question. The project is focused on research and not on commercialisation, however at the final stage of the project the partners start discussing the commercialisation potential of the project findings.

Question 25: Party to pay for the benefits

"*According to you, who would have to pay to benefit from the solution tested?*"
• Government (either partially or fully) • Authorities • Railway manager or public authority • Infrastructure managers • Rail operator • Railway operators, road users • Railway and transport operators, infrastructure managers • The parties responsible for LC protection in the respective country (e.g. in Germany, this would be both rail and community / federal authorities, depending on the LC) • Rail traffic operators and / or public authorities • Since it is a safety service the information/data should be made available for free at NAPs, but the service as such could be commercialized as part of the suite of c-ITS services bundled in the safety applications • Road and/or rail manager public authority

Question 26: Willingness to pay

As end-users, the majority of the respondents would be willing to pay indirectly (Figure 10).

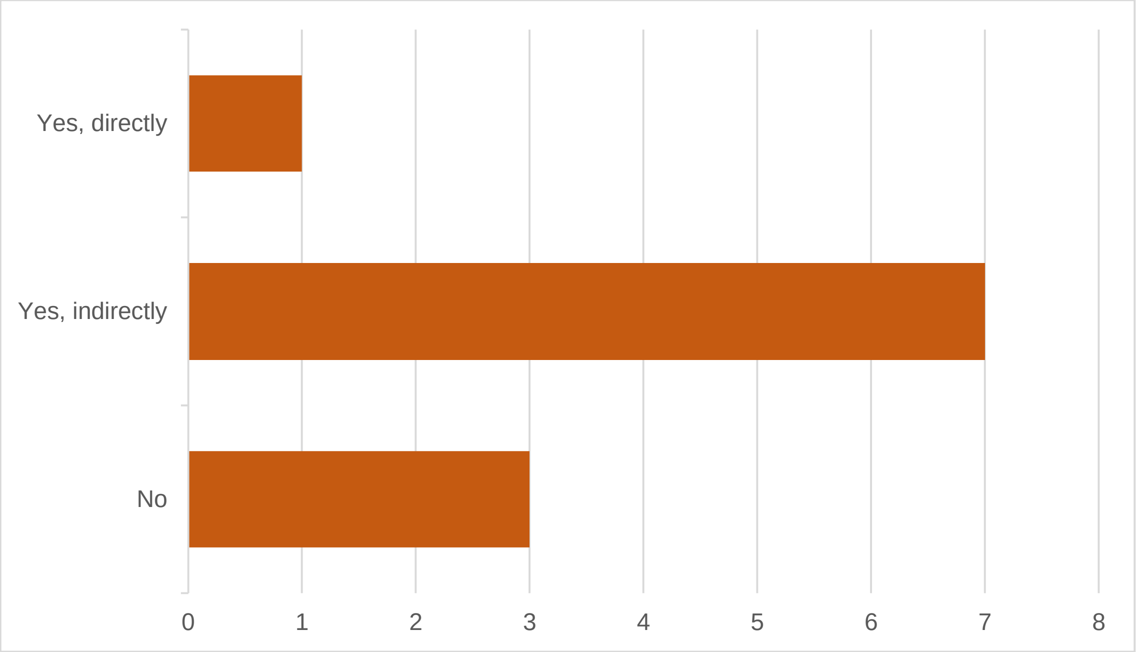

Figure 10: *Willingness to pay for the solutions tested.*

Question 27: Possibilities to provide sustainable revenues

The partners tend to believe that the solutions can return sustainable revenues (Figure 11).

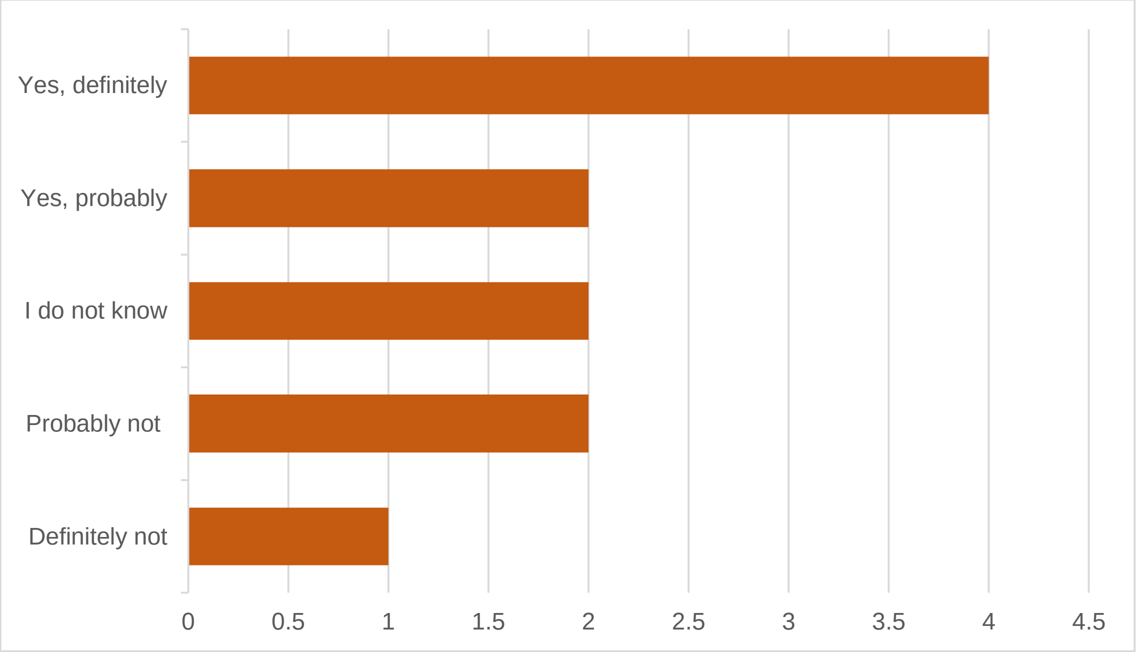

Figure 11: *Economic sustainability of the solution.*

Question 28: Provision of the solution for free

The solutions tested should be distributed for free to some stakeholders as indicated in Figure 12.

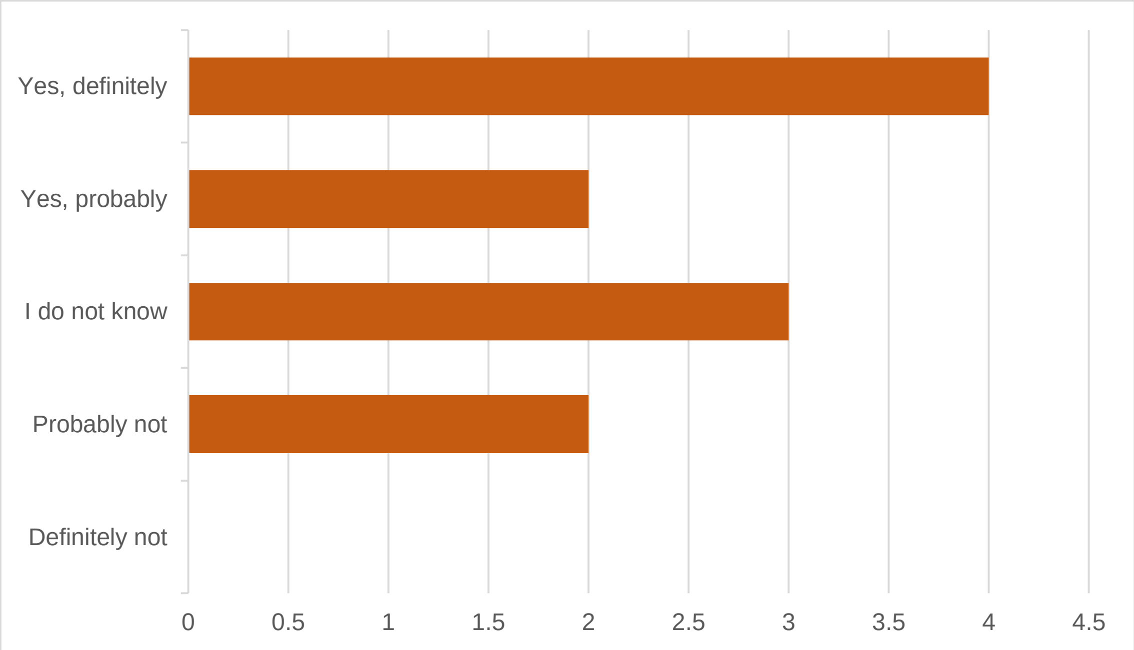

Figure 12: *Should the solution tested be offered for free to some stakeholders?*

Question 29: Break-even point

The average response for the marketing of the tested solution to reach a break-even point was 4.2 years. The majority of the respondents replied that 5 years would be required for that.

Question 30: Cost structure

"*Please describe the cost structure of the solution tested. Try to estimate what would be the main costs to consider to introduce the solution into the market (cost per type of equipment used, standardisation and certification costs, cost of installation, operation costs, maintenance and replacement costs, other relevant costs [planning, back office…] etc.)*"
• Maintenance and replacement • Standardisation and certification cost • A set of GPS devices and a server room • Difficult to give figures: video sensors, processing units, RSU, communication system, implementation cost, maintenance. It is a global solution of a number of level crossings (depending of the number of level crossings) • High Power LED units are the most expensive part of the technical system --> Installation and calibration costs might be rather cheap --> electric power supply will be a continuous cost, however, LED do not consume a high amount of electricity --> maintenance costs might play a role with regard to vandalism. Technical maintenance costs are relatively

low, since LED units are long living. No back office costs because system works autarchic.

- Standardisation and certification costs might or might not be high. If it is no safety critical System it should be rather cheap. Technically, the high-power LED would probably be the most expensive subpart of the system. Maintenance costs could be relevant as well, however, LED are very long living. Therefore, maintenance efforts should not be too high.
- The main costs of the solution would be the system's electronic components (online servers) and the back office who maintains or even expands the solution. It may be needed to standardize it following the ETSI and CEN standards for ITS and C-ITS.
- Design and testing costs, certification costs
- Non-standard solution elements need to be standardized by SDOs following the existing C-ITS technology standards.
- Installation, maintenance and operation

Question 31: Existing competition

The majority of the consortium members responded negatively on whether the SAFER-LC solutions would compete to solutions that already exist in the market. More specifically, 9 out of 11 believe that there is no direct or partial competition with existing solutions.

Question 32: Entrance to the market for new actors

New actors can potentially take part in the market on the short term according to the responses shown in Figure 13.

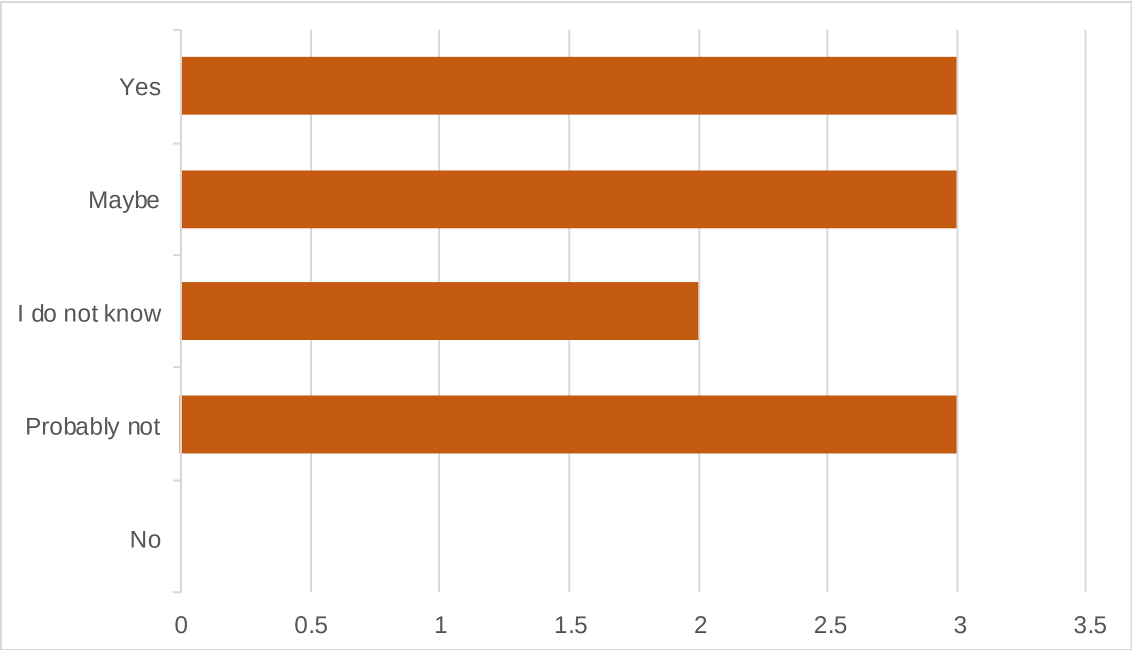

Figure 13: *Could new actors take part in the market on the short term?*

Question 33: Property rights

There is uncertainty regarding the property rights out of the technological know-how of the solutions tested as indicated in Figure 14.

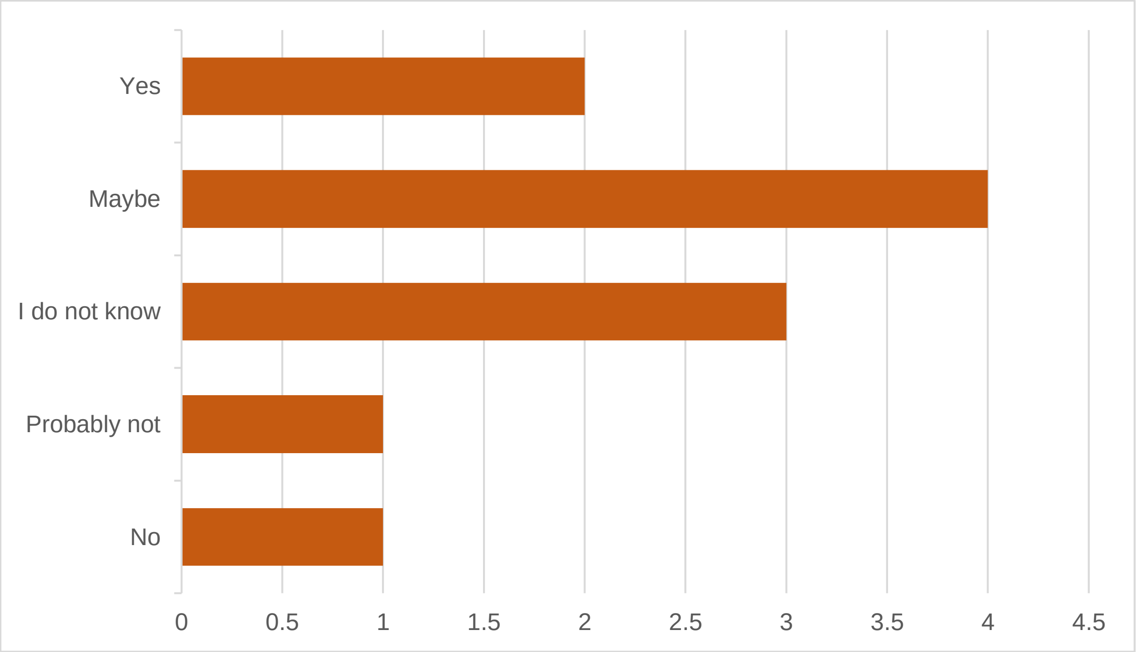

Figure 14: *Could the technological know-how of the solution tested be subject to property rights?*

Question 34: Regulation

None of the respondents expressed negative or positive opinion on the need for change in the regulation after the implementation of the solutions tested (Figure 15).

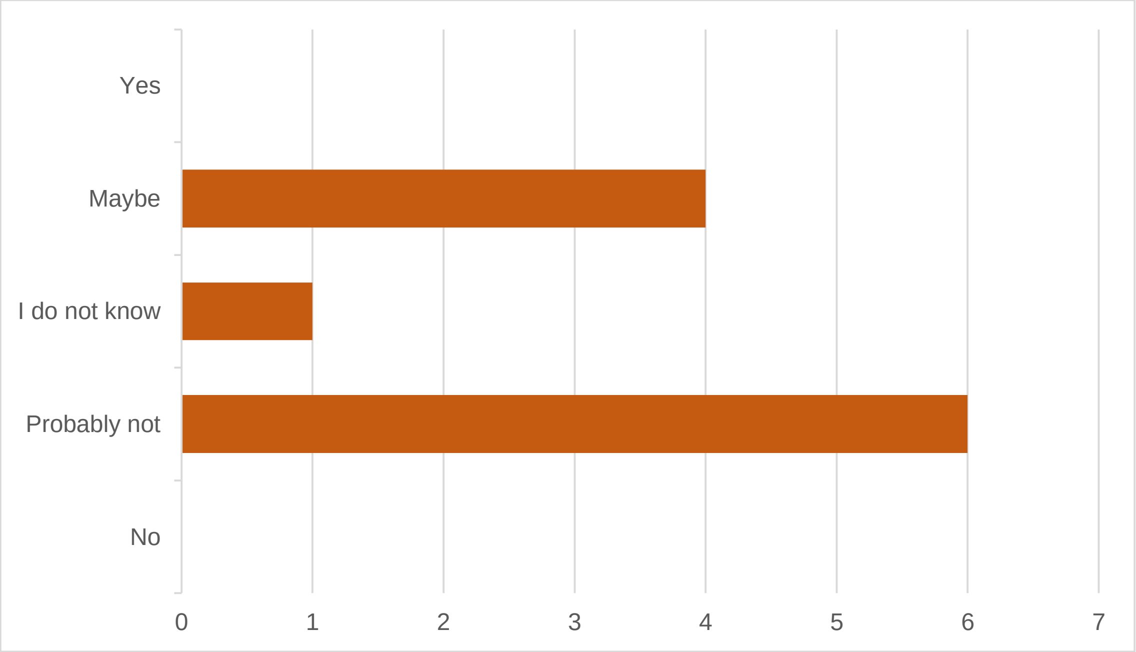

Figure 15: *Need for legislative change.*

Question 35: Integration with current LC infrastructure

The SAFER-LC solutions can be integrated with the current/existing LC infrastructure. Out of eleven replies, eight respondents replied ‘Yes’ to this question and three ‘Maybe’.

2.3. Conclusions from the online survey

The online survey was designed to capture the consortium’s views and intentions for the business aspects and potential exploitation of the proposed SAFER-LC solutions. The responses given by the consortium members played an important role in the development of the SAFER-LC Business Models and more specifically in the identification of the stakeholders, the revenue streams and the cost structures, the distribution channels etc. We can conclude that in some questions the consortium has a good and common understanding on how to proceed with the development of the solutions while there is a confusion in a few questions as in Question 29 - “According to you, who would have to pay to benefit from the solution tested?” – where there was no consensus or majority to one direction. This tendency is absolutely justified due to the diversity of the consortium. The project partners also did not show a common understanding of main beneficiaries, pricing aspects and channels of distribution. Of course, the SAFER-LC project is considered as a research project and at this point there is no clear mandate from the partners on the next steps. We should consider that the distribution of this survey started at month 24 of the project. The consortium members showed a different point of view, for example, rail companies focused on their activities and consider their industry as the main customer. The same pattern was followed by the rest of the partners.

The majority of the partners intend to continue the collaboration with the other partners in order to develop the solutions or/and exploit them after the end of the project, since they find the solutions useful and it seems possible to position the solution(s) as standards. The nature of the sales is clearly B2B, and as end-users, the majority of the respondents would be willing to pay indirectly. The partners believe that the solutions can return sustainable revenues after exploitation and the break-even point was estimated on average after 4.2 years (break-even point is the point that a company covers all its costs and after this point is considered sustainable or even profitable). Nine out of 11 respondents believe that there is no direct or partial competition with existing solutions in the market and the SAFER-LC solutions can be integrated with the current/existing LC infrastructure.

However, a lack of knowledge on the regulation aspects and whether changes might be needed after the implementation of the solutions tested together with a relative lack of knowledge regarding the distribution channels utilised for selling was expressed. In addition, there is uncertainty regarding the property rights out of the technological know-how of the solutions tested.

3. COST-BENEFIT ANALYSIS - TOWARDS THE SAFER-LC BUSINESS MODELS

3.1. Building the SAFER-LC solutions as a good or product

3.1.1. Technology Readiness Level categorisation (TRL)

SAFER-LC solutions were developed with the target of validating and demonstrating the results from previous research. At this stage, the solutions' (or non-mature products') success and viability in terms of market exploitation are not guaranteed. The Technology Readiness Level (TRL) for most solutions in the beginning of the project was regarded as "experimental proof of concept" (TRL 3), however, after the pilot test period, some solutions have reached the TRL 7, having "system prototypes demonstrated in operational environment" with real user groups such as railway companies, pedestrians and private vehicle drivers. The ambition of SAFER-LC is, in some cases, after testing within the project, that some of the solutions will reach higher TRL and will be commercially deployed. The various "Technology Readiness Levels", as defined by the EC (Table 3), provide a consistent recognition of the technical maturity of a technological solution or innovation.

Table 3. *Technology readiness levels in the SAFER-LC project*

TRL level	Description
TRL 1	Basic principles observed
TRL 2	Technology concept formulated
TRL 3	Experimental proof of concept (*beginning of the SAFER-LC project*)
TRL 4	Technology validated in lab
TRL 5	Technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
TRL 6	Technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)
TRL 7	System prototype demonstration in operational environment (*end of the SAFER-LC project*)
TRL 8	System complete and qualified
TRL 9	Actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

Table 4 gives a summary of how the TRL of the piloted LC safety solutions were advanced in the course of the SAFER-LC project.

The ***In-vehicle train and LC proximity alert*** solution, tested in Thessaloniki, is a mobile application aiming to enhance road user safety around level crossings by issuing audio and visual warnings when the user is heading towards a LC of any type. The solution was tested for several months in real life conditions by more than 600 taxis floating in the streets of the city, with promising results. The system was at TRL 2 before the project, as the solution was not developed, but its technological concept was formulated at a theoretical level by CERTH-HIT. In later stages, several existing ICT technologies and concepts were leveraged in order to research and develop the system. Numerous tests were implemented during the development phase, in simulated environments with artificially generated data for moving trains and vehicles, to tests for technological validation in real LC environment. At the phase of pilot testing, the system's operation was demonstrated in operational environment, achieving a TRL 7.

The ***Blinking lights for the locomotive front*** are a system to enhance the detection of a train by road users especially at passive LCs, but also all other types. Additional blinking lights were installed to the train according to the prevailing regulations, e.g. below the three head lights. The blinking is triggered automatically at a set distance from the LC and stops when the train has passed the LC. A technical prototype consisting of three high-intensity LED lights was developed and tested in a real rail environment. Moreover, the system's positive effects on road user attention and behaviour at LCs were demonstrated in a driving simulation study (Silla et al., 2019). In previous efforts, prototypes of similar systems have been technically developed and tested in operational environments (Cairney, 2003; Carroll, Multer & Markos, 1995). During the SAFER-LC project the TRL of this solution increased from 3 to 6.

The ***Peripheral blinking lights near the tracks*** are a system to enhance the detection of a train by road users at passive LCs. Two lights located near the tracks to the left and right of the road start blinking when a car passes an in-road sensor on approach to the LC. The blinking lights appear in the periphery of the driver's visual field. This triggers an automatic and effortless visual orientation reaction in the road user towards the peripheral regions of the level crossing that require visual scanning in order to detect a train (exogenous attraction of attention; Yantis, 2000). A prototype of the system has been developed before and successfully tested in a real-traffic environment (Grippenkoven, Thomas, & Lemmer, 2016). At this stage, the system already reached TRL 6. However, in SAFER-LC, the empirical basis for its positive effects on road user attention and behaviour at LCs was significantly broadened by testing it in comparison to other solutions in a driving simulation study (Silla et al., 2019).

The **Road sign *← Is a train coming? →*** is a solution conceived for passive LCs to enhance the probability that road users detect oncoming trains, by providing a reminder of the necessity to scan the tracks for a train. Below the question text *Is a train coming?* the sign contains two arrows pointing to the left and right and two train pictograms where the arrows are pointing (cf. Silla et al., 2019). These are included to illustrate the message and facilitate the allocation of attention to the periphery. The pictograms contribute to making the sign comprehensible also to road users who cannot read or do not understand the given language. In the driving simulation used to pilot the solution, the sign was positioned at 100 m ahead of the LC. In some countries, supplemental LC signs requesting road users to look for a train are already in use. However, the design tested here (including arrows, train symbols, and a question instead of an instruction) was new. Thus, the TRL of this solution increased from 2 to 5 during the SAFER-LC project.

The ***Rumble strips ahead of the LC*** are a solution conceived to enhance general attention and induce speed reduction in drivers at passive LCs. In previous efforts, rumble strips have already been tested in real LC environments (Hore-Lacy, 2008; Radalj & Kidd, 2005; Skládaný et al., 2016), thus the measure reaches TRL6. While the technological development of the measure was not the focus, in SAFER-LC, the empirical basis for assessing its ultimate effects on driver behaviour was significantly enhanced by testing the solution in a driving simulator study in comparison to other measures (Silla et al., 2019).

The ***V2X messaging system between automated vehicles and passive level crossings*** was developed with the aim of enabling automated vehicles (AV) to cross passive LCs safely. The measure was implemented in two simulation environments: 1) In Junavaro data simulator which contains train and level crossing data from Finnish rail section 142 between Hanko and Karjaa and uses train traffic data recorded during May 2010, and 2) in road traffic simulator which utilises GIS information from OpenStreet Map. Additional tests were performed in May 2019 due to the challenges that occurred in the simulator exercises. The test scenario involved a vehicle approaching a junction controlled by a traffic light in a test track. According to the tests, the average distance from the car front to the virtual stop line was 0.42 meters. In one case, the virtual stop line was overshoot by 0.86 meters. However, this overshooting was not severe. During the SAFER-LC piloting the TRL of this solution was estimated to increase from 5 to 6.

The **Message ← Is a train coming? →** written on the road is a measure conceived for passive LCs that is supposed to work by the same principle as the sign described above. However, in the SAFER-LC pilot implementation, no train pictograms were included in the road pavement message. The measure was piloted at a real-world LC used by vulnerable road users, where it was applied to the road surface at around 35 m ahead of the LC. While there is no need to further develop the basic technology needed to implement the measure (road markings), there is a need for research and development concerning a behaviourally effective design of such road markings (cf. Silla et al. 2019). As the measure had not been tested before, its TRL evolved from 2 to 6 through the SAFER-LC project.

The **Blinking Amber Light** is a solution conceived for passive LCs to enhance the probability that road users detect oncoming trains by increasing road users' awareness that a train might be approaching and thus the motivation to scan the tracks to the left and right. The system consists of a traffic light with a train symbol that is positioned at the side of the road directly ahead of the LC and a mechanism to actuate the flashing of the light whenever a road user approaches the LC. In SAFER-LC, the system was piloted at a real-world LC used by vulnerable road users (Silla et al., 2019) and was found to positively influence road users' active search for a train. In the pilot study, the actuation of the flashing of the amber light was controlled via a mobile traffic data acquisition system (that was simultaneously used to record road user's behavioural responses), using wireless communication. The actuation could also be achieved with easier technical solutions, e.g. by using a sensor in or near the road (Grippenkoven et al., 2016; Noyce & Fambro, 1998). Ultimately, a blinking light with a train symbol could also work steadily, independent of road users approaching. The system as it was implemented in SAFER-LC had not been tested before. Thus, its TRL was advanced from 2 to 6 within the project.

The summary of the development of technology readiness level by each piloted safety solution is presented in Table 4. Most of the piloted solutions obtained TRL 6–7 during the SAFER-LC project while for example the "In-vehicle and LC proximity alert" was TRL2 and reached TRL7.

Table 4. *The development of TRL by solution during the SAFER-LC project.*

Solution	Technology readiness level	
	Before	After
In-vehicle train and LC proximity alert	TRL 2	TRL 7
Blinking lights for the locomotive front	TRL 3	TRL 6
Peripheral blinking lights near the tracks	TRL 6	TRL 6
Sign '← Is a train coming? →'	TRL 2	TRL 5
Rumble strips ahead of the LC	TRL 6	TRL 6
V2X messaging system between automated vehicles and passive level crossings	TRL 5	TRL 6
Message '← Is a train coming? →' written on road	TRL 2	TRL 6
Blinking Amber Light	TRL 2	TRL 6

3.1.2. SAFER-LC solutions as public goods

In our effort to categorise the SAFER-LC solutions' commercialisation future, the definition of the potential products and the way they can be introduced in the market is of great importance. SAFER-LC solutions cannot be put in place as usual commercial products and they cannot follow the usual business models, otherwise, an equilibrium could be found by the market, meaning that customers would be willing to pay the market price and companies to offer their products in such prices.

The definition of the Cambridge Dictionary for a commercial product concerns *a product that can make money (dictionary.cambridge.org).* In the case of the SAFER-LC solutions, the commercialisation would be one of the biggest challenges as there is no clear customer and producer identified as in the cases of commercial products. On the contrary, the SAFER-LC solutions have all those characteristics of a public good. A public good cannot easily be priced because of the free riders' problem. The free riding is explained by the Economist (Retrieved December 1, 2019, from https://www.economist.com/economics-a-to-z) as:
"Getting the benefit of a good or service without paying for it, not necessarily illegally. This may be possible because certain types of goods and services are actually hard to charge for--a firework display, for instance. Another way to look at this may be that the good or service has a positive externality. However, there can sometimes be a free-rider problem, if the number of people willing to pay for the good or service is not enough to cover the cost of providing it. In this case, the good or service might not be produced, even though it would be beneficial for the economy as a whole to

have it. Public goods are often at risk of free riding; in their case, the problem can be overcome by financing the good by imposing a tax on the entire population."

The majority of the SAFER-LC solutions follow the above-mentioned characteristics: whether it is signalling, infrastructure on the road or light warning while the train approaches, the user is hard to be charged. However, the solutions have positive externalities for the society, and the combination of non-rivalry and non-excludability leads to the conclusion that the solutions could be regarded as examples of public goods. The market failure in these cases drives the government to provide such services that can be paid through compulsory taxation. Additional ways of charging the users, for instance a direct charge with tolls, sound unrealistic in the context of a SAFER-LC solution.

The above-mentioned approach follows the assumption that the customer is mainly the road user (commercial vehicle users etc.). This could be changed if we consider as customers the rail infrastructure companies, and the application or software providers that offer route planning services or other road related information. The business models in this case can totally change and the value proposition can differ. Thus, the customer could be a rail infrastructure company, or a rail operator who in order to gain benefits from the solutions would be interested to purchase them. Unfortunately, this has already been the case for the busiest level crossings but not for the ones where the marginal utility or the increased benefit per unit resulting from each additional solution is small.

However, the benefits – externalities – for the society in total can be higher than the individual (companies, operators, users etc.) benefits and thus, it might be worthy for the government to invest. The same example applies for public education or public health – the society will be benefited by more well educated and healthy citizens and decides to pay the price.

3.1.3. SAFER-LC solutions customer segmentation

In the case of a rail infrastructure management company or rail operator company, the customer segmentation differs from the other potential customers as the government and the business model that can be developed will test alternative customers' relations, customers' segments and channels which can be applied in a market exploitation endeavour.

Potential customers of the SAFER-LC solutions
1. Government, regional governments, cities or similar (in this scenario, the SAFER-LC scenarios will have all those characteristics of a public good and they will be financed by taxation)
2. Rail operators or rail infrastructure managers (in this case, the SAFER-LC scenarios will be financed by those companies. The benefits for the companies – fatalities avoided, injuries avoided, environmental damage, infrastructure damages, traffic delays (primary and secondary), rescue services costs avoided and others – have to be higher than the costs - development, installation, operational, maintenance and other – in order for the solutions to be economically viable for them to put in place, maintain and update)

3. **Road infrastructure managers: The possibility that the road infrastructure manager is the customer is smaller than the above mentioned. The road infrastructure managers have revenues either directly from the government or the local governments (regions, cities etc.). However, where tolls are applied or other kinds of revenues arise, the road infrastructure companies can use the solutions and benefit from better road conditions, safer conditions for the drivers etc.**
4. **Application and service providers may be willing to pay for data in order to enrich their services like route planning or mapping. Companies like Google with Google maps or similar providers of GNSS-based applications and services can integrate notification systems such as the SAFER-LC solution developed in Thessaloniki in order to provide up-to-date information to drivers, cyclists or even pedestrians**

3.2. Expected results of the CBA

Our scope in regard to the SAFER-LC CBA is to create the framework and the approach not only for the existing SAFER-LC pilot-tested solutions but also a method for future developments of the safety measures for LCs. The CBA method is quite clear and similar in most cases which in turn gives all the necessary tools to calculate the economic results for a selected invention, policy or innovative solution or product. However, it is quite challenging to reach the point of estimating the exact benefits and costs. The selected cost and benefit categories should be defined in the best way and the valuation of them should be executed as close to the reality as possible. In order to do so, the weights of the estimations for these two categories (costs and benefits) and the data that must be included in the analysis are of great importance.

A wide variety of cost and benefit categories and estimates on their valuation were acquired through a questionnaire which aimed at including as many relevant aspects as possible. It is important to consider that most of the personnel employed for the SAFER-LC project who provided the information in the questionnaire consisted of researchers with limited knowledge of the pricing aspects. The circulated questionnaire can be found in Annex B of this deliverable.

The questionnaire was designed with a twofold objective; firstly, in order to identify the cost or benefit categories related to each solution and secondly to define the monetary values for the costs and benefits. This way, whenever a valuation was missing (not possible to be calculated by a respondent) it was possible for us to define a value sourced in the literature. Moreover, phone interviews took place whenever necessary to further explain the questions and acquire data that were not provided by the respondents.

3.3. The adopted CBA approach

The CBA approach for the SAFER-LC solutions was introduced in deliverable D5.1 (El-Koursi & Ghazel, 2018). The established approach has defined the various cost and benefit types in a comprehensive way. It also established the main indicators to be calculated for the cost-benefit assessment. The timing of the current deliverable allows us to include data from a more mature stage of the SAFER-LC project after the pilot-site trials were implemented. In the following, we will recall the main elements and features of the adopted CBA approach.

1. Cost-benefit analysis is often required before starting a new project, making a new investment or taking important decisions. In fact, all the potential costs and revenues that a company might generate from the project should be evaluated. The outcome of the analysis will determine whether the project is worthy or if the company should pursue another project.
2. In many models, a cost-benefit analysis will also factor the opportunity cost into the decision-making process. By considering all options and the potential missed opportunities, the cost-benefit analysis is more thorough and allows for better decision-making. It takes into account both quantitative and qualitative factors for analysis of the value for money for a particular project or investment opportunity.

The objective is to ascertain the soundness of any investment opportunity and provide a basis for making comparisons with other such proposals. All positives and negatives of the project are first quantified in monetary terms and then adjusted for their time-value to obtain correct estimates for conducting cost-benefit analysis. Most economists also account for opportunity costs of the investment in the project to get the costs involved. Generally speaking, 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 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 a sensibility analysis which aims at checking in which way the profitability of the project is affected by possible variations of the considered variables. Depending on the context, such a sensibility analysis may lead to reconsider the output of the CBA.

The results of CBA can be synthesized by means of indicators. Such indicators give a direct idea on the profitability/worthiness of the investigated investment, project or decision. Three main indicators are often used in this respect; namely, the Net Present Value (NPV), the Internal Rate of Return (IRR) and, most importantly, the Cost Benefit Ratio (CBR), as defined below. It is worth noticing that a combination of them can also be used depending on the context (Ben Aoun et al., 2008) (Ben Aoun et al., 2009).

1. 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 (Ben Aoun et al., 2008) (Ben Aoun et al., 2009):

   $$\mathbf{NPV = (A0 - C0) + (A1 - C1) / (1 + r) + (A2 - C2) / (1 + r)^2 + \ldots(An - Cn) / (1 + r)^n}$$

   where:

   Ai: all the awaited advantages for the “i”th period,

   Ci: 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 (in years) of the project operation/use

2. 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:

$$(A0 - C0) + (A1 - C1) / (1 + r) + (A2 - C2) / (1 + r)^2 + \ldots (An - Cn) / (1 + r)^n = 0$$

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.

3. A last measure that is often 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 = Σ Ct / Σ Bt

Where **Bt** is the present value of the cash inflows

Ct 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.

BCR is the inverse indicator of CBR and can be defined as: **BCR = Σ Bt / Σ Ct**

The BCR value will be used in the analyses in this deliverable. BCR > 1 means that the discounted benefits are higher than the discounted costs. 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 highest BCR 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. It is worth noticing here that some thresholds regarding the profitability/worthiness level/degree of the project can be defined (see Annex C - Interpretation of BCR values).

One essential issue that one may have to deal with in CBA analysis is pertaining to the monetary quantification of some costs or benefits. In the context of SAFER-LC, several costs and benefits are related to safety aspects and determining their corresponding monetary values may be quite challenging, especially due to lack of data and the lack of standard ways to monetarize safety related aspects (lives saving, injuries avoidance, etc.). In addition, the quantification of costs and benefits related to the societal impacts of some measures such as, for instance, the impact of some decisions on the railway reputation is even more challenging. The reader can refer to SAFER-LC deliverable D5.1 (El-Koursi & Ghazel, 2018) for more details on theses aspects.

3.4. **Data collection for the CBA**

To collect the estimations of costs and benefits of each measure that was used as input to the CBA, a questionnaire was sent to the SAFER-LC pilot site leaders who piloted the respective measures. The questionnaire was targeted to solutions which were implemented mostly in real-world pilot conditions but also to solutions tested in simulation environments. The first question on identifying the solutions was separated in three categories (detection, communication and measure). The next four questions were focused on the identification of costs and benefits and valuation. The questionnaire has been included as Annex A of this deliverable. In some cases, additional interviews were conducted to discuss the inputs from the questionnaire and the results were adapted to more realistic numbers by taking into consideration the scenario examined (e.g. application of the solution for 100 LCs).

The pilot-site leaders estimated the applicable cost categories and the respective cost and benefit values for the commercial deployment for each solution. We have to mention here that the costs do not represent real values or prices of the solutions but only estimations – differences may result in a realistic attempt of commercial deployment. The questionnaire was filled-in by mainly researchers, and in many cases, they did not have access to or experience of the commercial prices, investments etc. Moreover, different prices, wages etc. may be found in different quantities and in different countries, which makes it really difficult to assess each and every solution at a pan-European level. In the final results, the benefits that were applied into the CBA were based on a similar calculation method for similar solutions for reasons of consistency. However, it is not possible to estimate one benefit-for-all due to the special circumstances in each and every LC. Different driving behaviours, different cultures in each country and different natural environment on the one side, and different cost of life, environment and time on the other side can have a huge impact on the calculations. The analysis took into consideration the estimated effectiveness for each solution from the deliverable D4.4 (Silla et al., 2019).

The applied CBA for the SAFER-LC solutions produced the results of the CBA using all the necessary input and taking into consideration that it is a “use case or model CBA” and not a de facto result. Therefore, we propose to the policy makers, infrastructure managers etc. to estimate the BCR and the Net Present Value (NPV) taking into consideration the specific external factors applying in each country, region and specific conditions.

3.5. **Assumptions made and parameters used in the CBA**

The parameters that should be examined for the benefits calculation of the SAFER-LC solutions should include:

- the traffic both from rail and road users and the probability of an accident,
- the number and the severity of the accidents that may occur in such type of LCs (historical data or if not existing, conditions similar to cases where historical data exists),

- the environmental damage an accident can create (trucks or trains carrying toxic, inflammable or toxic goods, use of land close to the LC etc.),
- the rescue services costs (helicopters may be needed),
- the traffic of the train and road users and the impact this may have to the users (delays),
- the potential costs on infrastructure if damaged etc.

The above-mentioned parameters are examples and their list is not exhaustive. The amounts can differ from case to case and from country to country. Each LC type and environment has to be analysed as unique. For the needs of this deliverable, the estimations will be generic without taking into consideration special circumstances, as we need to show the trends and not selected case studies. Of course, in case a decision maker plans to analyse LCs which are selected to bring the most benefits, then the parameters will be differently weighed.

We make the simplified assumption that one fatal accident would occur per 100 LCs every ten years in a "baseline" scenario with no additional safety measures applied. The benefit of avoiding one fatality was valuated by an amount of **2,384,033 €** (see below). This benefit is multiplied for each measure by this measure's estimated effectiveness for preventing LC accidents - high and low probabilities – as presented in Table 5 – to calculate the benefits from the fatalities avoided.

Table 5. *Estimated effectiveness by safety measure included in CBA (Silla et al., 2019).*

Measure - Solution	**Effectiveness estimate (%)**	
	Low	**High**
In-vehicle train and LC proximity alert	10.0	15.0
Peripheral blinking lights near the tracks	5.0	20.0
Blinking Amber Light	5.0	10.0
Rumble strips ahead of the LC	2.5	10.0
Sign '← Is a train coming? →'	0.0	5.0
Message '← Is a train coming? →' written on road	0.0	5.0
Blinking lights for the locomotive front	15.0	30.0

Another assumption includes the avoided injuries. In that case we include a fixed benefit of 2 injuries avoided per 100 LCs in 10 years. The valuated benefit will be **10,000€** for each solution for reasons of simplicity. In reality, of course there are differences between the measures in their effectiveness to prevent injuries caused by LC accidents. The reader should keep this in mind and also consult the estimated effectiveness values of the measures in addition to the CBA results (see *Table 5*).

The benefit from the rest of the categories such as *environmental damages avoided, infrastructure damages (rail, road – vehicles included)*, and *rescue services costs avoided* was estimated by the pilot-site leaders on average at 51.500€. We make the assumption of avoiding two non-fatal accidents per 10 years in 100 LCs which sums up to **103,000€.** There was no estimation for traffic delays.

Each solution will be examined in a structured way. The benefits from injuries avoided and the rest of the categories will be used as a flat amount of **113,000€** for every solution. However, the benefits from avoiding fatalities will be calculated individually for each measure as huge differences can be found between the measures in their estimated effectiveness to prevent accidents.

The NPV presented in the figures below is calculated with an interest rate of 2% (opportunity cost). The value of preventing fatality utilised for this CBA was taken from the research and is one of the most recent calculations that can be found in literature:

"*An estimate of the value of preventing a fatality (VPF), which can be used for the valuation of safety benefits and disbenefits in decision taking processes, has been made for June 2019. The most recent Department for Transport (DfT) VPF (published in September 2019) is £1,958,303, which is in 2018 prices. For RSSB members who wish to use a more up to date forecast this figure has been up-rated to June 2019 prices using the latest available data from the Office for National Statistics and following the DfT up-rating method. As such, the VPF figure for 2019 has been estimated by RSSB to be:*

VPF2019 = £2,017,000" RSSB, 2019.

(which is 2,384,032.66€ in values of 12.12.2019)"

Provisional estimates of economic performance for the value of the VPF is subject to some level of uncertainty that should be taken into consideration while evaluating any options and taking decisions.

3.6. **Results**

The CBA results are presented in this chapter together with the responses of the pilot-site leaders and the Benefit-Cost Ratios (BCR). For the computation of the CBA, an interest rate of 2% was taken into account. The initial investment represents the installation costs and the annual net cash flows represent the benefits from the solution [(safety effect * value of prevented fatality) + benefits from injuries + environmental damages avoided + infrastructure damages avoided + rescue services avoided] – annual operational and maintenance costs. Most of the BCRs were calculated as greater than 1, however, in some cases costs were greater than benefits. Those solutions might be positive if the CBA is applied for a longer period of time (initial investment costs are high).

3.6.1. In vehicle train and LC proximity alert

The cost categories and valuation for 'In-vehicle train and LC proximity warning' are presented in Table 6.

Table 6. *In vehicle train and proximity alert – Cost categories and valuation.*

Costs	Description of costs	Monetary valuation
Development	The first step is to develop the installation for the type of rolling stock and the second step to setup the device per train. Study for the new type of rolling stock is almost one man-month. The core of the software exists, however, in order for the solution to be applicable to more LCs and monitor more trains, the train monitoring and predictive algorithms should be revised and adapted to the changes. It is foreseen that approximately half a man month is needed for each new LC incorporated to the system	One man-month per new type of rolling stock. (2,800€) and half a man month per new LC added to the system (~1,400€) Total: 4,200€
Installation	Almost quarter of one man-month. This depends from the type of rolling stock, the technology of it etc.	100–150€ per device and 500 € personnel costs – installation on trains.
Operation	A monthly cost of the platform and a 3G/4G subscription. Costs for the backend infrastructure. It is foreseen that the most appropriate technological solution is to adopt cloud-based services, with an adaptive fee according to usage and no extra installation/maintenance fees.	50 euro per month for subscription and 500€ / month starting price for cloud services. Total: 2,800€
Maintenance	Monthly maintenance of the devices and any extraordinary maintenance in case of a problem. Costs for monitoring the system operation.	Half a person month for all of the fleet (1,400€) and half a man month (~1,400€)

The Thessaloniki pilot-site implemented the "in-vehicle train and LC proximity alert" measure which was tested by taxi drivers using the mobile application in real life conditions.

We make the assumption of one fatal accident per 100 LCs in 10 years that would occur without the measure, of which between 10 and 15 percent could be prevented at LCs with the measure applied for vehicles with the system installed and activated by the drivers (application). The system is already developed, installed, maintained and operated in 95 trains in the case of Greece, with the functionality applied at 30 LCs in the wider area of Thessaloniki, Greece and possibility for application at all LCs with minor improvements in the system. In this specific case, we assume that the rail operator has already GPS devices installed on the trains and telecommunication connection monthly subscription for all the devices was included in the operational costs. The application is free of charge for the vehicle drivers during the project-life.

Benefits included on a 10 years assumption: 238,403.27€ and 357,604.90€ as value for preventing fatality (10% and 15% reduction of 1 fatality respectively) and 113,000€ for environmental damages, infrastructure damages (rail, road – vehicles included), and rescue services costs and injuries avoided.

NPV (Low interest alternative - savings account)		**NPV (Low interest alternative - savings account)**	
In-vehicle train and LC proximity warning		In-vehicle train and LC proximity warning	
Reduction 10%		Reduction 15%	
Interest Rate	2.00%	Interest Rate	2.00%
Initial Investement	198,000.00	Initial Investement	198,000.00
Net Cash Flows		**Net Cash Flows**	
Year 1	32,340.33	Year 1	44,260.49
Year 2	32,340.33	Year 2	44,260.49
Year 3	32,340.33	Year 3	44,260.49
Year 4	32,340.33	Year 4	44,260.49
Year 5	32,340.33	Year 5	44,260.49
Output:		Output:	
NPV	**-45,565.16**	**NPV**	**10,620.03**

Figure 16: *In vehicle train and proximity alert – NPV calculation.*

The results range from marginally negative to positive by applying the two assumed reductions in accidents scenarios (10% and 15%). The annual benefits were calculated as: 35.140,33€ and 47.060,49€ for the two scenarios and the costs: initial investment cost of 198.000€ and annual maintenance and operational cost of 2.800€. The results from the calculations are presented in *Figure 16*, same for the rest of the solutions.

BCR (BCR = Σ Bt / Σ Ct):

- Assuming low effect in prevention of fatalities: 0.83
- Assuming high effect in prevention of fatalities: 1.11

3.6.2. Blinking lights on locomotive

The Cost categories and valuation for 'Blinking lights on locomotive' are presented in Table 8.

Table 7. *Blinking lights on locomotive – Cost categories and valuation.*

Costs	**Description of costs**	**Monetary valuation**
Development	Development and design of the system (development of control unit including the definition of optimal functioning of the system and programming of the software). This is mostly personnel costs. Rail standard approval testing to prove that the system fulfils all requirements/standards (planning of tests + actual testing)	Development and design of the system: Personnel costs estimated as 40–60k€. Rail standard approval testing: Personnel costs estimated as few weeks of working time (5–15 k€)
Marketing	Activities (working time + advertisement costs) to market the solution to railway stakeholders	5–15 k€
Installation	High intensity LED lights: Purchase cost (control unit + lights)	Purchase costs: 150–300 € Retrofit installation (few hours): 200–500 € once per train Integration to new rail fleet: No separate installation costs expected.
Operation	None (the lights are triggered automatically based on the position) Update of LC database and operational parameters of the system: Estimated to be a 50% job for one person	Update of LC database and operational parameters of the system: 40–60 k€/year
Maintenance	Exchange of broken lights or GNSS units: This can be partly done during the 'normal' maintenance of trains. We assume that extra maintenance (e.g. change of broken unit) is needed every five years.	0–200 € per year per train
General	Information sessions to personnel (i.e. what is the system about, how it functions, how it can be repaired). Depend on the country and the size of railway company (number of employees). This could be partly done as part of existing training.	5,000–10,000 € The cost of information sessions depend on the country and the size of railway company (number of employees).

In general, we make the assumption that one deadly accident would occur in 100 LCs in 10 years. However, the "blinking lights on locomotive" solution concerns more than one LCs, so it was decided to assume that 20 equipped trains would be the equivalent for 100 LCs (the trains will cover more than 100 LCs while travelling). For the estimation of the costs, we assume that the measure is installed, operated and maintained at for a considered time span of 5 years.

NPV (Low interest alternative - savings account)	
Blinking lights on locomotive	
Reduction 15%	
Interest Rate	2.00%
Initial Investement	40,000.00
Net Cash Flows	
Year 1	38,360.49
Year 2	38,980.65
Year 3	38,980.65
Year 4	38,980.65
Year 5	38,980.65
Output:	
NPV	**143,125.72**

NPV (Low interest alternative - savings account)	
Blinking lights on locomotive	
Reduction 30%	
Interest Rate	2.00%
Initial Investement	40,000.00
Net Cash Flows	
Year 1	74,120.98
Year 2	74,120.98
Year 3	74,120.98
Year 4	74,120.98
Year 5	74,120.98
Output:	
NPV	**309,366.24**

Figure 17: *Blinking lights on locomotive NPV calculation (5 years)*

For a 5-year analysis, both the NPVs are positive (143.125,72€ and 309.366,24€), and the BCR is greater than 1 in the two assumptions.

BCR for a 5-year investment period:

- Assuming low effect in prevention of fatalities (15%): 2.08
- Assuming high effect in prevention of fatalities (30%): 3.36

3.6.3. Peripheral blinking lights near the tracks

The cost categories and valuation for 'Peripheral blinking lights near the tracks are presented in Table 8.

Table 8. *Peripheral blinking lights near tracks – Cost categories and valuation.*

Costs	Description of costs	Monetary valuation
Development	Further development of the system, including development of the functionality to adapt the brightness of the blinking lights to environmental illumination conditions (e.g. day vs. night) Additional tests to ensure robustness	100,000 € once
Installation	Digging holes for a concrete fundament Equipment cost and implementing the system	4,000 € once per LC
Operation	Lights are triggered automatically by roadside sensors	0 €
Maintenance	Cleaning from time to time Broken / vandalized lights or roadside sensors or power supply parts have to be exchanged. Testing from time to time	500 € per LC every 5 years
General	Manpower to advertise the system within railways	10,000 €

We make the assumption that one deadly accident would occur in 100 LCs in 10 years without additional safety measures. For the estimation of the costs, we assume that the measure is installed, operated and maintained at 100 LCs in Germany for a considered time span of 10 years. The NPV and BCR were calculated for the lower bound of the estimated safety effect of 5%, and for the upper bound of 20% reduction in accidents (5% and 20% of the value for preventing a fatality was calculated).

NPV	
Peripheral blinking lights near tracks	
Reduction 5 %	
Interest Rate	2,00%
Initial Investement	400.000,00
Net Cash Flows	
Year 1	13.220,17
Year 2	13.220,17
Year 3	13.220,17
Year 4	13.220,17
Year 5	13.220,17
Year 6	13.220,17
Year 7	13.220,17
Year 8	13.220,17
Year 9	13.220,17
Year 10	13.220,17
Output:	
NPV	**-281.248,74**

NPV	
Peripheral blinking lights near tracks	
Reduction 20 %	
Interest Rate	2,00%
Initial Investement	400.000,00
Net Cash Flows	
Year 1	48.980,66
Year 2	48.980,66
Year 3	48.980,66
Year 4	48.980,66
Year 5	48.980,66
Year 6	48.980,66
Year 7	48.980,66
Year 8	48.980,66
Year 9	48.980,66
Year 10	48.980,66
Output:	
NPV	**39.972,94**

Figure 18: *Peripheral blinking lights near tracks NPV calculation (10 years).*

The NPV for a 10-year period remains negative when assuming a small effect in accident reduction but is positive when assuming a strong safety effect of the measure. Likewise, the BCR is greater than 1 when high effectivity is assumed.

BCR for a 10-year investment period:

- Assuming low effect in prevention of fatalities (5%): 0.46
- Assuming high effect in prevention of fatalities (20%): 1.18

3.6.4. Blinking Amber Light

The cost categories and valuation for 'Blinking Amber Light' are presented in Table 9.

Table 9. *Blinking Amber Light – Cost categories and valuation.*

Costs	Description of costs	Monetary valuation
Development	Overall System, detection system Light sensor to alternate brightness during day and night Robustness has to be ensured.	120,000 € once
Installation	Digging hole for a concrete fundament Implementing System (including cost of material)	4,000 € once per LC
Operation	Lights are triggered automatically by sensor.	0 €
Maintenance	Cleaning from time to time Broken / vandalized lights or sensor for detection have to be exchanged. Testing from time to time to ensure that everything still works	500 € per LC every 5 years
General	Manpower to advertise it within railways	10,000 €

We make the assumption that one deadly accident would occur in 100 LCs in 10 years without additional safety measures. We assume that the measure is installed, operated and maintained at 100 LCs in Germany for a time span of 10 years. The NPV and BCR were calculated at a safety effect of 5% and 10% (5% and 10% of the value for preventing a fatality was calculated).

NPV		NPV	
Blinking Amber Light		Blinking Amber Light	
Reduction 5 %		Reduction 10 %	
Interest Rate	2,00%	Interest Rate	2,00%
Initial Investement	400.000,00	Initial Investement	400.000,00
Net Cash Flows		**Net Cash Flows**	
Year 1	13.220,17	Year 1	25.140,33
Year 2	13.220,17	Year 2	25.140,33
Year 3	13.220,17	Year 3	25.140,33
Year 4	13.220,17	Year 4	25.140,33
Year 5	13.220,17	Year 5	25.140,33
Year 6	13.220,17	Year 6	25.140,33
Year 7	13.220,17	Year 7	25.140,33
Year 8	13.220,17	Year 8	25.140,33
Year 9	13.220,17	Year 9	25.140,33
Year 10	13.220,17	Year 10	25.140,33
Output:		Output:	
NPV	**-281.248,74**	**NPV**	**-174.174,85**

Figure 19: *Blinking Amber Light NPV calculation.*

For a 10-year analysis, the NPV remains negative, and the BCR remains smaller than 1 for both low and high potential benefits. With the pricing estimates used here, a BCR of 1 would be achieved for the first time after 16 years, assuming an effectivity of 10 % accident reduction.

BCR for a 10-year investment period:

- Assuming low effect in prevention of fatalities (5%): 0.46
- Assuming high effect in prevention of fatalities (10%): 0.70

3.6.5. Rumble strips on approach to the LC

The cost categories and valuation for 'Rumble strips on approach to the LC' are presented in Table 10.

Table 10. *Rumble strips on approach to the LC – Cost categories and valuation. Information on installation and maintenance needs based on FHWA Safety, 2016; valuation estimated.*

Costs	Description of costs	Monetary valuation
Development	Rumble strips solutions exist already, tested specifications for LCs are available from research (e.g. Hore-Lacy, 2008; Radalj & Kidd, 2005; Skládaný et al., 2016), choice needs to be made by a technical expert.	20,000 €
Installation	Rumble strips need to be integrated in the road. On existing roads, this can be done by milling-in or fastening raised plastic/ceramic units. In new road construction, additional other techniques are possible (forming, rolling-in).	1000 to 2000 € per LC approach road direction
Operation	None	
Maintenance	Milled rumble strips typically do not require maintenance during the life of the pavement. Raised rumble strips can be displaced by traffic and may periodically require replacement. Rumble strips have little if any effect on the rate of deterioration of new pavements. Snow: When installed in durable pavement (whether new or existing), rumble strips are not affected by freeze/thaw cycles any more than the surrounding pavement. Rumble Strips and Snow Plowing: For milled rumble strips, weather appears to play no significant role in durability. Field observations refute concerns about the effects of the freeze-thaw cycle as water collects in the grooves. These observations show that wind and the action of wheels passing over the rumble strips in fact knock debris, ice, and water out of the grooves. With regard to raised rumble strips, snow plow blades passing over them tend to scrape them off the road surface. As a result, raised rumble strip use is usually restricted to areas that do not contend with snow removal.	500 € to 1000 € per LC approach road section every 10-20 yrs
General	Manpower to advertise them as a LC safety measure	10,000€

We make the assumption that one deadly accident would occur in 100 LCs in 10 years without additional safety measures. We assume that the measure is installed, operated and maintained at 100 LCs for a time span of 10 years, with one implementation costing 1500 € and renewal costing 750 € every 15 years on average. The safety effect was calculated at 2.5% and 10% (2.5% and 10% of the value for preventing a fatality was calculated).

NPV	
Rumble strips	
Reduction 2,5 %	
Interest Rate	2,00%
Initial Investement	150.000,00
Net Cash Flows	
Year 1	12.260,08
Year 2	12.260,08
Year 3	12.260,08
Year 4	12.260,08
Year 5	12.260,08
Year 6	12.260,08
Year 7	12.260,08
Year 8	12.260,08
Year 9	12.260,08
Year 10	12.260,08
Output:	
NPV	**-39.872,77**

NPV	
Rumble strips	
Reduction 10 %	
Interest Rate	2,00%
Initial Investement	150.000,00
Net Cash Flows	
Year 1	30.140,33
Year 2	30.140,33
Year 3	30.140,33
Year 4	30.140,33
Year 5	30.140,33
Year 6	30.140,33
Year 7	30.140,33
Year 8	30.140,33
Year 9	30.140,33
Year 10	30.140,33
Output:	
NPV	**120.738,08**

Figure 20: *Rumble strips NPV calculation.*

The NPV values for a 10-year period range from marginally negative to clearly positive when applying the two accident reduction scenarios.

BCR for a 10-year investment period:

- Assuming low effect in prevention of fatalities (2.5%): 0.86
- Assuming high effect in prevention of fatalities (10%): 1.76

3.6.6. Road sign “ ← Is a train coming? → ”

The cost categories and valuation for ‘Road sign “ ← Is a train coming? → ”’ are presented in Table 11.

Table 11. *Road sign “ ← Is a train coming? → ” – Cost categories and valuation.*

Costs	Description of costs	Monetary valuation
Development	Ready for implementation in principle; first implementation should be used to further assess the effects in the field, concrete sign design needs to be specified by a technical expert in accordance with local regulations.	20,000 €
Installation	Sign needs to be made and installed at the road	500 to 1,000 € per sign (sign + post + foundation + installation)
Operation	None	
Maintenance	Signs need to be replaced every 12–30 years, status needs to be assessed regularly (will be integrated in traffic-infrastructure assessments that need to take place anyway).	500 to 1,000 € per sign every 12–30 yrs.
General	Manpower to advertise the sign as a LC safety measure	10,000€

We make the assumption that one deadly accident would occur in 100 LCs in 10 years without additional safety measures. We assume that the measure is installed, operated and maintained at 100 LCs for a time span of 10 years, with one implementation costing 800 € and renewal every 20 years on average. The NPV and BCR were calculated for a safety effect of 1% and 5% (1% and 5% of the value for preventing a fatality was calculated).

NPV	
Road sign “Is a train coming?”	
Reduction 1 %	
Interest Rate	2,00%
Initial Investement	80.000,00
Net Cash Flows	
Year 1	9.684,03
Year 2	9.684,03
Year 3	9.684,03
Year 4	9.684,03
Year 5	9.684,03
Year 6	9.684,03
Year 7	9.684,03
Year 8	9.684,03
Year 9	9.684,03
Year 10	9.684,03
Output:	
NPV	**6.987,65**

NPV	
Road sign “Is a train coming?”	
Reduction 5 %	
Interest Rate	2,00%
Initial Investement	80.000,00
Net Cash Flows	
Year 1	19.220,17
Year 2	19.220,17
Year 3	19.220,17
Year 4	19.220,17
Year 5	19.220,17
Year 6	19.220,17
Year 7	19.220,17
Year 8	19.220,17
Year 9	19.220,17
Year 10	19.220,17
Output:	
NPV	**92.646,77**

Figure 21: *Road sign “is a train coming?” NPV calculation*

The NPV values are positive for both accident reduction scenarios.
BCR for a 10-year investment period:

- Assuming low effect in prevention of fatalities (1%): 1.14
- Assuming high effect in prevention of fatalities (5%): 1.94

3.6.7. Message "🡐 Is a train coming? 🡒" written on the road

The cost categories and valuation for 'Message "🡐 Is a train coming? 🡒" written on the road' are presented in Table 12.

Table 12. *Message "🡐 Is a train coming? 🡒" written on the road – Cost categories and valuation.*

Costs	Description of costs	Monetary valuation
Development	Ready for implementation in principle; first implementation should be used to further assess the effects in the field	10,000 €
Installation	Message has to be painted on the road (temporary road closure for installation, work cost, paint)	500 to 1000 € per road marking
Operation	None	
Maintenance	Pavement markings need to be renewed every 1-8 yrs. (depending on material used), status needs to be assessed regularly (can be integrated in traffic-infrastructure assessments that need to take place anyway).	500 to 1000 € every 1-8 years
General	Manpower to advertise the markings as a LC safety measure	10,000 €

We make the assumption that one deadly accident would occur in 100 LCs in 10 years without additional safety measures. We assume that the measure is installed, operated and maintained at 100 LCs for a time span of 10 years, with one implementation costing 800 € and renewal every 5 years on average. The safety effect was calculated at 1% and 5% (1% and 5% of the value for preventing a fatality was calculated).

NPV	
Message "Is a train coming?" written on road	
Reduction 1 %	
Interest Rate	2,00%
Initial Investement	80.000,00
Net Cash Flows	
Year 1	-2.315,97
Year 2	-2.315,97
Year 3	-2.315,97
Year 4	-2.315,97
Year 5	-2.315,97
Year 6	-2.315,97
Year 7	-2.315,97
Year 8	-2.315,97
Year 9	-2.315,97
Year 10	-2.315,97
Output:	
NPV	**-100.803,37**

NPV	
Message "Is a train coming?" written on road	
Reduction 5 %	
Interest Rate	2,00%
Initial Investement	80.000,00
Net Cash Flows	
Year 1	7.220,17
Year 2	7.220,17
Year 3	7.220,17
Year 4	7.220,17
Year 5	7.220,17
Year 6	7.220,17
Year 7	7.220,17
Year 8	7.220,17
Year 9	7.220,17
Year 10	7.220,17
Output:	
NPV	**-15.144,25**

Figure 22: *Message "is a train coming?" written on road NPV calculation.*

For a 10-year analysis, the NPV remains negative, and the BCR remains smaller than 1 for both low and high potential benefits. With the pricing estimates used here, a BCR of 1 would be achieved for the first time after 11 years, assuming an effectivity of 5 % accident reduction.

BCR for a 10-year investment period:

- Assuming low effect in prevention of fatalities (1%): 0.57
- Assuming high effect in prevention of fatalities (5%): 0.97

3.6.8. Smart detection system

This system is not – in current situation – estimated to have direct effects on safety. Therefore, it is not possible to apply the CBA. The costs for the 'Smart detection system' were estimated by the pilot-site leader as presented in Table 13.

Table 13. *Smart Detection system – Cost categories and valuation.*

Costs	Description of costs	Monetary valuation
Development	100 Restricted Stock Units (RSU)	170,000 €
Installation	Restricted Stock Unit (RSU) installation	700 € per LC: 70.000 €
Operation	Initial cost: 1 platform for 100 LCs	130.000 €
Maintenance	Maintenance and operation of the system	75.000 €
General	None	

3.6.9. V2X messaging system between automated vehicles and passive level crossings

This system is not – in current situation – estimated to have direct effects on safety. Therefore, it is not possible to apply the CBA. However, it enables the introduction of automated driving on road network with passive level crossings.

Recent developments in the transportation field are paving the way for this system. Specifically, the railway traffic is moving towards the European Rail Traffic Management System (ERTMS) which means that more and more railway vehicles are equipped with ETCS (European Train Control System). In the most developed ETCS systems there is no need for lineside signals or train detection systems on the trackside other than Euro-balises. ETCS system requires railway network information, train location information, signal information of the railway network, and train timetable information that are also required for the input information for the functioning of this piloted system. Therefore, these costs should not be considered as direct development costs of this system. In road transport, the communication capabilities of cars are constantly developing and developments within C-ITS technology enable the communication between cars and infrastructure.

The costs that are specifically needed for this system are presented in Table 14.

Table 14. *V2X messaging between automated vehicles and passive level crossings – Cost categories and valuation.*

Costs	Description of costs	Monetary valuation
Development	Development of the back-office system which calculates the information delivered to the LC (including the interface to deliver the data to system users)	Several hundred thousand €.
Operation	Administrative costs related to the back-office system	Estimated to be a fulltime job for one person (around 100 k€ per year).

3.7. **Conclusions on the CBA results**

The calculation of safety benefits of each solution is based on the effectiveness estimates drawn as part of WP4 of the SAFER-LC project (Silla et al., 2019) and on the estimates of the value of life based on previous studies (*RSSB, 2019)*. The partners were asked to identify the benefits separately for injuries avoided, environmental pollution avoided (fires, dangerous goods, etc.), infrastructure damages (rail, road – vehicles included), traffic delays (both primary and secondary) and rescue service costs avoided.

The interest rate calculated (as the opportunity cost of a safer investment) was estimated as 2% in all cases. It was not considered necessary to calculate alternative interest rates as at the case of road safety solutions the scope of economic analysis is not to compare different returns on investment but to define the sustainability and the benefits to the society by applying such measures.

In the consideration of the results, the reader should keep in mind that the inputs to the CBA are estimates provided by the piloting partners and may not reflect the reality encountered in other contexts (e.g. another country, using different technical implementations, quantities etc.). Therefore, the calculation examples should be adapted and updated to the specific context of the respective use case for obtaining the best results.

In addition to the relation of costs and benefits, the absolute magnitude of the effect that can be achieved by a measure should always be considered. For example, though a measure may be worth its costs in the prevention of 5% of accidents, still, the overall safety effect achieved (5%) will be smaller than for the application of a measure that could prevent, e.g., 20% of accidents.

Last but not least, the increase in safety can be more beneficial than estimated. For reasons of practicability, some existing additional benefit categories could not be considered in the analysis, e.g. benefits due to avoiding delays in road and rail traffic. Moreover, it is highly possible to underestimate the values of the benefits (fatalities result to big negative impacts on families and societies). We can calculate only the value by terms of product a person can produce during his/her life but we cannot easily identify the impact they may have through other activities such as volunteering or the value brought to the person's family. A loss may have impact to other people's lives and this cannot easily be valuated.

4. ANALYSIS OF THE BUSINESS MODELS APPROACH FOR THE SAFER-LC SOLUTIONS

The current chapter results to the SAFER-LC final business model (BM), which is going to be an inclusive plan on the potential organisational structure for the SAFER-LC exploitation phase. The first subchapter is a literature review of the existing business model techniques. Before deciding to use the final tool, the most relevant techniques are listed. The second subchapter presents the BM for the SAFER-LC solutions.

4.1. Business Model Techniques – Our tools for BM presentation – visualisation

The "Business Model Techniques" or "Business Model Tools" (BMT) will be presented in this chapter with the scope to select the most suitable for the SAFER-LC solutions. The selected BMT has to cover the following aspects:

1. *"Identify your specific audience.*
2. *Establish business processes.*
3. *Record key business resources.*
4. *Develop a strong value proposition.*
5. *Determine key business partners.*
6. *Create a demand generation strategy.*
7. *Leave room for innovation." (Larry Alton, 2015)*

It is of great importance to select a BMT that can successfully describe and visualise the business model idea, transactions, partners, and of course the value proposition. The following techniques are included in this document as tools that can help.

The Business Model Canvas

The Business Model Canvas (BMC) is the most well-known and well-established BMT (Figure 23). It is used by enterprises, innovative start-ups and organisations. It is constituted by 4 segments (infrastructure, offering, customers and finances) with totally nine blocks (key partners, key activities, key resources, value proposition, customer relationships, channels, customer segments, cost structure and revenue streams) as depicted in the figure below and was introduced by Osterwalder (2008). Since the first appearance of the BMC, similar approaches have been invented adjusting the initial Canvas to the needs of different business model ideas.

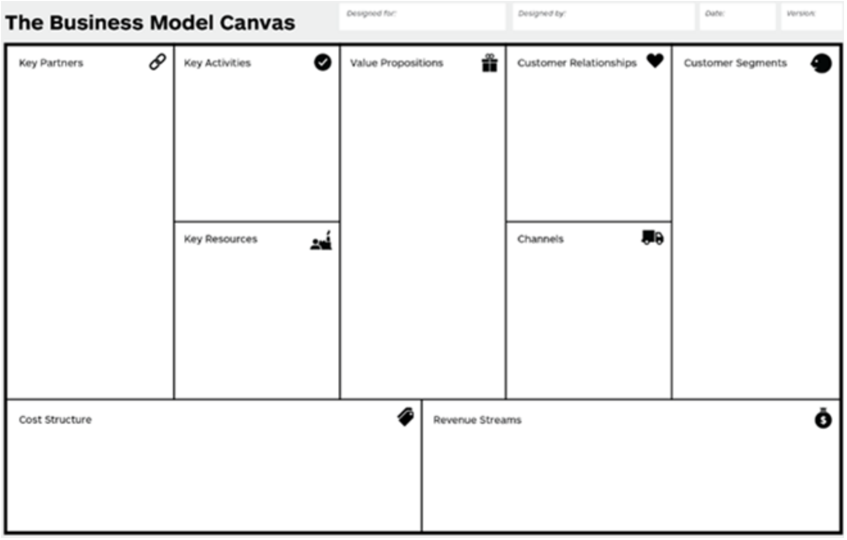

Figure 23: *The business Model Canvas (BMC).*

The nine elements of business model Canvas are (Barquet et al., 2011):

- ***"Customer Segments*** *(distinct segments with common needs, common behaviours, or other attributes): defines the different groups of people or organizations an enterprise aims to reach and serve. Once this decision is made, a business model can be carefully designed around a strong understanding of specific customer needs.*
- ***Value Propositions****: It seeks to solve customer problems, satisfy customer needs and describes the bundle of products and services that create value for a specific Customer Segment.*
- ***Channels****: describes how a company communicates with and reaches its Customer Segments to deliver a Value Proposition, comprising a company's interface with customers.*
- ***Customer Relationships****: describes the types of relationships a company establishes and maintains with specific Customer Segments.*
- ***Revenue Streams****: results from value propositions successfully offered to customers, this element represents the cash a company generates from each Customer Segment.*
- ***Key Resources****: are the assets required to offer and deliver the previously described elements.*
- ***Key Activities****: are performed though the Key Resources to offer and deliver the previously described elements.*
- ***Key Partnerships****: describes the network of suppliers and partners that make the business model work. Some activities are outsourced and some resources are acquired outside the enterprise. Companies create alliances to optimize their business models, reduce risk, or acquire resources.*
- ***Cost Structure****: describes all costs incurred to operate a business model. Costs can be calculated relatively easily after defining Key Resources, Key Activities, and Key Partnerships."* (Barquet et al., 2011)

There are several differentiations of the classic BMC presented above, depending on where the focus is being placed, e.g. on the product, value proposition, or team, etc. To name but a few: Lean Canvas, Mindmap Canvas, Product Canvas, Team Canvas, Value Proposition Canvas, etc. Below, in the next paragraphs, the most important types of Canvases for the SAFER-LC solutions, like the

Service-Dominant Strategy Canvas, the Partnership Canvas, the Strategic Innovation Canvas and Lean Change Canvas are presented.

Service Dominant Strategy Canvas

Described as "*a new innovative mind-set that addresses this change towards a service dominant economy focused at the network level*" (Lüftenegger et al., 2012), the Service Dominant Strategy Canvas (Figure 24) is a differentiation of the conventional Canvas.

The Service-Dominant Strategy Canvas is broken into the following three segments and ten sub-segments (Figure 24):

- **Value-in-use** which includes customer, experience and interactions elements
- **Service ecosystem** segment referring to the core services and core partners, the focal organisation and the enriching services and partners of the service to be provided
- And finally, the **collaboration management** segment with the core and enriching relationships illustrated

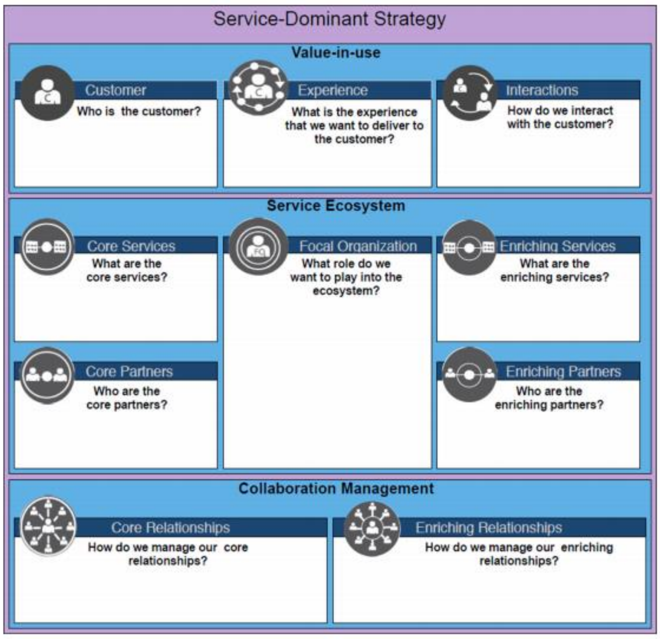

Figure 24: *Service-Dominant Canvas (Lüftenegger, 2015).*

Partnership Canvas

As its name indicates, the Partnership Canvas is a way of modelling a BM between two partners (Figure 25). This tool can be an added to the BMC and present the activities the two partners are going to do to deliver a product or service.

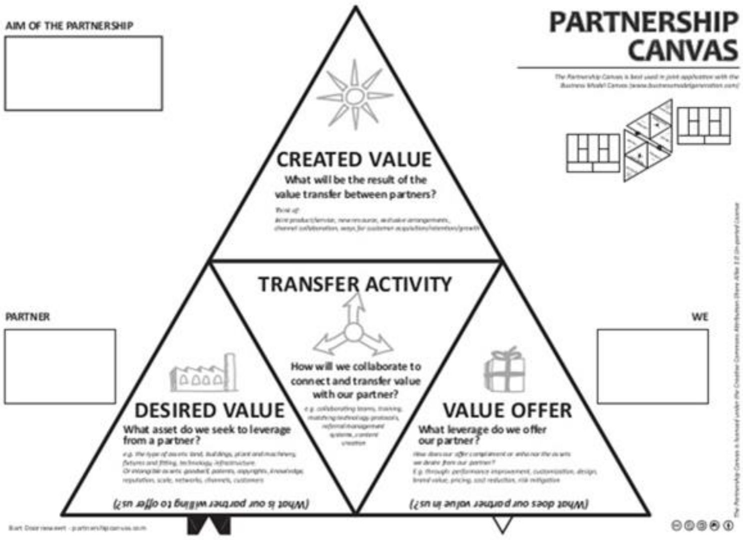

Figure 25: *Partnership Canvas (Doorneweert, 2014).*

Strategic Innovation Canvas

The Strategic Innovation Canvas (Figure 26) is mostly a categorisation of the innovations and the day-to-day activities of a business. Those two have to be balanced for a company to be viable both in the short and long term.

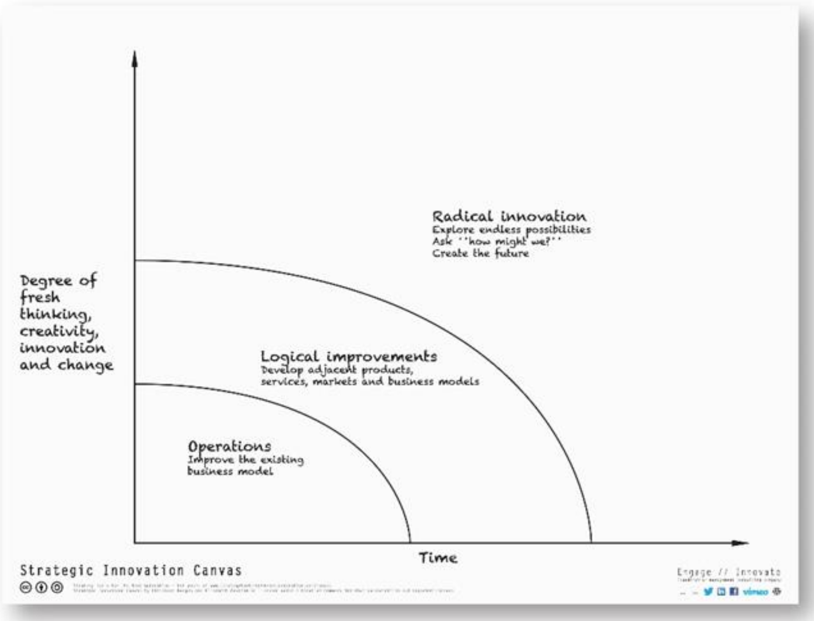

Figure 26: *Strategic Innovation Canvas (engage-innovate.com).*

Lean Change Canvas

The Lean Change Canvas is structured in the same way as the Business Model Canvas (Figure 27). However, it introduces and describes change in a product or service.

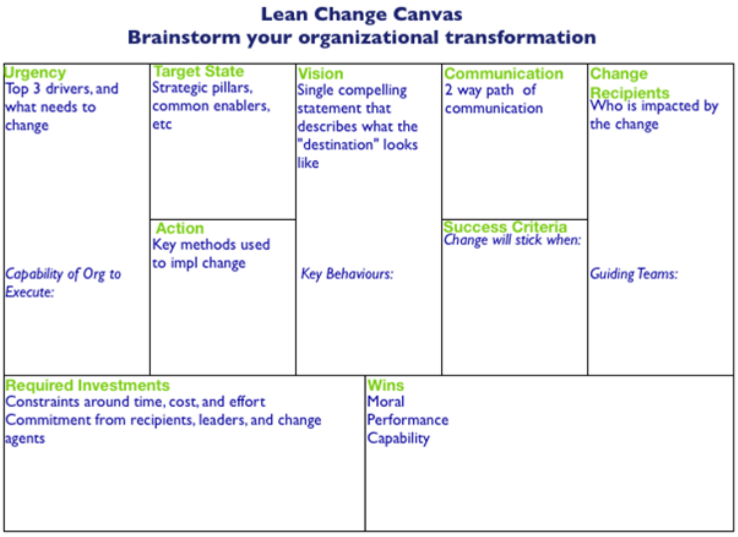

Figure 27: *Lean Change Canvas (canvanizer.com).*

Three Horizons of Innovation

Figure 28 presents the three horizons of innovation, a similar tool to the Figure 26 for categorisation of the innovation to short-term, mid-term and long-term.

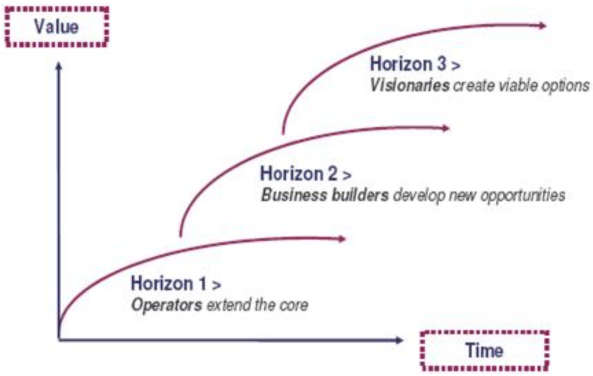

Figure 28: *Three Horizons of Innovation (Baghai et al., 1999).*

Lean start-up

The Lean Start-up is a method for introducing and improving an innovative idea. As in Figure 29, the circle is starting from ideas which with the right design become products and with the right measurements provide valuable data in order to feed the procedure from the beginning with the experience from the lessons learnt.

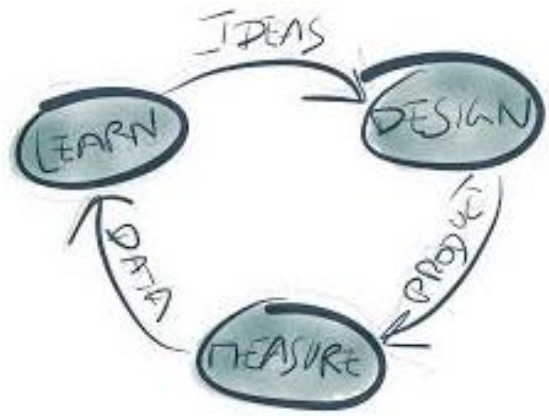

Figure 29: Lean Start-up (ekito.fr).

Service Dominant Radar

The Service-Dominant Radar (Figure 30) is a tool that can be used in case the actors for the production of a good or service are clearly defined and the actions and roles need to be defined.

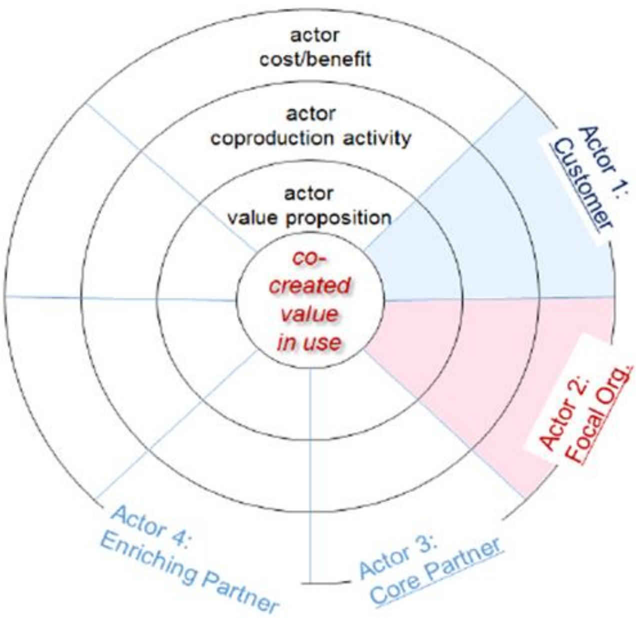

Figure 30: *Service-Dominant Radar (Grefen et al. 2015).*

Business Model Roadmap

A Business Model Roadmap is a presentation of the next steps required for a Business Model to be realised (Figure 31).

Figure 31: *Roadmap (nexleveladvisors.com).*

Summary of Business Model Techniques

In addition to the above BMTs there are also numerous other tools that have been introduced for this purpose in the literature. These additional approaches found in the web through a desktop research are listed below. The first category includes different variations of the Business Model Canvas, whereas the items 2-12 include different categories of Business Model Techniques:

1. Canvases
    a. Mindmap Canvas
    b. Lean Canvas
    c. Strategy Canvas
    d. Business Model Environment
    e. Team Alignment Map (TAM)
    f. Product Canvas
    g. Team Canvas
    h. Value Proposition Canvas
    i. Feedback Canvas
    j. Open Innovation Canvas
    k. Canvas for Change
    l. Zen Canvas
    m. Adapted Canvas including Social and Environmental costs and benefits
    n. Product Vision Board Canvas
    o. Mission Model Canvas
    p. Product-Market-Fit Canvas
    q. Disruption by Design Canvas
    r. Etc
2. Value Network
3. Ambidextrous Organisation
4. Business Model Wheel
5. Innovation Pyramid
6. Business Model Yacht
7. Staehler's model
8. Value Networks from Verna Allee
9. SEMPORCES

10. Base Board
11. Docherty’s Innovative mindset
12. The fluidminds’ 6 step approach to business model innovation etc.

With regards to the SAFER-LC solutions, it is of great importance to choose one (or even more) BMTs in order to present the chosen Business Model and visualise it in the best way. In this case, after examining the suitability of the BMTs for our solutions, Business Model Canvas was considered as the most suitable as a current step to be taken. Moreover, tools like the Service-Dominant Radar can be used to describe each solution separately when the actors are defined. The Business Model Roadmap can describe the next steps and the Three Horizons of Innovation will be useful in defining the short-term, mid-term and long-term innovative solutions and how they can be introduced to the market. In chapter The SAFER-LC Business model below, the BMC for the organisational structure of the SAFER-LC solutions is presented.

4.2. **Building blocks of the Business Model Canvas (BMC)**

4.2.1. SAFER-LC Value Proposition

The most important aspect of a business model is the value proposition, which can be defined as “*the value a company promises to deliver to its customers should they choose to buy their product*” (Investopedia.com). SAFER-LC solutions have the goal to both complement the current LC infrastructure wherever safer solutions are required and increase safety at LCs where low-cost solutions are needed by proposing to the potential customers:

- Improved safety in all types of LCs during day and night (active or passive)
- Providing low-cost solutions (lower costs than for automatic barriers or other classic upgrades of LC safety measures)
- Providing mixed solutions for specific needs that can support numerous LCs with little or no need for employees to monitor and/or inspect
- Fit with the environmental and traffic needs
- Possibility for integration with autonomous vehicles in the future (in some cases) and integration with navigation applications
- More efficient network operations due to less accidents and hence less disruptions to traffic
- Less damage costs (infrastructure, environment and rescue services)

4.2.2. Cost structure

The different SAFER-LC solutions involve several cost categories depending on the nature of the measure. The pilot site leaders reported the cost categories for each solution through the questionnaires (see Annex B) and the results are listed in the chapter 3.5 of this deliverable.

The main cost categories are:

- Product development costs (e.g. hardware or software development costs)
- Personnel costs

- Installation costs
- Operational costs
- Maintenance costs
- General, administrative and other costs

4.2.3. Revenue streams

The main revenue streams are:

- Consultancy fees for counselling to define the best solutions for LCs
- Studies on the suitability of the solutions, the prospective effects etc.
- Hardware sales
- Software – application sale / subscription
- If applicable, taxes, tolls, charges from government

4.2.4. Key partners

The key partners are:

- Public authorities (regional, national or European level)
- Rail infrastructure managers
- Road infrastructure managers
- Hardware developers
- Software developers
- Research institutes
- Rail operators
- Road operators (commercial fleet managers)
- Rail users (passengers, train drivers, …)
- Road users (drivers, riders, cyclists, pedestrians, …)

4.2.5. Key Resources

The SAFER-LC solutions will require specific key resources in order to deliver benefits to the customers. Those resources might include:

- Hardware devices constructed for some solutions
- Software developed for the SAFER-LC needs
- Personnel (further research, installation, maintenance etc.)
- The SAFER-LC developed solutions – know-how

4.2.6. Key Activities

The key activities include:

- Consulting on the most suitable and efficient LC solutions
- Development of the solutions
- Installation activities
- Operational activities
- Maintenance of the solutions and updates
- General and/or other (updating, research for improvement etc.)

4.2.7. Channels

The SAFER-LC solutions are directed towards a very limited and specific audience which is specialised and can be easily reached through:

- Conferences (rail, safety oriented etc.),
- Networking with experts in safety, rail industry etc.,
- Domain-specialised magazines and websites,
- Associations where rail infrastructure managers (or other potential customers are represented,
- Applications for tender calls (in regional, national or European level) for safety solutions,
- Salespersons etc.

The Community of European Railway and Infrastructure Companies (CER) lists its 70 members according to the website *"cer.be"* covering up to 92% of rail passenger operations in Europe. Thus, there is no need for multiple channels when approaching potential customers. However, the way of building a channel has to be as efficient as possible because of the importance of each of the customers.

4.2.8. Customer Relationships

A close collaboration between the SAFER-LC "ambassadors" and the customers is needed. Depending on the most applicable "customer" category, whether it is going to be the government, the rail infrastructure managers or a synergy of different stakeholders, in all cases the market will be characterised as an oligopsony (few buyers with big negotiating power) or even a monopsony (one single buyer in the market). However, each customer can implement a big amount of LCs. The only possibility of how the market could be a bit more open is the case of regional or even city level, where different strategy has to be followed.

4.2.9. Customer Segments

The customer segmentation of the SAFER-LC solutions was introduced at the beginning of this chapter. At this point, we list the main categories of potential customers that will be illustrated in the Business Model:

- Government, regional governments, cities, etc.

- Rail operators or rail infrastructure managers
- Road infrastructure managers
- Application and service providers

4.3. The SAFER-LC Business model

The SAFER-LC business model as presented below is the result of the previous sub-chapter on Building blocks of the Business Model Canvas (BMC). Useful views of the partners were included from the online survey together with the CBA outcomes and views on costs and benefits. At this point, the Business Model will describe the whole SAFER-LC organisational structure instead of individual solutions and will present the general picture of how the solutions can be exploited after the project period.

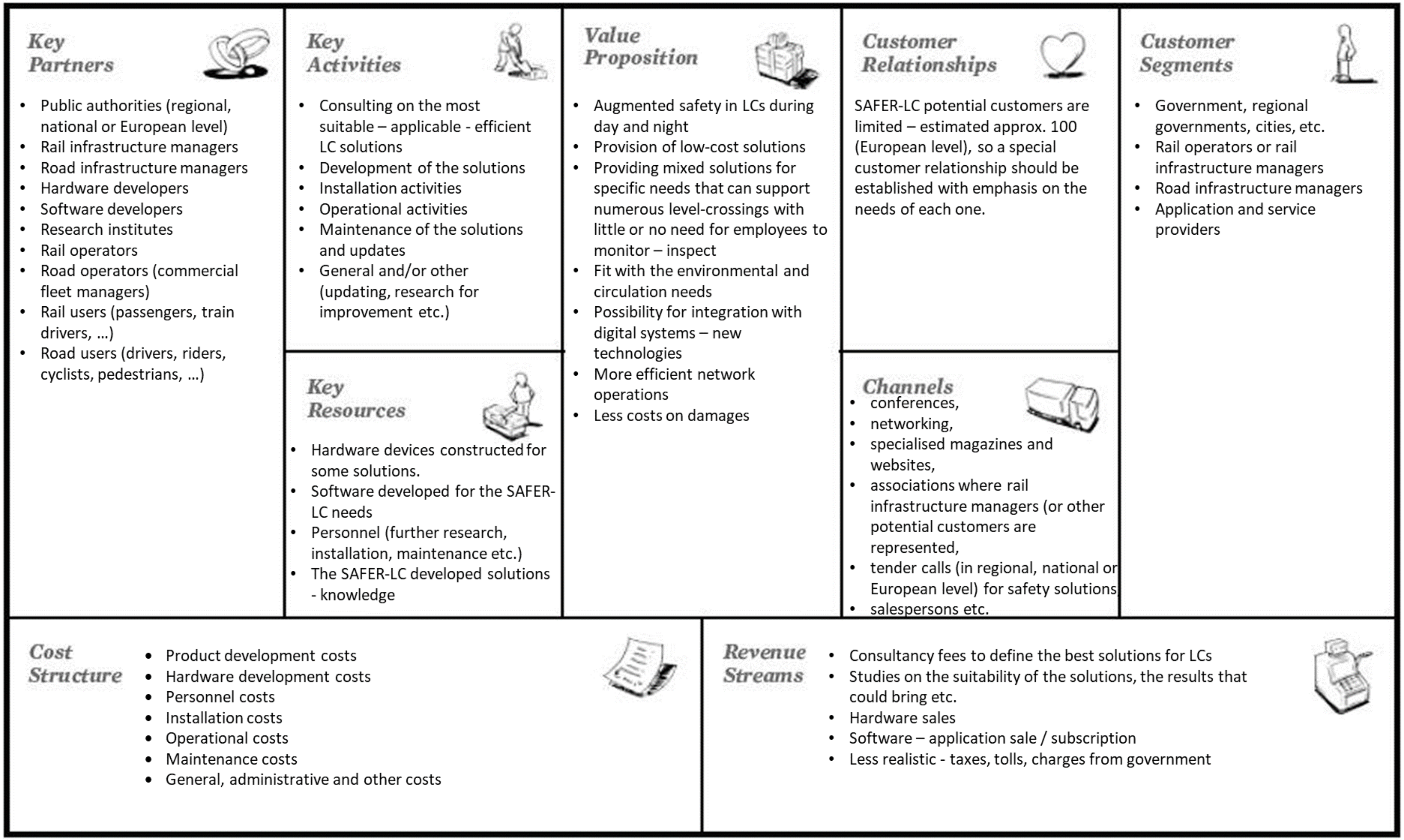

Figure 32: SAFER-LC Business Model Canvas

5. SAFER-LC SELECTED BUSINESS SCENARIOS

Business scenarios describe some real-life cases of partners in the SAFER-LC consortium who are closer to the stakeholders and hence play an important role in the exploitation plans of the solutions. The business scenario of TRAINOSE (chapter 5.1) describes the business information such as the partners involved, the transactions taking place, the business processes, the stakeholders involved and the benefits from the solutions.

This analysis is of great interest for the SAFER-LC project because it offers a vision of the partners on how to proceed. The following examples can be found useful not only by the consortium members but also by other stakeholders.

5.1. **Business scenario**

Accidents at LCs are the second most frequent type of accident in railway reality. The cost of an accident is measured in terms of material and psychologically, especially if it involves a fatality. One of the main reasons that potentially hazardous LCs still exist is the high cost of upgrading them. For that reason, innovative safety- and cost-efficient solutions have to be developed, tested and adopted by the operators and infrastructure managers. The market and targeted customers set the basis for several routes to markets and business models of the project. For example, an interesting route to market is through companies in the railway industry or the public sector.

From the railway operator perspective, the LC proximity warning system of Thessaloniki consists of a GPS device which can be connected to any locomotive. From the road user's side, any common smart mobile phone is sufficient to run the app and receive the warnings. The system works with promising results in a large city, and successful continuity of such a system could be foreseen with the arrival of new technologies like 5G, which will offer a more robust car-to-train communication channel.

The most important users of this platform are the railway companies and road users. Moreover, this system does not require any new upgrade in the existing infrastructure. The main channels that can be used are public authorities and spread by word-of-mouth and other marketing initiatives. Also, retailers can assist in promoting the service in their channels.

In terms of market, this service now works between trains and a large taxi fleet of service. The next step is this model to be adopted by more road companies in the Thessaloniki region. Because of the "training sophistication" the new type of fleet will bring new changes in algorithm modelling. In terms of the Hellenic territory, the service is already installed in the Hellenic GAIOSE fleet rented by TRAINOSE. In case a private company operates a train in Greece, a GPS device should be installed on-board the locomotive in order for its trains to be tracked by the main platform. A region like Greece is challenging for such a service because all the railway network must be mapped, and all LCs must be located accurately in this map. Then the service must be installed in the fleets of taxi, truck and bus operators. The installation in private cars can be done in a voluntary way through a campaign or advertisements.

At this point this solution must be drafted in industrial specifications. All the railway industry standards must be followed, therefore the solution might need to be re-designed before reaching a final consumer product. A standardized implementation of the idea will increase costs, however, the system's simplicity is expected to keep costs in reasonable levels.

The most difficult part is to import such a service in the EU region since the network is more complicated in comparison to Greece. The first channel that should be used is the contacts of the main railway company and railway infrastructure manager of every country. Since these companies are commonly public ones, they can contact other EU organisations. The operation and the maintenance of the trains belong to other stakeholders (maintenance companies, railway owners etc.), which may put barriers in the overall implementation.

The channels that should be used come through these initiatives. One complicated task is the LC network mapping. Since locating the position and development of the model to estimate train arrivals are the most important parts, high quality and accuracy maps and data should be used. The estimation model has to be trained in every country network with data from the country's local railway.

Table 15 presents the business model canvas for the business scenario of TRAINOSE.

Table 15. *Business model canvas for LC proximity warning system.*

Business Model Canvas	
Key partners	▪ Railway operators ▪ Infrastructure managers ▪ City authorities
Key activities	▪ Long distance rail transport ▪ Road transport
Value proposition	▪ Reduction of accidents in LC's ▪ Reduction of accidents costs ▪ Increased reliability of trains
Customer relationships	▪ B2B – From railway operators to railway companies ▪ B2B – From railways to car industry ▪ B2C – From industry to users ▪ C2C – From user to user through
Customer segments	▪ All people using cars ▪ All people using trains ▪ All people working on trains ▪ Pedestrians ▪ Residential area near LC
Key resources	▪ Vehicles ▪ Trains

	▪ LC hubs ▪ SAFER-LC platform
Internalization of externalities	▪ Reduce of accidents in railway networks ▪ Reduction of costs in case of accident
Channels	▪ Railway companies ▪ International initiatives ▪ Internet
Revenue streams	▪ A fee of the platform ▪ Advertisements ▪ Operational charges from users
Cost structure	▪ Train, rail and LC hub (operational costs) ▪ Road vehicle (operational cost) ▪ IT platforms (LC platform)

6. GENERAL CONCLUSIONS AND RECOMMENDATIONS

The last chapter of this deliverable is dedicated to the general conclusions from the economic analysis conducted in WP5 and recommendations for decision makers who consider using the safety solutions piloted in the SAFER-LC project.

The safety solutions included in this document are low-cost safety measures: Even those of the reported solutions that cost more in comparison to others cost a lot less than the conventional solutions found in the market. They are easily applicable in the vast majority of the LCs in Europe and worldwide, and able to bring considerable safety benefits to the LC users and railway stakeholders. The data collected for the CBA gave us the qualitative data and estimations of costs and benefits in order to build some scenarios and present the estimations for an economic analysis necessary for the continuation of the exploitation of the SAFER-LC solutions.

The online survey presented in chapter 2 of this document provides an overview on the willingness of the partners to collaborate after the project-life and how this collaboration can be shaped. The partners' answers concerning the economic potential of the solutions and certain barriers for their wide deployment were recognised. It is important to note that in order to proceed to full production of the solutions from a research project, many steps have to be followed though. Through this exercise, crucial elements for the development of the business models were defined. Through calls with partners and during sessions in the framework of the project meetings the consortium agreed on the Business Model Canvas of subchapter 4.3. The Business Model presents how the SAFER-LC solutions can be commercially exploited and who is going to participate in the process. The Business Model can serve as a "living document" and can be adjusted to the new conditions at every phase of the exploitation. The Business Model Canvas is a visualisation of how the SAFER-LC solutions can go forward with a market-readiness approach, involving stakeholders and target customers and focusing on the value proposed and channels to be used.

Moreover, in the framework of deliverable D5.3, the SAFER-LC CBA was applied. The CBA based on the estimations from the pilot-site leaders related to the costs and the benefits is a categorisation of the solutions related to the financial aspects. The cost categories for all interested parties are crucial information for decision makers and customers in general before deciding which safety measures to take. In *Table 16*, the solutions are categorised by initial investment costs and by operational and maintenance costs. For the initial investment cost per LC, a categorisation of *Low*: <10,000 €, *Medium*: 10,001 – 100,000 € and *High*: >100,001 € has been followed for the classification, as it is done in the SAFER-LC toolbox, a web-based tool that presents the central results of the project (http://toolbox.safer-lc.eu/). All the solutions (in Table 16, the costs are for 100 LCs as in the CBA) are categorised as low-cost. Regarding the operational and maintenance costs the categories were: *Low*: < 20,000 €, *Medium*: 20,001 – 50,000 € and *High*: > 50,001 € again for 100 LCs (assumptions made for the CBA). The cost categories were assigned based on the estimates provided by the pilot-site leaders.

Table 16: *Cost categorisation of the solutions. If not otherwise specified, the values are for the implementation of the measure at 100 LCs.*

Solution	**Initial investment (€)**	**L/M/H**	**Average annual operation/ maintenance (€)**	**L/M/H**
In-vehicle train and LC proximity warning*	198,000	L	2,800	L
Blinking lights on locomotive**	40,000	L	20,000	L
Peripheral blinking lights near tracks	400,000	L	10,000	L
Blinking amber light with train symbol	400,000	L	10,000	L
Rumble strips	150,000	L	5,000	L
Road sign “Is a train coming?”	80,000	L	4,000	L
Message "Is a train coming?” written on the pavement	80,000	L	16,000	L
Smart Detection System	370,000	L	75,000	H

*The solution concerns 95 equipped trains and 100 LCs.

**The solution concerns 20 equipped trains.

Beyond the costs, the benefits calculated have taken into account different aspects such as the prevented fatalities and injuries (both light and severe), environmental damages avoided, infrastructure damages (rail, road – vehicles included), traffic delays (primary and secondary) and rescue services costs avoided. In addition to the relation of costs and benefits, the absolute magnitude of the effect that can be achieved by a measure in terms of accident reduction should be considered.

Each decision maker has to consider the specific conditions in the respective country or region regarding driving behaviour, natural conditions etc. before applying a CBA for the scenario tested. The increase in safety can be more beneficial than estimated and it is highly possible to underestimate the values of the benefits. Fatalities result in big negative impacts and negative externalities. We can calculate only the value in terms of product a person can produce during his or her life but we cannot easily identify the social impact they may have through other activities such as volunteering or the loss for the person’s family. A loss may impact other people’s lives and this can hardly be valuated.

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ANNEX A: ONLINE SURVEY

Question 1: Name of the SAFER-LC partner (organisation):

Question 2: Test site location

Question 3: Please describe very briefly the characteristics of the test site.

Question 4: Name of the solution taken into consideration in the following survey.

Question 5: Please describe briefly the main objective and characteristics of the solution tested.

Question 6: As a partner of SAFER-LC would you envisage to keep working with other partners of the consortium after the end of the project to implement some of the solutions developed and tested within the project?

- Yes, definitely
- Probably
- I do not know
- Probably not
- Definitely not

Question 7: According to you, what would be the most suitable type of partners to introduce the solution tested in the "market"?

Question 8: According to your expertise, what would be the steps to follow after the testing phase to introduce the solution to the market and implement it in the real world? (e.g. R&D, product development, production planning [process, capacity] and control, communications, sales support…)

Question 9: What would be the key resources needed to produce, sell, set-up, operate and maintain the solution tested? (Typical equipment required, nature of the workforce…)

Question 10: In your opinion, could the solution tested have the potential to be introduced in the market as a stand-alone product or should it be part of a broader set of solutions? Please specify briefly why.

Question 11: What are the main benefits of the tested solution for the customers? What critical problems are being solved for them?

Question 12: According to you, what is the unique value proposition (or obvious advantage) of the solution tested in comparison to other solutions available on the market?

Question 13: As an end-user, would you be keen in benefiting from the solution tested?

- Yes
- Maybe
- I do not know
- Probably not
- No

Question 14: Could the solution tested position itself as a standard in the sector?

- Yes
- Maybe
- I do not know
- Probably not
- No

Question 15: Could the solution tested become obsolete soon?

- Yes
- Maybe
- I do not know
- Probably not
- No

Question 16: What would be the size of the targeted market? Local, national, continental or global?

Question 17: What type of customers do you foresee for the solution tested?

Question 18: Please rank from 1 to 7 the main beneficiaries (stakeholders who would benefit the most) from the solution tested, according to you:

- Public authorities
- Rail infrastructure managers

- Road infrastructure managers
- Rail operators
- Road operators (commercial fleet managers)
- Rail users (passengers, train drivers...)
- Road users (drivers, riders, cyclists, pedestrians...)

Question 19: Please rank from 1 to 7 the stakeholders who are the most likely to implement the solution tested, according to you.

- Public authorities
- Rail infrastructure managers
- Road infrastructure managers
- Rail operators
- Road operators (commercial fleet managers)
- Rail users (passengers, train drivers...)
- Road users (drivers, riders, cyclists, pedestrians...)

Question 20: What kind of relationship you would expect to have with the customers of the solution tested? (e.g. purely transactional, long-term, personal assistance, co-creation, switching costs…) If possible, please explain briefly.

Question 21: Would potential customers of the solution tested be loyal/captive?

- Yes
- Maybe
- I do not know
- Probably not
- No

Question 22: How would you categorise the solution tested?

- B2B (business to business)
- B2C (business to consumer)

Question 23: Do you know which kind of distribution channel(s) could be used to sell the solution tested?

Question 24: Has a "go to market" strategy already been envisaged for the solution tested?

Question 25: According to you, who would have to pay to benefit from the solution tested?

Question 26: As an end-user, would you be willing to pay to benefit from the solution tested?

- Yes, directly
- Yes, indirectly
- No

Question 27: Do you think the solution tested can generate sustainable revenues to those who provide them?

- Yes, definitely
- Yes, probably
- I do not know
- Probably not
- Definitely not

Question 28: According to you, should the solution tested be offered for free to some stakeholders?

- Yes, definitely
- Yes, probably
- I do not know
- Probably not
- Definitely not

Question 29: After how many years do you think the marketing of the tested solution could reach a break-even point?

Question 30: Please describe the cost structure of the solution tested. Try to estimate what would be the main costs to consider to introduce the solution into the market (cost per type of equipment used, standardisation and certification costs, cost of installation, operation costs, maintenance and replacement costs, other relevant costs [planning, back office…] etc.)

Question 31: Is the solution tested in direct or partial competition with existing solutions?

- Yes
- No

Question 32: Could new actors come and take part in the market on the short term?

- Yes
- Maybe
- I do not know
- Probably not
- No

Question 33: Could the technological know-how of the solution tested be subject to property rights?

- Yes
- Maybe
- I do not know
- Probably not
- No

Question 34: Would the implementation of the solution tested require a change in the regulation governing safety at level crossings?

- Yes
- Maybe
- I do not know
- Probably not
- No

Question 35: Can the solution tested be integrated in a straightforward way with the current level-crossing systems and other existing safety measures?

- Yes
- Maybe
- I do not know
- Probably not
- No

ANNEX B: QUESTIONNAIRE ON THE COST & BENEFIT IDENTIFICATION

Cost categories

We are going to define the five cost categories that a single solution or a set of solutions includes:

- Development costs (for both hardware and software) – includes all the costs that can occur after the project–life for the development of the solution, the planning and consulting on the best practices fitting for each LC etc.
- Installation costs – costs to install the hardware or the software (applications, APIs etc.)
- Operational costs – costs related to the day-to-day operations (fees etc.)
- Maintenance costs - maintenance of the hardware and software, critical updates etc.
- General and administrative costs – it includes the administrative costs to provide the solution(s), e.g. management, marketing, sales and all the other costs that are not included in the above categories

Question 1:

What kind of solution(s) did you develop / apply in the framework of the SAFER-LC pilot site? (Provide a short description for each of them)

Detection	Communication	Measure
1.	1.	1.
2.	2.	2.
3.	3.	3.

Question 2:

Please fill in the costs for each cost category that you included in the table above; provide a short explanation and description for each one of them (each table has to be filled in for the different solutions):

Solution 1: ………………………………

Development	Installation	Operational	Maintenance	General
1.	1.	1.	1.	1.
2.	2.	2.	2.	2.
3.	3.	3.	3.	3.
4.	4.	4.	4.	4.
5.	5.	5.	5.	5.

Solution 2: ………………………………

Development	Installation	Operational	Maintenance	General
1.	1.	1.	1.	1.
2.	2.	2.	2.	2.
3.	3.	3.	3.	3.
4.	4.	4.	4.	4.
5.	5.	5.	5.	5.

Solution 3: ……………………………….

Development	Installation	Operational	Maintenance	General
1.	1.	1.	1.	1.
2.	2.	2.	2.	2.
3.	3.	3.	3.	3.
4.	4.	4.	4.	4.
5.	5.	5.	5.	5.

Solution 4: ……………………………….

Development	Installation	Operational	Maintenance	General
1.	1.	1.	1.	1.
2.	2.	2.	2.	2.
3.	3.	3.	3.	3.
4.	4.	4.	4.	4.
5.	5.	5.	5.	5.

Question 3:

Please estimate the monetary value of the above listed costs.

Solution 1: ………………………………

Development	Installation	Operational	Maintenance	General
1. €	1. €	1. €	1. €	1. €
2. €	2. €	2. €	2. €	2. €
3. €	3. €	3. €	3. €	3. €
4. €	4. €	4. €	4. €	4. €
5. €	5. €	5. €	5. €	5. €

Solution 2: ………………………………

Development	Installation	Operational	Maintenance	General
1. €	1. €	1. €	1. €	1. €
2. €	2. €	2. €	2. €	2. €
3. €	3. €	3. €	3. €	3. €
4. €	4. €	4. €	4. €	4. €
5. €	5. €	5. €	5. €	5. €

Solution 3: ……………………………….

Development	Installation	Operational	Maintenance	General
1. €	1. €	1. €	1. €	1. €
2. €	2. €	2. €	2. €	2. €
3. €	3. €	3. €	3. €	3. €
4. €	4. €	4. €	4. €	4. €
5. €	5. €	5. €	5. €	5. €

Solution 4: ……………………………….

Development	Installation	Operational	Maintenance	General
1. €	1. €	1. €	1. €	1. €
2. €	2. €	2. €	2. €	2. €
3. €	3. €	3. €	3. €	3. €
4. €	4. €	4. €	4. €	4. €
5. €	5. €	5. €	5. €	5. €

Benefit categories

At this point, we are going to define the six + cost categories that a single solution or a set of solutions includes:

- Fatalities avoided – How many fatalities can be avoided due to the application of the solution per year?
- Injuries avoided (either severe or light) – How many injuries can be avoided due to the application of the solution per year?
- Environmental damage – mainly from freight transport of dangerous goods or from oil leaks
- Infrastructure damages – What kind of cars, trains, rail and road network infrastructure damage can be avoided due to the application of the solution?
- Traffic delays – primary traffic delays due to the accident and secondary due to damages in the network – How many people are delayed? How many hours on average?
- Rescue services – By avoiding an accident, firefighters, ambulances, rescue teams etc. will not be deployed as much – public money can be used in other ways e.g. for investments.
- Other sources of benefits – feel free to add any other benefit category that we may have missed

Question 4:

Please fill in the benefits for each category; provide a short explanation and description for each one of them (each table has to be filled in for the different solutions – use annual values):

Solution 1: ……………………………….

Fatalities avoided	**Injuries avoided (Severe and light)**	**Environmental damage**	**Infrastructure damages (rail, road – vehicles included)**	**Traffic delays (primary and secondary)**	**Rescue services costs avoided**	**Other**
1.	1.	1.	1.	1.	1.	1.
2.	2.	2.	2.	2.	2.	2.
3.	3.	3.	3.	3.	3.	3.
4.	4.	4.	4.	4.	4.	4.
5.	5.	5.	5.	5.	5.	5.

Solution 2: ……………………………….

Fatalities avoided	Injuries avoided (Severe and light)	Environmental damage	Infrastructure damages (rail, road – vehicles included)	Traffic delays (primary and secondary)	Rescue services costs avoided	Other
1.	1.	1.	1.	1.	1.	1.
2.	2.	2.	2.	2.	2.	2.
3.	3.	3.	3.	3.	3.	3.
4.	4.	4.	4.	4.	4.	4.
5.	5.	5.	5.	5.	5.	5.

Solution 3: ………………………………..

Fatalities avoided	Injuries avoided (Severe and light)	Environmental damage	Infrastructure damages (rail, road – vehicles included)	Traffic delays (primary and secondary)	Rescue services costs avoided	Other
1.	1.	1.	1.	1.	1.	1.
2.	2.	2.	2.	2.	2.	2.
3.	3.	3.	3.	3.	3.	3.
4.	4.	4.	4.	4.	4.	4.
5.	5.	5.	5.	5.	5.	5.

Solution 4: ………………………………..

Fatalities avoided	Injuries avoided (Severe and light)	Environmental damage	Infrastructure damages (rail, road – vehicles included)	Traffic delays (primary and secondary)	Rescue services costs avoided	Other
1.	1.	1.	1.	1.	1.	1.
2.	2.	2.	2.	2.	2.	2.
3.	3.	3.	3.	3.	3.	3.
4.	4.	4.	4.	4.	4.	4.
5.	5.	5.	5.	5.	5.	5.

Question 5:

Please estimate the monetary value of the above listed benefits:

Solution 1: ……………………………….

Fatalities avoided	Injuries avoided (Severe and light)	Environmental damage	Infrastructure damages (rail, road – vehicles included)	Traffic delays (primary and secondary)	Rescue services costs avoided	Other
1. €	1. €	1. €	1. €	1. €	1. €	1. €
2. €	2. €	2. €	2. €	2. €	2. €	2. €
3. €	3. €	3. €	3. €	3. €	3. €	3. €
4. €	4. €	4. €	4. €	4. €	4. €	4. €
5. €	5. €	5. €	5. €	5. €	5. €	5. €

Solution 2: ……………………………….

Fatalities avoided	Injuries avoided (Severe and light)	Environmental damage	Infrastructure damages (rail, road – vehicles included)	Traffic delays (primary and secondary)	Rescue services costs avoided	Other
1. €	1. €	1. €	1. €	1. €	1. €	1. €
2. €	2. €	2. €	2. €	2. €	2. €	2. €
3. €	3. €	3. €	3. €	3. €	3. €	3. €
4. €	4. €	4. €	4. €	4. €	4. €	4. €
5. €	5. €	5. €	5. €	5. €	5. €	5. €

Solution 3: ………………………………..

Fatalities avoided	Injuries avoided (Severe and light)	Environmental damage	Infrastructure damages (rail, road – vehicles included)	Traffic delays (primary and secondary)	Rescue services costs avoided	Other
1. €	1. €	1. €	1. €	1. €	1. €	1. €
2. €	2. €	2. €	2. €	2. €	2. €	2. €
3. €	3. €	3. €	3. €	3. €	3. €	3. €
4. €	4. €	4. €	4. €	4. €	4. €	4. €
5. €	5. €	5. €	5. €	5. €	5. €	5. €

Solution 4: ………………………………..

Fatalities avoided	**Injuries avoided (Severe and light)**	**Environmental damage**	**Infrastructure damages (rail, road – vehicles included)**	**Traffic delays (primary and secondary)**	**Rescue services costs avoided**	**Other**
1. €	1. €	1. €	1. €	1. €	1. €	1. €
2. €	2. €	2. €	2. €	2. €	2. €	2. €
3. €	3. €	3. €	3. €	3. €	3. €	3. €
4. €	4. €	4. €	4. €	4. €	4. €	4. €
5. €	5. €	5. €	5. €	5. €	5. €	5. €

ANNEX C: INTERPRETATION OF BCR VALUES

BCR	Ratio
< 0.1	Extremely unfavourable
0.1 ... 0.5	Unfavourable
0.5 ... 2	Well-balanced
1 ... 5	Favourable
> 5	Extremely favourable

Table 7. Interpretation of CBR values