NEWBITS

Project Acronym: **NEWBITS**

Project Title: New business models for ITS

Project Number: 723974

Topic: **MG.6.3-2016**

Type of Action: **CSA**

D5.1 (C)- ITS business case guidelines

(Version 1.0 20/12/2018)

Deliverable:	(C)- ITS business case guidelines
Work Package:	WP5: NEWBITS Business case validation, guidelines and training
Due Date:	30/11/2018
Submission Date:	20/12/2018
Start Date of Project:	Oct 2016
Duration of Project:	30 Months
Organisation Responsible of Deliverable:	CUE
Version:	1.0
Status:	Final
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Nature:	☒ R – Report ☐ P – Prototype
	☐ D – Demonstrator ☐ O - Other
Dissemination level:	☐ PU - Public
	☐ CO - Confidential, only for members of the consortium (including the Commission)
	☐ RE - Restricted to a group specified by the consortium (including the Commission Services)

Revision history			
Version	**Date**	**Modified by**	**Comments**
0.1	12/11/2018	A. Chinnaswamy (CU)	First Draft
0.2	14/11/2018	ORT	Comments provided and suggestions made
0.3	26/11/2018	INTELSPACE SA	Revised document structure Comments added Figures/ Tables caption Formatting
0.4	30/11/2018	A. Chinnaswamy (CU)	First Draft revised and updated version
0.5	15/12/2018	Riccardo Enei (ISINNOVA)	Update to Literature and Methodology
0.6	17/12/2018	Iván Zaldívar Santamaría (ATOS)	Input for the Key outcomes of WP3
0.7	19/12/2018	Dr Alexeis Garcia-Perez (CUE) Xavier Verge (UAB) Gennaro Ciccarelli (TTS) Arno Schroten (CED)	Input to Business template, Business case guidelines for respective case studies
0.8	20/12/2018	INTELS	Revised content added
0.9	20/12/2018	ORT	Review by PM
1.0	20/12/2018	A.Chinnaswamy (CU) A. Garcia-Perez (CU)	Updates to complete all the sections

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Abbreviations

API	Application Programming Interface
ATA	Actual Time of Arrival
BC	Business Case
BCR	Benefit Cost Ratio
CBA	Cost Benefit Analysis
CED	CE Delft
C-ITS	Cooperative Intelligent Transport Systems
C-ITS	Cooperative Intelligent Transport Systems
CS	Case Study
CS1	Case Study 1
CS2	Case Study 2
CS3	Case Study 3
CS4	Case Study 4
CSF	Critical Success Factor
CUE	Coventry University Enterprises, Ltd
DoW	Description of Work
EC	European Commission
EP	European Parliament
ETA	Estimated Time of Arrival
EU	European Union
GLOSA	Green Light Optimised Speed Advice
ITS	Intelligent Transport Systems
KPI	Key Performance Indicator
MAF	Multiple Account Framework
NEWBITS	New Business Models for ITS
NNP	NEWBITS Network Platfom
NPV	Net Present Value
OBU	On-board unit
PV	Present Value
RSU	Road-side units
SF	Success Factor
TLA	Traffic Light Assistance
TTG	Time to Green
TTS	TTS Italia
UAB	Universitat Autònoma de Barcelona
UVP	Unique Value Proposition
WP	Work package

Executive summary

This deliverable reports the work conducted in task 5.1, work package 5. In line with the need for an efficient exploitation and deployment of C-ITS across Europe, task 5.1 builds on the understanding of the concepts developed by the project so far, as a key enabler for the diffusion of C-ITS innovation. Task 5.1 will therefore develop the NEWBITS understanding of the potential system benefits and fundamental economics of new business models suited to (C-) ITS in the European context, as reached by previous work packages.

The starting point for this task has been a combination of the Innovative Business Models developed by WP4 and the Holistic Intelligence process that resulted from WP3 once the ITS context had been mapped and understood. Those lessons enabled a detailed analysis of the costs and benefits associated to each of the four case studies informing the NEWBITS project and its findings. While the costs have a primarily financial nature, case study leaders in discussions with their stakeholders were able to identify and to some extent quantify monetary and non-monetary benefits for each case study. The differences between case studies (from a carpooling service to a traffic light infrastructure, a track-and-trace solution and a predictive maintenance solution), along with the varying nature of their cost-benefit ratios, meant that a range of lessons could be learned for future planning and implementation of C-ITS in a variety of contexts defined by aspects such as geography, transport mode, stakeholders etc.

Once the cost-benefit relation for each individual case study had been understood, a joint set of conclusions were drawn with a view to generalise the lessons learned. A business case template previously developed for the analysis of transport-related initiatives was adopted from a European Department for Transport and adapted to the conditions of the NEWBITS case studies. New business guidelines were generated for each case study and then generalised, considering elements such as the relationship between costs and monetary and non-monetary benefits (e.g. revenues, collaboration, knowledge sharing, resource pooling, branding, citizen engagement) for different stakeholders of C-ITS, and the KPIs and strategies for implementation of the different solutions.

The bottom-up approach adopted by NEWBITS for the development of business case guidelines will ensure the validity and applicability of the lessons learned, supporting decision making in the context of European C-ITS and ITS initiatives.

1 Introduction

The intention of this document is to describe the overall methodology of Work Package 5 and in particular for its task 5.1, which is an integral part of the project NEWBITS, and elaborate on the methods and techniques to be used in the conduct of the cost-benefit analysis to be used to understand the monetary and non-monetary benefits of C-ITS solutions for individual operators.

1.1 Description of WP5 and key interrelations

WP5 (Business case validation, guidelines and training) and in particular its Task 5.1 (C-ITS business case guidelines) builds on the concepts developed by NEWBITS to create an understanding of the potential system benefits and fundamental economics of new business models suited to C-ITS in the European context. On completion of Task 5.1, the WP will focus on the dissemination of the lessons learned in this and previous WPs.

The work conducted by the partners in the four case studies is used in this task to create a set of business guidelines that consider:

1. The understanding of the challenges underlying the (C)-ITS context, through the mapping of relevant C-ITS initiatives and their KPIs, as well as the assessment of main barriers to their implementation, as conducted by WP2
2. The definition and assessment of the current market situation along with a consideration of how users' preferences might shape the diverse strategies for profitable growth and a benchmark analysis on the innovation diffusion of (C)-ITS applications, as learned by WP3.
3. will be developed aiming at generating a comprehensive description of where value lies in a network of (C)-ITS stakeholders and how value is created, as generated through a Value Network Analysis (VNA) in WP4.

The relationships between these WPs and their influence on the work conducted in Task 5.1 has been represented in previous deliverables (and included here to aid the understanding of the context) as follows:
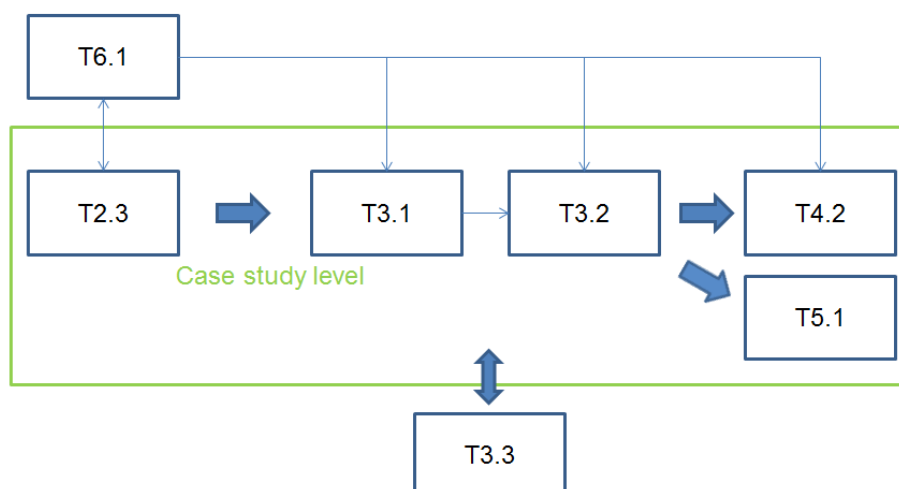
Figure 1 Diagram showing key interrelations influencing the delivery of WP5

Task 5.1 will use the work conducted by the partners in the four case studies to outline specific business guidelines that will then be generalised. Key elements informing these guidelines include the relationship between costs and both monetary and non-monetary benefits (e.g. revenues, collaboration, knowledge sharing, resource pooling, branding, citizen engagement) for different stakeholders of (C)-ITS, and the KPIs and strategies for implementation of the different solutions. A generic and robust (C)-ITS business case template will be validated, highlighting the core objectives of each business case, its areas of opportunity and the potential for improvement. This will allow NEWBITS consortium to evaluate the service/product developed by each case study from alternative decision-making perspectives and under alternative policy scenarios where the trade-offs among the project's stakeholders can readily be identified and quantified.

1.2 Objectives and structure of the document

The specific objectives for this deliverable are:

1. The identification and validation of factors that are relevant for the purpose of evaluating the service/project delivered by each of the four case studies underpinning the NEWBITS project.
2. The conduct of a cost-benefit analysis for each of the four case studies underpinning the NEWBITS project, on the basis of the relevant factors previously identified. This will result in an understanding of the monetary and non-monetary benefits of the individual projects as well as the strategies for their implementation.
3. The description of each business case by following a relevant business case template.
4. The design of a set of (C)-ITS business case guidelines that have the potential to inform decision-making in future European (C)-ITS initiatives.

This deliverable is therefore structured as follows:

Section **2** describes the methodology used for the implementation of this deliverable, in line with the approach to implementation adopted by the NEWBITS project.

Section **3** outlines the elements from WP3 and WP4 that have been key to the implementation of WP5 and in particular for Task 5.1.

Section **4** describes the findings of the work of case study leaders in the definition of key factors that are relevant for the purpose of evaluating the service/project delivered by each of their projects.

Section **5** describes the main part of this deliverable: a Cost-Benefit Analysis (CBA) conducted for decision making in investments, providing an ex-ante assessment of policy options on the basis of the lessons learned through the detailed analysis of the four case studies underpinning the NEWBITS project. A thorough analysis of costs and benefits attained by each case study is reported as a mechanism to evaluate the economic advantages or disadvantages derived from the case and so inform decisions to be made by future European (C)-ITS initiatives.

Finally, a template for C-ITS business case is used in section **6** to analyse each case and then inform the business case guidelines that are created in section **7**. The differences between the four case studies (from a carpooling service to a traffic light infrastructure, a track-and-trace solution and a predictive maintenance solution), along with the varying nature

of their cost-benefit ratios, informed the lessons learned by the project, outlined in section 7 for future planning and implementation of (C)-ITS in a variety of contexts defined by aspects such as geography, transport mode, stakeholders etc.

2   Deliverable implementation methodology

Based on the information gathered in WP3 and WP4, this deliverable will formalise the learning in order to deploy two differentiated outcomes: on the one hand, tools and guidance to support public and private stakeholders with the development of efficient policies for (C)-ITS deployment. The analysis about the results and dynamics of the network-based business modelling, together with a consolidation of the outputs from the deliverable, will support the elaboration of the report on Guidelines and Strategies to foster (C)-ITS deployment in deliverable 5.1.

This Work Package responds to the need for an efficient exploitation and deployment of C-ITS across Europe. The WP formalises the understanding of the potential system benefits and fundamental economics of new business models suited to (C-) ITS in the European context reached by previous work packages. This will lead to policy recommendations that will inform corporate-, local- and regional-level decision-making as well as provide recommendations for action in the transport development arena.

Figure 2 demonstrates the stages of deliverable 5.1. Initially the requirements of the deliverable as stated in the GA-DoW were identified. The planning stage included collecting the information from the outputs of WP2, WP3 and WP4. The commonly accepted structure by NEWBITS consortium was co-designed. Background work was then conducted on business case guidelines. The 4 cases chosen by the NEWBITS consortium were then individually subject to a CBA analysis. The CBA analysis included scoping the problem, identification of costs and benefits and monetising it. A CBA modelling was then used to calculate the net present value of costs and benefits using a discount rate. Sensitivity analysis was also performed. Results of the CBA was then presented as Net Present Value and Benefit Cost Ratio.

A business case template was then adapted for the 4 case studies that guided in the provision of a business case summary that included core findings and also recommendations for future investment development.

Finally, business case guidelines were derived from all the 4 case studies based on the analysis and findings of the deliverable that included the description of Critical Success Factors and KPIs for implementation.

2.1 Description of work

Figure 3 is an illustration of the description of work of deliverable 5.1. While the previous WP is focused on C-ITS innovative strategies (business models), this task will be answering the question 'What elements would make the introduction of (C-) ITS successful?'

Based on WP4 and WP3 outcomes, a generic and robust (C-) ITS business case template will be validated in this task. The core objectives of the business case, its areas of opportunity and improvement potential will determine the following business case factors to be validated:

- Enabling elements:
- Financial analysis
- Business modelling
- Core deliverables:
- Top-down business case: will enable definition of the template or framework
- Bottom-up benefits case: defines critical success factors and KPIs for implementation

The validation will result in a series of guidelines that will include the following elements (indicative list):

1. Monetary and non-monetary benefits for individual operators (e.g. revenues, collaboration, knowledge sharing, resource pooling, branding, citizen engagement). For the Cost-Benefit Analysis, the Multiple Account Framework (MAF) will be used. This will allow NEWBITS consortium to evaluate the project/product from alternative decision-making perspectives and under alternative policy scenarios where the trade-offs among the project's stakeholders can readily be identified and quantified
2. Societal benefits (e.g. environmental protection, job creation, overall European economic competitiveness, attractiveness of territories).
3. Risk and sensitivity analysis
4. Testing
5. Strategies for implementation
6. Sustainability

The business case template will detail value capturing strategies (on the full lifecycle), governance and collaboration schemes, and will recommend adapted support schemes/ incentives/regulations, in particular to address the "last mover advantage" issue.

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NEWBITS
Task 5.1 C- ITS business case guidelines

According to GA DoW and role of partners

business case factors to be validated

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  - o Business modelling
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Proposed deliverable structure

Figure 2 Understanding Task 5.1 Requirements upon the Grant Aggreement DoW

Figure 3 elaborates the structure of the report in delivering the requirements of this deliverable as stated in the DoW.
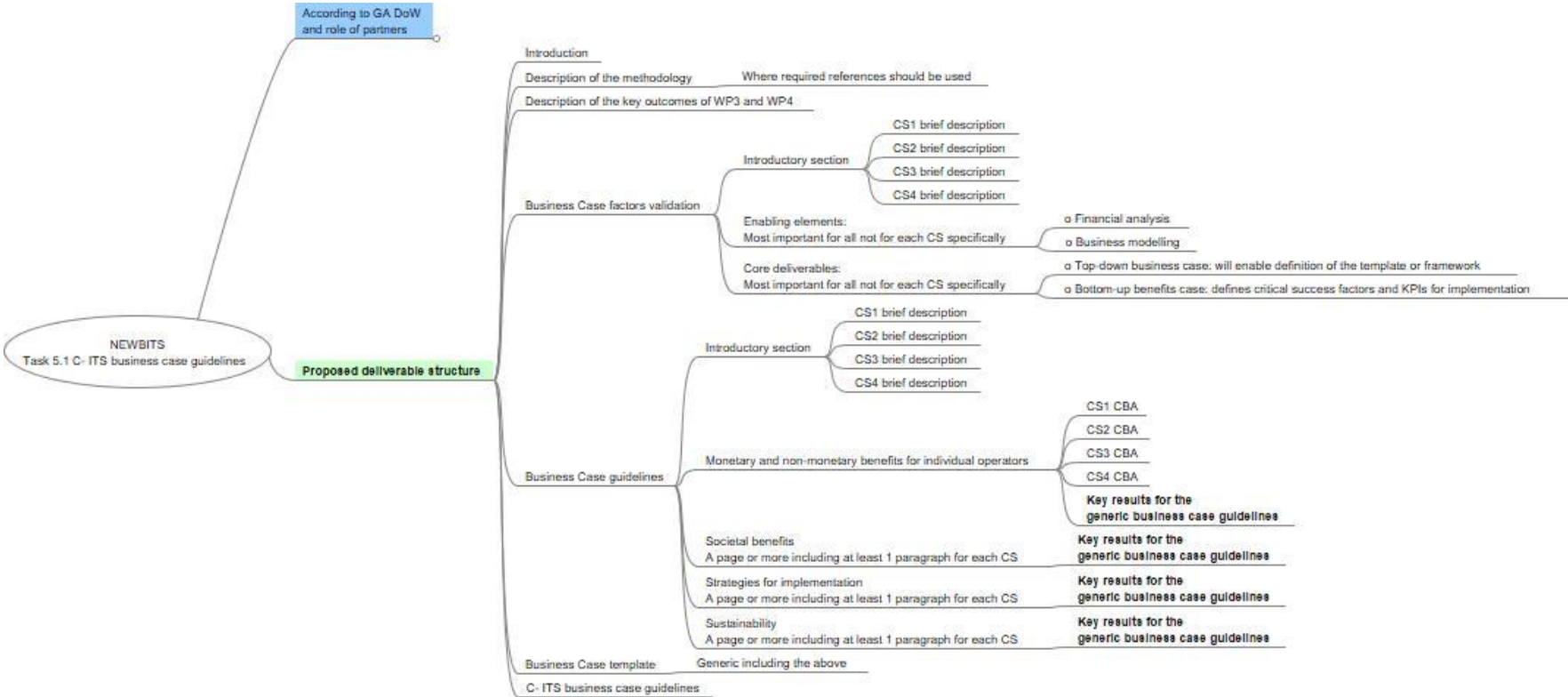
Figure 3 Deliverable 5.1 Proposed structure to cover GA DoW requirements

The dates on the following PERT chart are indicative for creating it and not the actual days that each task has been performed.
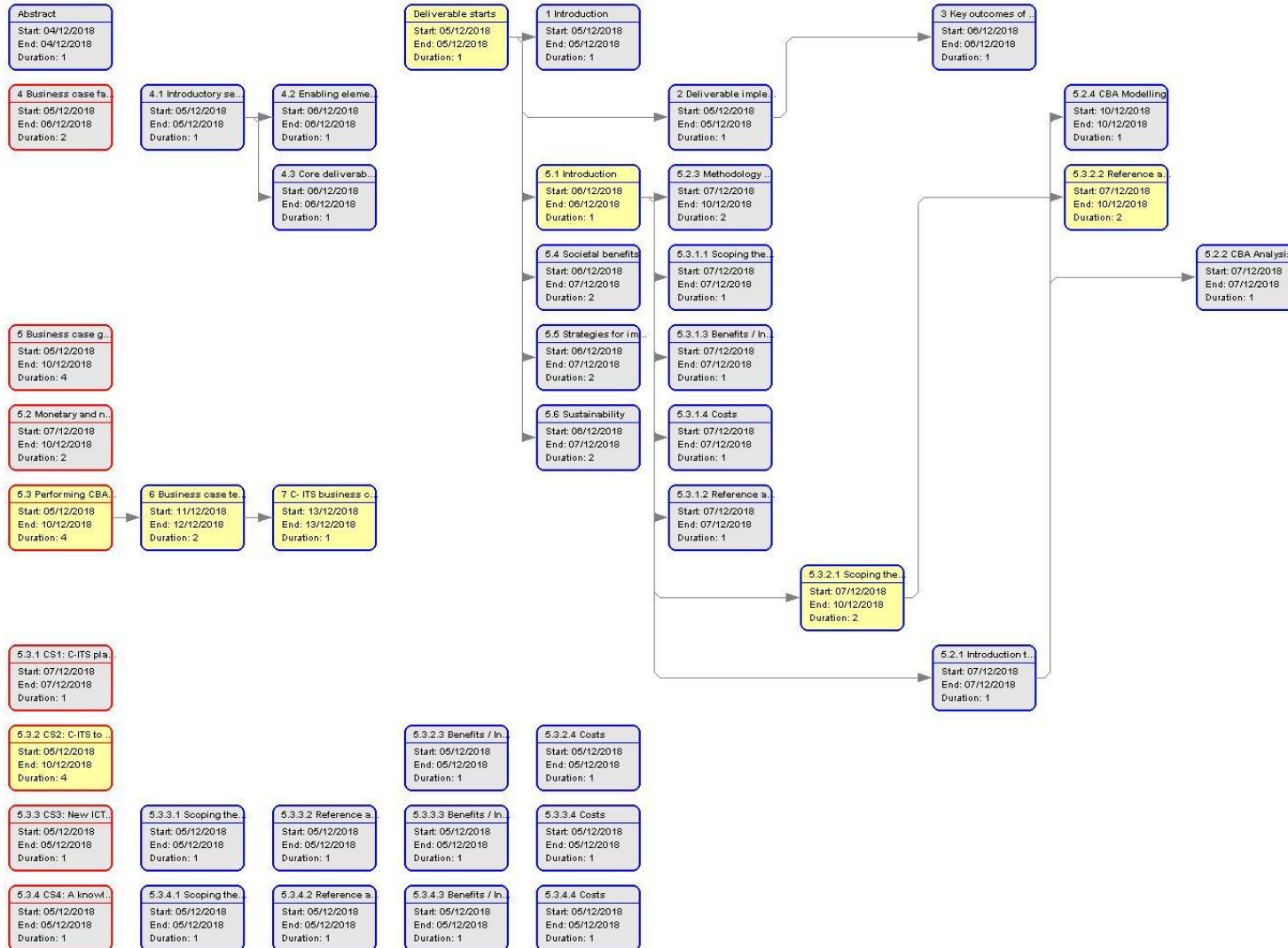
Figure 4 D5.1 Pert Diagram

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1)1st Version	• CUE provided a draft version of the CBA (including the latest feedback from all partners)
1)2nd Revision	• INTELSPACE prepared a revised structure of the Deliverable 5.1 meeting the specs according to GA and the attached mindmap
1)5.1 structure	• CUE verified the revised version of the Deliverable • CUE prepared an action plan for all partners • CUE sent the new version and proposed action plan to PM for verification
1)CBA Performed	• CUE performed CBA on the four Case studies
1)6 PMB on Stuttgart	• The revised deliverable has been verified during the PMB in Stuttgart
1)Deliverble conduction	• All partners updated the required content on the deliverable.

Figure 5 D5.1 Performed actions

3 Key outcomes of WP3 and WP4

This section describes the key outcomes of WP3 and WP4.

3.1 Key outcomes of WP3

The WP3 aimed to provide a definition of the ITS market with special focus in the NEWBITS case studies and to identify the key stakeholders taking part on each of them.

The specific objectives were:

- Provide a clear picture of the ITS market serving as background for the case studies specific information.
- Analyse the specific market for each case study including its definition, size, segmentation, target market and competitors.
- Analyse the key stakeholders for each case study identifying their characteristics, relevance and inter-relations.
- For each case study, extract the value chain resulted of the market and stakeholders' analysis.

WP3 outputs are divided in three different areas covered by each of the documents produced during the work package lifetime:

- The market research analysis outlined a general situation for the ITS market (NEWBITS Project, 2018) [1][1], followed by a specific market and stakeholder analysis over the case studies (NEWBITS Project, 2018) [2][2].
- The benchmarking analysis provided a comparison of the ITS deployment in the EU and US (NEWBITS Project, 2018) [3][3] along with an identification of ITS innovation areas (NEWBITS Project, 2018) [4][4] and the relevant indicators and recommendations for improving innovation diffusion over the selected areas (NEWBITS Project, 2018) [5][5].
- The conjoint analysis added another level of dissection to the case studies [2] to extract the end-users preferences [4].

More specifically, the most relevant information derived from WP3 that summarizes/synthesizes the enablers and barriers identified and that has been used in the elaboration of this deliverable is:

- Case study one is a carpooling service deployed in the campus of the Universitat Autonoma de Barcelona with a B2C approach. The market situation locates the main customers of the solution in Spain extending the service to other campuses and industrial areas, although the solution is potentially scalable to any other city of region in Europe. The resulting value chain of the case study locates the highest cost in the operations activities and the solution could highly benefit of an initial investment in making the end-users aware of the existence of the solution.
- Case study two is a traffic light infrastructure integrated in the Urban Traffic Control and an Energy Efficient Intersection Service (EEIS) deployed in the Municipality of Verona. It has a B2C approach where the solution is applicable to any of the 45,000 delay hot-spots in Europe. The inbound logistics activities are the main costs deduced from the value chain affecting the operations activities too. The solution can take advantage from a strong marketing campaign increasing the direct and indirect benefits and accelerating the profits of the solutions.

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[1] NEWBITS Project (2018) D3.1 Market Research Analysis Section 2, Available at: http://newbits-project.eu/wp-content/uploads/2016/12/NEWBITS_D3.1_Market-Research-Analysis_v1.0.pdf Accessed on November 2018

[2] NEWBITS Project (2018) D3.1 Market Research Analysis Section 3, Available at: http://newbits-project.eu/wp-content/uploads/2016/12/NEWBITS_D3.1_Market-Research-Analysis_v1.0.pdf Accessed on November 2018

[3] NEWBITS Project (2018) D3.2 Benchmarking ITS innovation diffusion and ITS production processes EU vs. US Section 3, Available at: http://newbits-project.eu/wp-content/uploads/2018/02/NEWBITS_D3.2_Benchmarking-ITS-in-EU-and-US_v1.0.pdf Accessed on November 2018

[4] NEWBITS Project (2018) D3.2 Benchmarking ITS innovation diffusion and ITS production processes EU vs. US Section 4, Available at: http://newbits-project.eu/wp-content/uploads/2018/02/NEWBITS_D3.2_Benchmarking-ITS-in-EU-and-US_v1.0.pdf Accessed on November 2018

[5] NEWBITS Project (2018) D3.2 Benchmarking ITS innovation diffusion and ITS production processes EU vs. US Section 5, Available at: http://newbits-project.eu/wp-content/uploads/2018/02/NEWBITS_D3.2_Benchmarking-ITS-in-EU-and-US_v1.0.pdf Accessed on November 2018

- Case study three is a synchromodal track-and-trace solution including a forecasting of container arrival service located in the corridor Rotterdam-Limburg. The solution compounds a B2B model for shippers, inland terminals and warehouse operators. There are big opportunities in Netherlands for the solution (several shippers and around 30 other inland terminals are operating in the country) and the solution is applicable to other deep sea – inland corridors outside the country. The value chain locates the highest costs in the development phase and shows a great business potential with several models for the commercialised solution.
- Case study four is a predictive maintenance solution deployed in the London North Western route from London to Carlisle. The solution is clearly defined for the UK market with high potential to be expanded to other rail lines and other train and freight operators operating in these lines. The value chain shows the highest costs coming from the operation activities and the solution benefits of having an important stakeholder (Network Rail) able to promote the solution to the rest of the rail lines and operators in the UK market.

3.2 Key outcomes of WP4

The overall aim of WP4 was a practical tailor-made Value Network Approach, which is an integral part of both the project NEWBITS, and the particular work package, and then elaborate on the methods and techniques that were used. By DoW, there were five main objectives to be achieved. The WP4 Objectives were then to:

- Focus on economic and commercial aspects of C-ITS and ITS markets;
- Define the network context based on the theoretical perspectives and elaborate on new business models;
- Apply the Value Network Approach to generate sufficient information about value flows among stakeholders in the C-ITS and ITS networks;
- Implement the analysis to the case studies in order to extract specific details about the competitive environment;
- And set-up the grounds for a systemic approach to business modelling

The key outcomes of WP4 were the value flow maps. The following information[6] are the outputs from D4.3 and the key points are described in this section. The value flow maps in **CS1** provided a qualitative indication of all ways in which UAB as an institution, creating scientific knowledge and innovations, delivers value to the stakeholder network in Barcelona. The model showed the direct interactions between all units of UAB and the rest of the stakeholders, as well as the relevant direct interactions among other stakeholders. The maps demonstrated the connectedness of each stakeholder to the rest of the network. Also, certain stakeholders, such as members of university community End-users and the Government have direct interactions with the UAB management through the policy collaboration and engagement. The end-users or the public are also linked to the government institutions through expressing public opinions or participating in different polls. They play also an

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[6] NEWBITS Project (2018) D4.3 Report on Value Network Analysis for NEWBITS, Available at: http://newbits-project.eu/wp-content/uploads/2018/02/NEWBITS_D4.3_ Report on Value Network Analysis for NEWBITS.pdf Accessed on November 2018

important role in the delivery of value throughout the network. One of the significant type of value flows that are categorised as knowledge & information or policy & opinions are not easily quantifiable or monetizable, however, this was included in this analytical technique which gave the opportunity to complete understanding of the ultimate value delivered by the Barcelona network. In this network, the knowledge is treated as a public good and the knowledge-intensity of the network is high.

In **CS2**, the value flow maps demonstrate qualitatively how the city authority of Verona (Italy) as a public service unit delivers value to the stakeholder network. The model of this case shows all direct interactions between the municipality and the national government (EU agencies) on one side, and the relevant interactions among the rest of the network, on the other side. The final map identified thoroughly the connectedness of each stakeholder to the rest. Swarco Mizar provides all the innovative ITS mobility services to the municipality. Municipality is responsible for maintaining the digital infrastructure and delivering the mobile apps to the citizens of Verona (end-users). Knowledge & information and policy & opinions value flows are also included in the CS2's network interactions, although there is no huge volume of such exchanges among all stakeholders. The ITS scientific knowledge is produced by the R&D departments of the three major private actors and disseminated within the company internally. In this respect, when it comes to the knowledge-intensity of the network, it is more of a closed entity where the creation of knowledge is treated as private goods & services concentrated in a few stakeholders, which are sold to the public sector later, and then disseminated to the public.

In **CS3**, the value flow maps qualitatively indicate how a research organisation, co-financed by the network's stakeholders and the government, can lead the network entity in the starting-up stage and deliver value to all of them. As the model suggests there is very close connectedness between TNO and the rest of the stakeholders. The Dutch government transfers its policy directions and instructions via LIOF, Dinalog, TNO and Port of Rotterdam to the industry. Knowledge & information value flows as non-quantifiable categories suggest an intensive flow of scientific and technical knowledge between TNO and the stakeholders. TNO also keeps close relations with the educators in order to update them on technical topics and provide them with educational materials from the industry whenever necessary. The other stakeholders such as the information service provider, platform developer and Portdat that are involved with the operation of the ITS /ICT platform, whenever they detect ITS challenges, they communicate with the educators in order to find solutions to these issues.

The network in CS3 is very dependent on the sharing of data and data transfer to the platform developer. It is a data-driven operational entity and a knowledge-intensive network with an opening sharing of knowledge, information and data among all 13 stakeholders.

In **CS4**, the qualitative value flow maps demonstrate how additional big data analytics services offered by Coventry University Group to the Network Rail can create new value delivered to the stakeholder network. The university was not an originator of this network, the initiative was triggered by Network Rail that tries on a daily basis under the ORR's instructions to reduce its losses. The university's research unit was hired to deliver the big data analytic services. However, as the model suggests there is close connectedness between the university and the rest of the stakeholders via the knowledge value flows. The monopoly nature of the railway industry predefines the relations between the regulators and

the industry's players. The UK government has set up the framework within which the industry operates a long time ago. Department for Transport and Transport Scotland transfer its policy directions to the industry's regulators, which then inform the major actors of the railway sector how to comply with them.

In particular CS4, as the offered service in the North-west region of the United Kingdom relates to the exchange/ analysis of data and its sharing with stakeholders, the network's operations are data-driven and knowledge-intensive. Coventry university transfer scientific and technical knowledge to the rest of the network. All 10 stakeholders benefit from the value created by the exchange of structured and analysed data, which supports them in offering better and safer railway services in the UK. This in return leads to a better feedback coming from the UK public to the governmental institutions about the public satisfaction of the railway services. As there is a direct interaction between the citizens and the UK government, in CS4 the public plays a crucial role in the delivery of value throughout the stakeholder network.

4 Business case factors validation

4.1 Introductory section

A Business Case is a generic term for a collection of evidence assembled in a logical and coherent way, which explains the contribution of a proposed investment or project to organisational objectives (Metrolinx, 2018) [51]. Business Cases are prepared to provide timely information on potential investments to inform decision-making and support investment optimisation as the investment advances through planning, design, delivery and operation.

The aim is to identify the effect that a course of action will have on the finances and on securing efficiency, economy and safety of operation in transport services. The achievement of efficiency is defined by the business objective that focuses on maximising net social benefits within the funds available (TfL: Business Case Development Manual, 2013[7]) [6]. It is vital to state the objectives of the project as precisely as possible and referring to specific outputs against which the project can subsequently be monitored.

A Business Case defines the value a project will deliver. Costs and benefits are key reference points, but other elements contribute significantly to presenting a solid and coherent Business Case[8][7].

HM Treasury (2018) provide an overview of the Five Case Model Methodology for the preparation of business cases. The Five Case Model is applicable to policies, strategies, programmes and projects and comprises of five key dimensions:

- The Strategic Case
- The Economic Case
- The Commercial Case
- The Financial Case

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[7] Transport for London (TfL) (2013) Business Case Development Manual. Issued by TfL Programme Management Office, V101.2013.05

[8] https://www.pmi.org/learning/library/need-business-case-6730

- The Management Case

4.1.1 The Strategic Case

The purpose of the strategic dimension of the business case is to make the case for change and to demonstrate how it provides strategic fit. Demonstrating that the scheme provides synergy and holistic fit with other projects and programmes within the strategic portfolio requires an up-to-date organisational business strategy that references all relevant local, regional and national policies and targets. Making a robust case for change requires a clear understanding of the rationale, drivers and objectives for the spending proposal, which must be made SMART – Specific, Measurable, Achievable, Relevant and Time constrained – for the purposes of post-evaluation. Figure 6 provides the contents of the strategic case.

Strategic Context
Organisational overview
Business strategy and aims
Other relevant strategies

The Case for Change

Spending objectives
Existing arrangements
Business needs – current and future
Potential scope and service requirements
Main benefits and risks
Constraints and dependencies

Figure 6 Contents of the Strategic Case (Source: HM Treasury 2018)

4.1.2 The Economic Case

The purpose of the economic dimension of the business case is to identify the proposal that delivers best public value to society, including wider social and environmental effects. Demonstrating public value requires a wide range of realistic options to be appraised (the long-list), in terms of how well they meet the spending objectives and critical success factors for the scheme; and then a reduced number of possible options (the short-list) to be examined in further detail.

Critical Success factors
Long-listed options
Preferred Way Forward

Shortlisted options (including the "Business As Usual (BAU)" and 'do minimum')
NPSC/NPSV findings
Benefits appraisal
Risk assessment
Sensitivity analysis
Preferred option

Figure 7 Contents of the Economic Case (Source: HM Treasury 2018)

4.1.3   The Commercial Case

The purpose of the commercial dimension of the business case is to demonstrate that the preferred option will result in a viable procurement and a well-structured Deal between the public sector and its service providers. Demonstrating a viable procurement requires an understanding of the market place, knowledge of what is realistically achievable by the supply side and research into the procurement routes that will deliver best value to both parties.

Procurement strategy and route
Service requirements and outputs
Risk allocation
Charging mechanism
Key contractual arrangements
Personnel implications
Accountancy treatment

Figure 8: Contents of the Commercial Case (Source: HM Treasury 2018)

4.1.4   The Financial Case

The purpose of the financial dimension of the business case is to demonstrate the affordability and funding of the preferred option, including the support of stakeholders and customers, as required. Demonstrating the affordability and fundability of the preferred option requires a complete understanding of the capital, revenue and whole life costs of the scheme and of how the Deal will impact upon the balance sheet, income and expenditure and pricing arrangements (if any) of the organisation.

Capital and revenue requirements
Net effect on prices (if any)
Impact on balance sheet
Impact on income and expenditure account
Overall affordability and funding
Confirmation of stakeholder/customer support (if applicable)

Figure 9: Contents of the Financial Case (Source: HM Treasury 2018)

4.1.5   The Management Case

The purpose of the management dimension of the business case is to demonstrate that robust arrangements are in place for the delivery, monitoring and evaluation of the scheme, including feedback into the organisation's strategic planning cycle. Demonstrating that the preferred option can be successfully delivered requires evidencing that the scheme is being managed in accordance with best practice, subjected to independent assurance and that the necessary arrangements are in place for change and contract management, benefits realisation and risk management.

Programme management governance arrangements (roles, responsibilities, plans etc.)
Project management governance arrangements

Use of specialist advisers
Change and contract management arrangements
Benefits realisation arrangements (including plans and register)
Risk management arrangements (including plans and register)
Post-implementation and evaluation arrangements
Contingency arrangements and plans

Figure 10: Contents of the Management Case (Source: HM Treasury 2018)

The specifics for each case study for which the business case guidelines are developed are:

- **Case study 1:** this case study represents a good case for NEWBITS project to take and explore as an example of advancing ITS applications and applying them in social services which can benefit city communities. With an aim at developing sustainable business models, the case study could expand the market to a national level as it could be implemented in other university campuses, cities or industrial zones.
- **Case study 2:** this case study has a clear business model already defined and localised but it has a great potential of being extrapolated to other municipalities and therefore reaching many other drivers and road transport operators. The most interesting part is not only its scalability but also the implicit potential of growth through the creation of future value-added services by third parties which could both re-shape the current model and create new opportunities offering these services to citizens and industry and thus generating a variety of new business models.
- **Case study 3:** The case study is a B2B solution aiming at providing an overall improvement of the supply chain in freight transport (containers) from the sea to the hinterlands. The case study has great opportunities of commercialisation and is pretty open in the services it can offer to different customers, with high chances of customisation and different potential business models (fee-for-service, integration, service customisation, value added services, data exploitation, etc.).
- **Case study 4:** similarly, to case study 2, this case study is much localised but right now it only covers part of the complex and large railway network in the UK. The case study offers the potential to enter the market expanding its services to other railway lines in the UK (which is already a big market itself) and some of the components could be used in other countries too, creating (even with a reduced scope) potential business models / opportunities outside UK.

Based on the elements described in this section, a business case template for each individual case study is developed in this deliverable.

4.2 Enabling elements

Every business needs planning. "A business plan is a blue print, detailing what business are or business concept is, what is expected for the business, how management intends to get the firm to that point, and, of greatest importance, the specific reasons why it is expected to succeed" (DeThomas and Derammelaere, 2008)[8][9]. Business plan is made from different

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[9] DeThomas, A. R./Derammelaere, S. A. (2008): Writing a convincing business plan, 3rd edition, Hauppauge 2008.

parts and/or sections. It contains a market analysis and details of strategic marketing, management structure, personnel and finance forecasting (DeThomas and Derammelaere, 2008; McKeever, 2008)[9] [10]. "A full analysis of the market, the management, the finances, and the product is necessary to the health of any venture, and the planning process forces you to undertake that analysis. Without it, one or another of these areas may be neglected in the whirl of day-to-day operations" (Brooks and Stevens, 1987)[10][11]. Hence, it includes the object of activity, market analysis, and specific approach to strategy of marketing, management structure, personnel and all relevant financial information of the company.

4.2.1 Financial analysis

Business plan is made from different parts and one of them is financial plan. To write a good financial plan is recommended to use financial analysis. Financial analysis should be conducted in nominal terms (which means all costs and revenue changes should include the impact of inflation). Financial analysis is concerned with four overall factors based on their incremental impact over the BAU scenario:

- Capital Costs – changes in expenditure to procure/deliver infrastructure or core systems required to deliver the investment
- Operating and Maintenance Costs – changes in expenditure to operate and maintain the investment (example: cost of operating a bus)
- Revenue – changes to revenue from fares (or other customer ticketing products) and non-fares (example: revenue from property)
- Labour Requirements – changes to the level of staffing to deliver and operate the investment

Figure 12 demonstrates the financial case analysis over the business case lifecycle.

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[10] McKeever, M. (2007), "How to write a Business Plan" Ninth Edition, Consolidated Printers, Inc., The USA, 2007;

[11] Brooks, J. K. and Stevens B. A. (1987), "How to Write a Successful Business Plan", The USA, 1987

Initial Business Case

• Conduct an analysis of each option using best available cost and revenue estimates

• Conduct sensitivity testing to understand the key cost and revenue drivers and level of uncertainty for each option

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Preliminary Design Business Case

• Update the analysis conducted in the Initial Business Case based on any changes to investment specification or detailed design

• Analytic tools may be updated to ensure all analysis and forecasting is commensurate with the level of specification and scale of the investment

↓

Full Business Case

• Update the analysis conducted in the Preliminary Design Business Case based on any design refinements

• Analytic tools may be updated to ensure all analysis and forecasting is commensurate with the level of specification and scale of the investment

↓

Post In-Service Business Case

• Review financial narrative and compare estimated performance against collected data

• Update costs and revenue and re-forecast where relevant

Figure 11: Financial case analysis over the business case lifecycle

4.2.2 Business modelling

A business model is a set of assumptions about how an organization will create value for all its stakeholders (Traganos et al. 2015)[11][12].

While the general view in the past years has been that ITS in general would provide a revolutionary change in the efficiency and safety of transport, the truth is that many of the most promising (C)-ITS applications have failed to make it beyond trial phases. In order to support increased commercially sustainable (C)-ITS deployments, there is a need to develop sound, adaptive and innovative business models for the actors along the (C)-ITS value chain, identifying potential incentives to accelerate deployment and limit the impact of a "last mover advantage" approach. Moreover, since ITS are questioning the way transport innovation is developed, there is the need to define new collaboration models, building sufficient confidence for the private and public stakeholders to invest steadily. NEWBITS acknowledges this situation and proposes to apply a network-oriented approach in order to better define the C-ITS scenario and be able to assess truly effective value creation propositions from a dynamic system perspective.

The NEWBITS project as described in the DoW is built on the belief that better information leads to better decision-making. Organizations nowadays are still working in silos not effectively feeding each other with knowledge and basically not "seeing" each other as parts of an interconnected ecosystem. In order to enable stakeholders to learn from each other and build a common pool of knowledge, resulting in decisions that are most valuable to the system, shared tools and methods are needed.

Thus, the project fosters a business ecosystem approach for C-ITS which acknowledges the context of economics of networks by introducing a higher conceptual level than that of individual organisations, focusing at how organisations create value within the context of the networks in which they interoperate.

The consortium designs and implements a holistic intelligence process that maps the C-ITS ecosystem (initiatives, projects, actors), identify C-ITS enablers and barriers, investigating existing key performance indicators, and gathering relevant information on products, market, demand, stakeholder's involvement and innovation diffusion for C-ITS.

NEWBITS formalises the enhanced understanding of the potential system benefits and fundamental economics of new business models suited to C-ITS in the European context and develops relevant outcomes to support policy measures towards C-ITS deployment.

Business models are primary tools for the financial analysis of nearly all major business decisions (Tennent and Friend, 2011)[12][13]. A Cost Benefit Analysis is conducted in this deliverable to assist in decision-making and designing new business case guidelines. Organizations rely on cost benefit analysis to support decision making because it provides an

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[12] Traganos, Kostas & Grefen, Paul & den Hollander, Aafke & Turetken, Oktay & Eshuis, Rik. (2015). Business model prototyping for intelligent transport systems: a service-dominant approach. 10.13140/RG.2.2.23069.72160

[13] Tennent, J and Friend, G (2011) 'Guide to Business Modelling' 3rd Ed, John Wiley & Sons

agnostic, evidence-based view of the issue being evaluated without external influences [14]. A cost benefit analysis is an invaluable tool to assess the feasibility of a project.

The combination of the holistic intelligence process, the CBA analysis, tailored VNA and business model assessment throughout NEWBITS project expects to support an increased effectiveness of the generation of new business models, facilitating the connection amongst actors and visualizing specific interactions within the network while providing a practice-based perspective for understanding value-creating roles.

NEWBITS will generate valuable know-how about (C-) ITS deployment pathways, innovation diffusion and C-ITS value networks that should reach private and public stakeholders at operative and policy making level. The results extracted from the case studies will be generalized following NEWBITS method in order to present a more general conclusion on C-ITS business ecosystems.

4.3 Core deliverables

The NEWBITS project intends to develop novel business models in four case studies, effectively involving the target core stakeholders. The work performed in WP3 and WP4 of the project provide all the required information to identify the critical success factors and key performance indicators of the four business cases that are derived from the case studies. In the proposed business cases the novel business models will be adopted.

Cost-Benefit Analysis is a method to assess the effects of policies and projects on social welfare and is normally a top-down approach; meaning a central decision-making body issues guidance on which policies or projects are assessed, and how the costs and benefits to society are identified and then measured (Carolus et al, 2018)[14][15]. They further state that CBA outcomes are used in the policy development process and as a driver of regulatory decision-making. A bottom-up CBA on the other hand, Carolus et al (2018)[14] argue, allows a more informed development of regulatory policies. Instead of starting with a policy or project option, this approach begins with an environmental problem, and then assesses costs and benefits of strategies identified by "local" stakeholders in pursuit of addressing this problem. While a top-down CBA can be used to assess the trade-offs of an already-defined set of projects or policies, the bottom-up approach takes advantage of additional case-specific knowledge, and assesses strategies which might be more likely to be accepted by the local society, and are better adapted to local conditions (Carolus et al, 2018)[14].

The core deliverables of 5.1 are:

- Top-down business case: will enable definition of the template or framework
- Bottom-up benefits case: defines critical success factors and KPIs for implementation

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[14] https://www.smartsheet.com/expert-guide-cost-benefit-analysis

[15] Carolus, Johannes & Hanley, Nick & Olsen, Søren & Pedersen, S.M.. (2018). A Bottom-up Approach to Environmental Cost-Benefit Analysis. University of St. Andrews Discussion Papers in Environment and Development Economics. Paper 2018-03.. 10.13140/RG.2.2.15307.08480.

For the purposes of the NEWBITS project, the following operative descriptions explained in D2.1 [15][16] are used:

- Initiative–they are defined as FP7-Horizon2020 projects, scientific reports, policy papers, research reports, other strategic reports and communications;
- Case Studies (CS) –NEWBITS follows a case study-based approach. Case studies are envisaged to emphasize contextual analysis of a limited number of conditions and their relationships. They will bring understanding of the complexities of ITS and provide knowledge about the existing value creation systems;
- Application –the project considers applications as the use given to ITS in order to achieve a purpose, so this is a combination of several technologies in order to fulfil user requirements related to a transport mode. And applications are aligned with the concept of service. Examples of ITS services are traffic jam warning, green light optimal speed advisory, V2V merging assistance, etc.

From the DoW, these are the case studies suggested for the project's use:

- CS1: ITS intelligent carpooling system for daily mobility VAOPoint
- CS2: C-ITS to manage the drivers' behaviour crossing traffic lights intersections
- CS3: New ICT method to increase efficiency in logistic chain of ports
- CS4: A knowledge-based approach to understanding railway safety

The Top-down business Case will:

- provide details of the overall balance of benefits and costs against objectives and set out plans for monitoring and evaluating these benefits when required for each of the case study;
- provide the business and financial rationale for the project;
- demonstrate how the return would justify the overall investment of time and money;

The Bottom-up benefits case will:

- define critical success factors; and
- KPIs for implementation

4.3.1 Success factors

Critical success factor (CSF) is a management term for an element that is necessary for an organization or project to achieve its mission [16][17]. A CSF is a critical factor or activity required for ensuring the success of a company or an organization [17][18].

"Critical success factors are those few things that must go well to ensure success for a manager or an organization and, therefore, they represent those managerial or enterprise

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[16] NEWBITS, D2.1 "Overview of ITS initiatives in the EU and US", March 2017
[17] BusinessDictionary, Critical success factors (CSF) [Online] Available at http://www.businessdictionary.com/definition/critical-success-factors-CSF.html Accessed December 2018.
[18] Wikipedia (2017), Critical success factor, [Online], Available: https://en.wikipedia.org/wiki/Critical_success_factor , 19th December 2018

areas that must be given special and continual attention to bring about high performance. CSFs include issues vital to an organization's current operating activities and to its future success."[18][19].

As a definition, critical success factors refer to "the limited number of areas in which satisfactory results will ensure successful competitive performance for the individual, department, or organization"[19][20]. For each of the case studies, the CSFs will be defined. These maybe a result from specific industry characteristics, the chosen competitive strategy of the case study, a result of economic or technological change or resulting from organisational needs and changes.

The Critical Success Factors are captured in the mnemonic PRIMO-F [19] :

1. People – availability, skills and attitude
2. Resources – People, equipment, etc
3. Innovation – ideas and development
4. Marketing – supplier relation, customer satisfaction, etc
5. Operations – continuous improvement, quality,
6. Finance- cash flow, available investment etc

All the above factors will be considered in the CBA for each of the study and the results of the analysis will guide in describing the Critical Success Factors and KPIs.

4.3.1.1 *CS1 University VAOPoint Mobility*
Core success factor of VaoPoint car-sharing is its integration in an effective parking policy adopted by the university for all its campuses. Succeeding the above, VAOPoint Mobility will be considered as a valuable solution to a current problem, being an attractive value proposition for users such as students and personnel that ideally would like to save the time and expenses on parking.

During the performed analysis and through the collection of information from the case study stakeholder's, variable direct and indirect benefits of the case have been identified. The following are some of them from the perspective of UAB Mobility Unit and the rest of the stakeholders except the end users:

1) Reduction of the number of trips
2) Development of a transferrable model to assist other sites locally, nationally and internationally
3) Sharing data and data mining for the greater understanding of mobility issues, through the utilisation of ITS solutions / services
4) Adoption and visibility of the ITS solution through social media and web's campaigns
5) Foster further research upon the proposed ITS solution
6) Mutual learning, knowledge transfer and sharing expertise initiatives across all stakeholders

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[19] Boynton, A.C. and Zmud, R.W. (1984). "An Assessment of Critical Success Factors," Sloan Management Review, 25(4), pp. 17–27.
[20] RapidBi (2016), Critical Success Factors (CSF's) Made Easy. A step by step guide Available at https://rapidbi.com/criticalsuccessfactors/ Accessed: Nov 2018

7) Development of new skills and courses required to provide data-analysts in transport sector
8) Development of a framework for global solutions related to the problem that case study addresses.

From the end-user's point of view, i.e. the value proposition of the VAOPoint business case, the benefits of using ITS for assisting the development of car sharing at University, are the following:

1) Reduction in travel time and time taken to find parking spaces
2) Increase of traveling flexibility
3) Increase in the trust and confidence towards the drivers and the cars used
4) Reduction in total travelling expenditures for those sharing cars
5) Increase of income, if it is the case, for those who provide their vehicles
6) Increase in number and quality of the interaction between students
7) Reduction in mental health problems through sharing experiences
8) Increase number of supporting skills in psychology and sociology in the transportation sector

Following the above two lists of benefits, the foreseen success factors for VAOPoint in order to be transformed to a business case are the following:

Table 1 Success factors for VAOPoint Business Case

Direct and indirect effects / benefits	Success factors
Reduction of the number of trips	(BC1-SF-1) Behavioural change (BC1-SF-2) Use of the application by many users
Development of a transferrable model to assist other sites locally, nationally and internationally	(BC1-SF-3) Adoption of EC and global accepted standards, frameworks, regulations in the design and implementation of the application.
Sharing data and data mining for the greater understanding of mobility issues, through the utilisation of ITS solutions / services	(BC1-SF-4) Licensing data via proper open data licenses
Adoption and visibility of the ITS solution through social media and web's campaigns	(BC1-SF-5) Engagement in social media. Promotion of the application in different social media
Foster further research upon the proposed ITS solution	(BC1-SF-6) Academia enhances the use of the results deriving from the application in research as undergraduate and postgraduate thesis and PhD(s)
Mutual learning, knowledge transfer and sharing expertise initiatives across all stakeholders	(BC1-SF-7) Development of a human centric ecosystem for the mobility and car sharing

Development of new skills and courses required to provide data-analysts in transport sector	(BC1-SF-4), (BC1-SF-6)
Development of a framework for global solutions related to the problem that case study addresses.	(BC1-SF-3)
Reduction in travel time and time taken to find parking spaces	(BC1-SF-2)
Increase of traveling flexibility	(BC1-SF-2)
Increase in the trust and confidence towards the drivers and the cars used	(BC1-SF-8) Advanced features in the application to create confidence
Reduction in total travelling expenditures for those sharing cars.	(BC1-SF-2), (BC1-SF-3)
Increase of income, if it is the case, for those who provide their vehicles.	(BC1-SF-2), (BC1-SF-8)
Increase in number and quality the interaction between students	(BC1-SF-2)
Reduction in mental health problems through sharing experiences	(BC1-SF-1), (BC1-SF-2), (BC1-SF-8)
Increase number of supporting skills in psychology and sociology in the transportation sector	(BC1-SF-1), (BC1-SF-2), (BC1-SF-8)

4.3.1.2 *CS2 C-ITS to manage the drivers' behaviour crossing traffic lights intersections.*

According to the definition used in the deliverable "D3.3 Conjoint analysis on case studies" [20][21] case study 2 is defined as a Traffic Light Assistance (TLA) service, aiming at providing road drivers with the information to take the required driving actions when approaching traffic lights in urban areas and ultimately allowing them to avoid unnecessary stops and waiting times at urban intersections. This results in concrete traffic congestions improvements in urban areas as well as environmental and health-related benefits.

The direct and indirect benefits of transforming CS2 into a business case are related to mobility; productivity; safety and environment related issues. The proposed business case will benefit the mobility by reducing the peak period journey time and improving the traffic flow for all types of vehicles along routes where the TLA is implemented. By improving the mobility along the routes, the productivity of the users is improved. The reduction of the time

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[21] NEWBITS Project (2018) D3.3 Conjoint analysis on case studies

that vehicles are travelling; improvement of drivers' behaviour and the decrease of the resource's loss are other indirect benefits. The business case 2 will succeed to decrease the accidents along the routes. By improving the traffic flow and reducing time travel the proposed business case will succeed to affect positively environment by reducing the carbon footprint of mobility in the routes.

Following the above benefits, the foreseen success factors for CS2 to be transformed to a business case are the following:

Table 2 Success factors for C-ITS to manage the drivers' behaviour crossing traffic lights intersections business case

Direct and indirect effects / benefits	Success factors
Reduced peak period journey time	(BC2-SF-1) The solution uses real time big data, advanced alogrithms to monitor and control the intersections traffic lights
Improved traffic flow	(BC2-SF-1)
Increased of the productivity of the users	(BC2-SF-2) Use of the application by many users
Reduced time that vehicles are travelling	(BC2-SF-1), (BC2-SF-2) (BC2-SF-3) Promotion of the results deriving from the use of the application via intuitive dashboards to the city
Improved behaviour of drivers	(BC2-SF-2) Use of the application by many users (BC2-SF-4) Perform behavioural analysis and promote the results to the city. The results may attract more users and create a snowball effect
Decreased loss of the resources	(BC2-SF-1), (BC2-SF-2)
Decreased accidents in the intersections	(BC2-SF-1), (BC2-SF-2), (BC2-SF-3)
Reduced carbon footprint of mobility in the routes	(BC2-SF-1), (BC2-SF-2), (BC2-SF-3)

4.3.1.3 *CS3 New ICT method to increase efficiency in logistic chain of ports*

Case study 3 defined a track-and-trace service for container transport from the sea port to the hinterlands by inland waterway and truck (for the last mile of the container to the warehouse) [20]. The service visualises in a dashboard the real-time status, location and Estimated Time of Arrival (ETA) of containers from the moment the sea port is approached up to the moment at which the container reaches the warehouse where the container is unpacked, providing the following information: A centralised overview of the container

planning; Continuously updated ETA; Actual Time of Arrival (ATA); Container status (e.g. customs information, commercial release).

One of the benefits identified is the intelligent aggregation of information from several sources to improve logistics processes and increase the volume of containers transferred. More benefits are listed below. The volume and quality of data exchanged to be transformed into valuable information is a factor affecting the business case success. Other factors are the increase of clients using the specific port and the savings that they benefit from its use.

Table 3 Success factors for New ICT method to increase efficiency in logistic chain of ports business case

Direct and indirect effects / benefits	Success factors
Improve service functionality	(BC3-SF-1) Adopt co-creation methods in the development of the service (BC3-SF-2) Adopt creative User Interfaces for continuous user engagement
Improve logistics processes	(BC3-SF-3) Provide real time information based upon users' requirements (BC3-SF-4) Propose innovative evidence-based solutions to logistics issue
Reduced discussions on delays, container status information	(BC3-SF-5) Use innovative dashboards and AI for monitoring containers
Increase the volume of containers transferred	(BC3-SF-2), (BC3-SF-3), (BC3-SF-4), (BC3-SF-5)
Increase of clients using the specific port	(BC3-SF-6) Incorporate the service as a core service of the Port
Increase savings for customers	(BC3-SF-3), (BC3-SF-4)
Intelligent aggregation of information from several sources	(BC3-SF-3), (BC3-SF-4), (BC3-SF-5)
Increase volume and quality of data exchanged	(BC3-SF-3), (BC3-SF-4), (BC3-SF-5) (BC3-SF-7) Use Internet of Things
Skilled workforce	(BC3-SF-8) Include the use of the service and the platform in vocational training seminars
New educational material inputs	(BC3-SF-9) Collaborate with academia for the data analysis, prediction and proposition of solutions

4.3.1.4 *CS4 A Knowledge-based approach to understanding railway safety.*

Case study 4 is a predictive maintenance solution utilising state of the art computational intelligence to analyse railway data for the purpose of forecasting malfunctions of different components of the railway infrastructure [20]. The solution uses and exploits Big Data to inform decision making in key areas such as cost reduction and efficiency of the rail industry, which affects all stakeholders and rail customers in particular. The system provides informed recommendations for the optimisation of the allocation of human resources and the timely repair/replacement of equipment, enabling Network Rail (owner of the infrastructure in UK), train operators companies, rolling-stock operators and stakeholders to reduce maintenance costs, increase network availability and improve maintenance efficiency.

Benefits of CS4 are the improvement of maintenance of the railways network and the increase of passenger's safety when travelling by trains. CS4 transformed into a business case will succeed to reduce disruptions and delays during the train travelling and increase the innovation capacity in the industry moving towards secure and safe 'connected' trains.

Table 4 Success factors for a Knowledge-based approach to understanding railway safety business case

Direct and indirect effects / benefits	Success factors
Increased quantity and quality of railway acquired data	(BC4-SF-1) Use of IoT state of the art technologies (BC4-SF-2) Use of advanced data mining and data analysis methods
Improved maintenance of the railways network	(BC4-SF-3) Use of AI algorithms (BC4-SF-4) Enforcement of strict monitoring procedures from regulatory bodies
Increased safety of the passengers	(BC4-SF-1), (BC4-SF-2), (BC4-SF-3), (BC4-SF-4) (BC4-SF-5) Adoption of the method and use of the application in all railway lines
Reduced disruptions and delays	(BC4-SF-1), (BC4-SF-2), (BC4-SF-3), (BC4-SF-4), (BC4-SF-5)
Increased innovation capacity in the industry	(BC4-SF-1), (BC4-SF-2), (BC4-SF-2) (BC4-SF-6) Collaborate with academia for the data analysis, prediction and perform research related to IoT, advanced data mining and data analysis methods, AI algorithms
Skilled workforce	(BC4-SF-7) Include the use of the method / service in training seminars.

4.3.2 Key performance indicators (KPIs)

KPIs are measures which quantify management objectives, along with a target or threshold and enable the measurement of strategic performance. In the context of NEWBITS, key performance indicators measure the success of each of the four business cases. The following KPIs have been defined to quantify the expected benefits from each case study.

4.3.2.1 *CS1 VaoPoint inter-urban carpooling services in Barcelona, Spain*

The main metric that will measure the success of the system will be derived from the use made by the users and the effective reduction obtained from parking spaces and other derived benefits, for which the following metrics are proposed:

Table 5 KPIs for VaoPoint inter-urban carpooling services

Direct and indirect effects / benefits	KPIs
Reduction of the number of trips	(BC1-KPI-1) Number of trips made (BC1-KPI-2) Number of passengers in each car (BC1-KPI-3) Reduction in Car parking spaces (BC1-KPI-4) Reduction in CO_2 (BC1-KPI-5) Reduction in trip time (BC1-KPI-6) Reduction in complaints (BC1-KPI-7) Reduction in Congestion around University
Development of a transferrable model to assist other sites locally, nationally and internationally	(BC1-KPI-8) How many sites have used the model
Sharing data and data mining for the greater understanding of mobility issues, through the utilisation of ITS solutions / services	(BC1-KPI-9) Data sharing between members - number of hits
Adoption and visibility of the ITS solution through social media and web's campaigns	(BC1-KPI-10) Followers in social media
Foster further research upon the proposed ITS solution	(BC1-KPI-11) Research products / outcomes / results
Mutual learning, knowledge transfer and sharing expertise initiatives across all stakeholders	(BC1-KPI-12) Number of transfers
Development of new skills and courses	(BC1-KPI-13) Number of courses

required to provide data-analysts in transport sector	(BC1-KPI-14) Number of projects proposed
Development of a framework for global solutions related to the problem that case study addresses.	

4.3.2.2 *CS2 C-ITS City mobility platform in Verona, Italy*

Table 6 KPIs for C-ITS to manage the drivers' behaviour in crossing traffic lights intersections business case

Direct and indirect effects / benefits	KPIs
Reduced peak period journey time	(BC2-KPI-1) Peak period journey time
Improved traffic flow	(BC2-KPI-2) Number of trips made inside the area that service is available (BC2-KPI-3) Hours spent on travelling inside the area that service is available
Increased the productivity of the users	(BC2-KPI-3) (BC2-KPI-4) Average duration of the trip inside the area
Reduced time that vehicles are travelling	(BC2-KPI-3)
Improved behaviour of drivers	(BC2-KPI-5) Number of education materials
Decreased loss of the resources	(BC2-KPI-3), (BC2-KPI-7)
Decreased accidents in the intersections	(BC2-KPI-6) Number of accidents
Reduced carbon footprint of mobility in the routes	(BC2-KPI-6) CO_2 emissions

4.3.2.3 *CS3 New ICT method to increase efficiency in logistic chain of ports*

The KPIs for case study 3 are listed in table 7.

Table 7 KPIs for "New ICT method to increase efficiency in logistic chain of ports" business case

Direct and indirect effects / benefits	KPIs
Improve service functionality	(BC3-KPI-1) Customer satisfaction data
Improve logistics processes	(BC3-KPI-2) Time for completion logistics processes
Reduced discussions on delays, container status information	(BC3-KPI-3) Time for delays of containers delivery
Increase the volume of containers transferred	(BC3-KPI-4) Number of containers
Increase of clients using the specific port	(BC3-KPI-5) Number of clients
Increase savings for customers	(BC3-KPI-2)
Intelligent aggregation of information from several sources	(BC3-KPI-6) Number of data sources (BC3-KPI-7) Number of data sets (BC3-KPI-8) Number of records (data)
Increase volume and quality of data exchanged	(BC3-KPI-7), (BC3-KPI-8)
Skilled workforce	(BC3-KPI-9) Number of skilled employees
New educational material inputs	(BC3-KPI-10) Number of educational materials

4.3.2.4 *CS4 A Knowledge-based approach to understanding railway safety.*

Table 8 KPIs for a Knowledge-based approach to understanding railway safety.

Direct and indirect effects / benefits	KPIs
Increased quantity and quality of railway acquired data	(BC4-KPI-1) Number of data sources (BC4-KPI-2) Number of data sets (BC4-KPI-3) Number of records (data)
Improved maintenance of the railways network	(BC4-KPI-4) Number of identified incidents that required maintenance (BC4-KPI-5) Number of incidents addressed
Increased safety of the passengers	(BC4-KPI-6) Passengers satisfaction data (BC4-KPI-7) Reduction of accidents due to maintenance issues
Reduced disruptions and delays	(BC4-KPI-8) Reduction of disruptions due to maintenance issues (BC4-KPI-9) Reduction of delays due to maintenance issues
Increased innovation capacity in the industry	(BC4-KPI-10) Number of innovations adopted for the predictive maintenance of railway lines
Skilled workforce	(BC4-KPI-11) Number of skilled workers / employees (BC4-KPI-12) Number of training materials

5 Business case guidelines of NEWBITS four case studies

This section describes the case studies chosen by NEWBITS, the selection and configuration of the case studies has taken into consideration several key factors as described in the GA-DoW such as:

- Representative of a key business area of ITS / C-ITS and of all 4 modes of transport (highlighting the actual potentials and benefits of C-ITS cross-modally)
- Relevant in terms of functional scalability: all selected case studies are grounded on the ability to enhance the system by adding new functionalities
- Potential to facilitate knowledge sharing amongst involved actors
- Key actor mapping and involvement, considering a key factor to foster (C)-ITS innovative business modelling: willingness to share know-how amongst the key actors involved and existing potential to stimulate innovative public procurement processes

- Built on experience and context appropriate, therefore pivoting on existing capabilities and knowledge of the actors involved in its formulation and linked to prior/on-going accessible research
- Validated potential to nurture a new or recreated operating leverage proposal or growth-market opportunity, which could be adapted to the existing business environment or extrapolated to other (existing or to be created) business ecosystems.

The following introductions to the 4 case studies are adapted from the deliverable D3.1[22] as described, they provide how the case studies are defined and provide an insight to each of the case studies.

5.1 Definition of CS1: ITS intelligent carpooling system for daily mobility VAOPoint

After a failed attempt to recover administrative support from two municipalities in the Barcelona province in deploying a sustainable intercity mobility solution, University VaoPoint Mobility (CS1) offers a second level carpooling service for access to university campuses. CS1 aims to increase the average occupation and achieving a rational use of cars in a university environment with high levels of daily influx of private vehicles. It offers an intelligent carpooling service for daily mobility to the campus, where members of the university community can access numerous carpooling offers. In addition to traditional cost savings on sharing transportation expenses, VaoPoint promotes the reduction of users' carbon footprint and decrease traffic congestion by promoting high-occupancy vehicles.

The project initiated by an SME (Aslogic) has been piloted in its first city trial/deployment to members of the university community at the Autonomous University of Barcelona (UAB) for access to the campus. UAB's mobility plan includes promoting collective transport, journeys by bicycles as well as achieving more rational use of private vehicles matching the goals of VaoPoint. UAB campus get filled up with over 13,000 vehicles of a very low occupation index: 1.2 people per vehicle - the same average as that of the metropolitan region of Barcelona. CS1 primary objective is to reduce the number of cars accessing the campus, which in turn reduces users' carbon footprint (CO_2) and pollution.

The innovative platform was jointly developed by Aslogic and the Logistic and Aeronautics unit of the UAB under the Framework Programme 7 EU-funded project "frontierCities" [21][23]. "frontierCities" aims to promote the use of FIWARE technologies (through the awarded projects) and the uptake of developed mobility applications as well as to support SMEs and start-ups to develop Smart Mobility applications for cities across Europe.

CS1 objectives rely mainly on three aspects:

- Efficiency: Matching users to vehicles and minimising as much as possible trajectory deviations.

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[22] NEWBITS Project (2018) D3.1 Market Research Analysis, Available at: http://newbits-project.eu/wp-content/uploads/2016/12/NEWBITS_D3.1_Market-Research-Analysis_v1.0.pdf Accessed on November 2018

[23] Source: fronierCities|VAOPOINT Project http://www.fi-frontiercities.eu/frontiercities-2

- Comfort: Encourage social preferences matching of users, avoid campus pathway bottlenecks and guarantee access to parking area.
- Environmental issues: Reduce the carbon footprint (CO_2) and pollution as a result of the reduction in the number of cars used.

These objectives have been validated at the UAB with a measurable impact of an increase in car occupancy factor. This in consequence, has reduced the number of vehicles accessing the campus facilities through different control systems, in which a real time information sharing mechanism is critical for the robustness and resilience of the ITS service. CS1 proposes a differential innovation, since it introduces a new service in an existing market that can reduce the flow of vehicles into the university campus, but also can be applied to other transit scenarios with similar problems outside of the University such as interurban mobility and industrial parks.

5.2 Definition of CS2: C-ITS to manage the drivers' behaviour crossing traffic lights intersections

Case study 2 refers to the C-ITS applications implemented in the past few years in the city of Verona, with particular reference to the activities of the EC (European Commision) Compass4D project. Verona is located in the Veneto region, northern Italy, with approx. 265.000 inhabitants. It is the second largest municipality in the region.

Prior than the Compass4D pilot application, Verona city early introduced a traffic management platform in the traffic management centre (TMC), where autonomous ITS systems and applications exchange data and are coordinated by a higher-level subsystem.

Such a system included OMNIA, an ITS platform that supports an open architecture where any ITS system can be integrated within the platform, independently of the supplier product or technology. This system acquires all the traffic measures and stores it in the central system archive together with their estimated statistical profile such as traffic volumes, speed, etc. and traffic related data (e.g. signal plan, clearance capacity, turning proportions etc.). More than 150 intersections in Verona were connected with this platform. The system also included MISTIC, an Info mobility platform or Town Supervisor for cooperative traffic monitoring in the traffic management centre (TMC), and UTOPIA, a traffic management control system that provides adaptive traffic control strategies. Moreover 33 variable message signs in the urban were implemented for parking info (urban), traffic info and collective routing.

With the Compass4D pilot application, started in 2013, part of the city, in particular the main corridor and arteries, has been equipped with a cooperative RSU (Roadside Unit) system, made up of 25 ETSI 5G compliant units, OBUs (On-Board Unit) for various vehicles, and some cameras for the safety application, due to provide an Energy Efficient Intersection Service (EEIS).

Basically, an EEIS provides advice to optimize how vehicles pass through a crossroads. Both energy and emissions are saved, avoiding any unnecessary acceleration or braking from the driver of the vehicle. To achieve this, a bi-directional radio communication system is used between the traffic light control system and the equipped vehicles.

Traffic Light Status Information is transmitted by the traffic light control unit to incoming vehicles. Inside the vehicle, the driver receives information on when the traffic light changes, either in the form of a countdown or as a speed board. This information allows the driver to anticipate the next manoeuvre and to modify its driving mode, for example decelerating when a red light turns green and therefore does not need to stop.

Moreover, in this framework, a web application has been developed for mobile devices, allowing an increasing number of users' access to numerous mobility data. The web service has been provided through 4G communication service (for "day-one" C-ITS application), through the collaboration with the national telecom operator and project partner, Telecom Italia.

Due to Compass4D implementations, new services have been provided to users: Speed Advisor System (GLOSA system), Road Hazard Warning (RHW) service, Road Works Warning (RWW), and Red light violation function. Also included in the service bundle is the implementation of TSP (Transit Signal Priority) service.

The RHW System aims to prevent collisions in case of abnormal or blind queues, and Road Works Warning aims to prevent similar circumstances. Speed Advisory instead aims to improve driving behaviours due to prevent vehicles stopping at red lights: the objective is to make smoother the traffic stream, reducing energy consumption and pollution, but also improving mean speed while reducing peak speed which can be useful also to improve road safety; moreover, the same technology is useful to prevent red light violations, but also to detect it.

The case-study objectives rely mainly on three aspects: safety, efficiency (energy, level of service) and environmental issues (reducing CO_2 and pollutant). These objectives are intended to be pursued by improving the urban traffic performances, through improving driving behaviours and control systems, thanks to the specific cooperative-ITS system implementation.

5.3 Definition of CS3: New ICT method to increase efficiency in logistic chain of ports

The subject of case study 3 (CS3) is a project called "Synchro-modal container transport corridor Rotterdam-Limburg". Synchromodality refers to the possibility of choosing the most optimal transport modality at transhipment points. To allow for this, real-time information is needed on the transport chain. In the project of case study 3 a platform is developed to share real-time data on container transport from deep sea terminal Rotterdam to warehouses in Limburg (NL) (see Figure **12**). The data collection involves tracking of the seagoing ships heading for Rotterdam, container handling in the port of Rotterdam, inland ship and truck transport and handling of the containers at the inland terminal and eventually at the warehouse. The scope of the project excludes the last mile from warehouse to final destination. Better insight in arrival of containers in Rotterdam and the rest of the logistic chain allows for better planning and shorter transport times. Currently it can take about 10 days to ship the container from Rotterdam to Limburg, of which it is moving less than 24 hours. There is a lot of potential to reduce transport time by decreasing the amount of idle time. The project under study aims at proofing the principle with a research platform and to convert it to an operational platform by service providers.
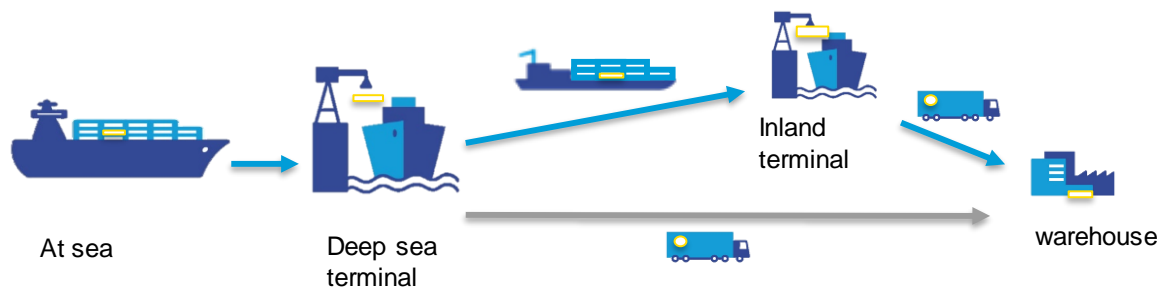
The main objective of the project is to give good insight in the status of containers from sea to warehouses in the hinterland. This allows to:

- Reduce slack (Slack in the planning takes into account the uncertainty in transport time.) in the planning; often containers remain on the terminals longer than necessary due to lack of information. The ambition is to reduce the maximum transport time from 10 to 6/7 days,
- Improve transport operation: by optimally plan resources and work teams, providing accurate and reliable delivery times and reduction of unreliable and long waiting times at terminals, and
- Reduce ad-hoc communication between different parties in the supply chain.

Overall the service will support synchro-modal transport and increase the share of inland waterway transport due to improved planning possibilities.

The innovation of the project is provision of real-time data to logistic planners on the complete chain of container transport from sea to hinterland, combining information of several different sources and data owners (see Figure **13**). The service includes information of seagoing ships, deep sea terminals, inland waterways, trucks and inland terminals on:

- Planning
- Position of trucks and ships
- Container status, e.g. customs

The service is currently in the pilot phase, with a terminal operator, a warehouse operator and a shipper as pilot customers. At this stage of the development the question arising is which type of stakeholder is going to exploit the service and which (type of) customers are going to take the product. An attractive business model is needed.
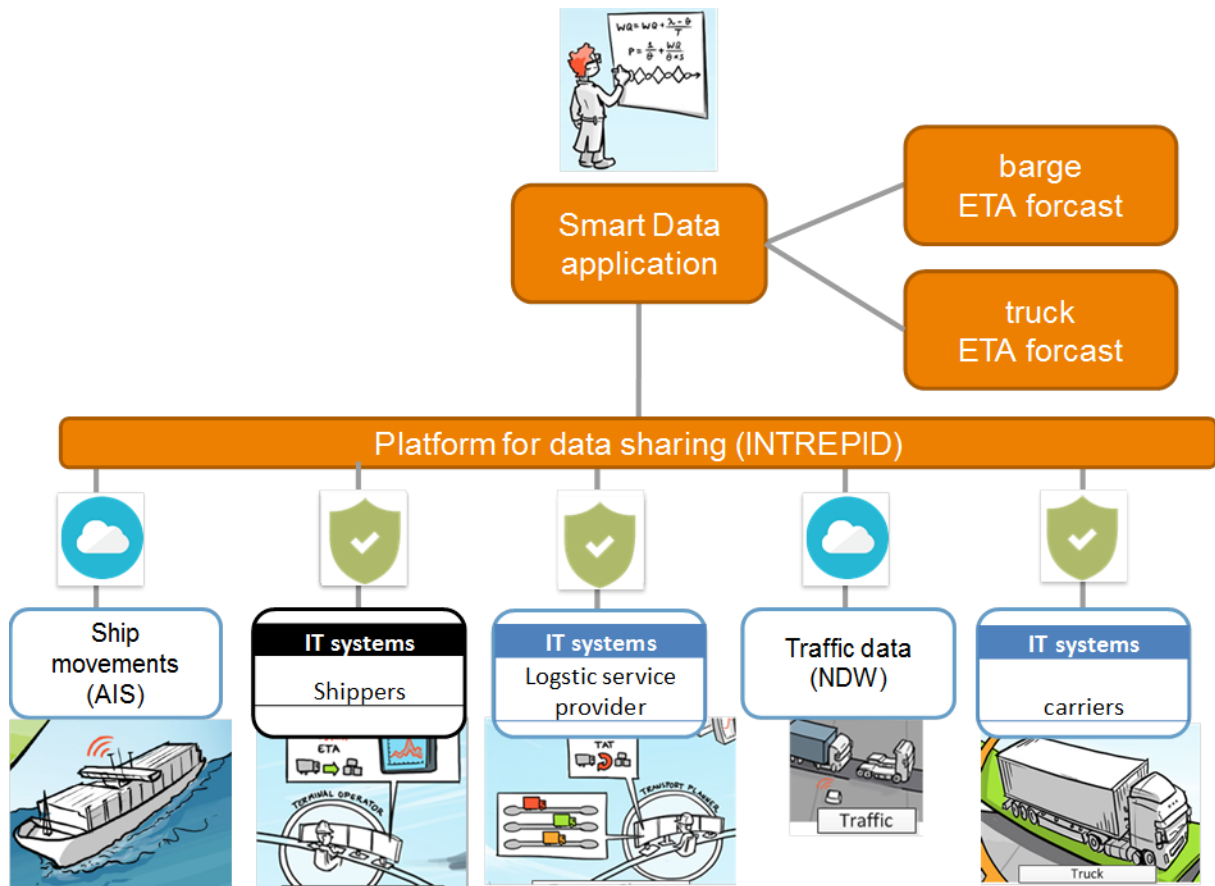
In the initial phase of the project, which ran in 2016, a demonstrator has been developed which has shown that it is technically feasible to track containers using Automatic Identification System (AIS) data of ships and truck GPS data. In this first phase a terminal operator, warehouse operator and shipper delivered the shipment information that was key to this service.

The project is currently in its second phase where a pilot is being set up. The goal is to broaden and expand the service. This is done by including more container information from container handling at the deep-sea port, including new inland terminals and by attracting additional customers (logistics companies). Furthermore, the platform is transferred into a more professional platform. For this purpose, additional stakeholders have been involved which include ICT/ITS companies and the Port of Rotterdam. At this stage of the development the question arising is which (type of) stakeholder could exploit the service and what types of customers are interested. The answer to the question is key to make the service ready for exploitation after the pilot study. Knowledge about the supply and demand side of the service is needed to generate an attractive business model. Also, the use of the service will require to (eventually) changing processes to actually act upon the identified improvement opportunities.

5.4 Definition of CS4: KEEP SAFE - A Knowledge-based approach to understanding railway safety

A vast range of data exists within the railway industry, and their availability continues to increase as a result of uninterrupted data collection processes across the industry. The initial phase of this project, which ran between 2013 and 2014, explored the feasibility of using the

data available within the railway industry to inform new mechanisms to assure safety and security of customers, staff and the public in an industry where the interdependence between physical and digital environments is set to grow exponentially over the next few years.

This case study "KEEP SAFE" addresses the need to use experts' knowledge when analysing data to inform decision making in the railway industry. In particular, the case study uses data and experts' knowledge to serve three overarching purposes within the British railway industry:

- Infrastructure management: Fault prognostics and predictive maintenance.
- Customer safety: Reducing the risk of accidents due to system failures.
- Business performance: Reducing disruptions caused by unplanned maintenance and repairs.

The project was structured in two phases:

1. Phase 1. Theory development (2013-2014): focused on developing a method for eliciting knowledge from experts and use that knowledge in data analysis;

   Phase one was based on the challenges derived from the availability and increasing nature of a vast range of data within the British railway industry as a result of uninterrupted data collection processes across the industry. At this stage the project explored the feasibility of using the data available within the railway industry to inform new mechanisms to assure safety and security of customers, staff and the public in an industry where the interdependence between physical and digital environments is set to grow exponentially over the next few years. This phase of the project delivered a small-scale solution which served as a proof of concept for a safety predictive tool. Using knowledge elicitation techniques, and involving leading industry and academic safety experts, the project created a series of models of railway data and safety, and then developed a metadata-driven, safety-focused model of railway operation and performance; a prototype software tool that uses metadata models for the prediction of safety-related faults was also developed.

2. Phase 2. Pilot, practical implementation (March 2017-present), consists of an implementation of the method in practice, an initiative funded by Network Rail to turn every train into an infrastructure monitoring train.

   On completion of its first phase, the approach to data analysis developed by KEEP SAFE were adopted by one of the initial partners to run a pilot study on how to turn every train into a monitoring train. The new project focused on the collection and analysis of infrastructure data to inform decision making. The new phase, currently underway, becomes both a validation of the method initially developed and a solution of a practical problem the railway industry is facing: improvement of the infrastructure monitoring mechanisms to support predictive maintenance and provide a better and safer service to the public.

To achieve its aims the project has relied on two main technologies for the following purposes:

- Data collection and secure storage. Sensors are placed on trains to capture V2I data, which is data related to the interface between the train and the railway network, e.g. overhead electrification. The data is then transmitted from the train to a secure server at Coventry University using the Internet.
- Data analysis and visualisation: Using among others the approach initially developed by KEEP SAFE, the data is analysed using experts' views and the outputs are fed back to the industry in a visual form for inspection and decision making.

The case study is currently being implemented with an ultimate aim to deliver a system which allows railway infrastructure owners to collect raw data and turn it into a visual artefact that will inform decision making. Such visual representation of the data is informed by experts' knowledge and therefore enables engineers to identify areas where potential failure modes are being developed and plan for their timely repair. This is supported by an Information Technology infrastructure which is placed at the University.

5.5 Monetary and non-monetary benefits for individual operators

5.5.1 Introduction to: Cost-Benefit Analysis

For decision making in investments, an analytical information tool such as the Cost-Benefit Analysis (CBA) is used for an ex-ante assessment of policy options. CBA assesses the costs and the benefits attributable to an investment to evaluate the economic advantages or disadvantages and allow decisions to be as objective as possible (Romijn and Renes, 2013) [22][24].

CBA quantifies the benefits and costs to express them in monetary form as this would be easier to measure and compare. By quantifying the advantages and disadvantages and providing an overview of any risks, uncertainties and effects of a measure, the CBA provides an insight into the social welfare of a project. Expressing the effects in monetary terms also allows to easily present results in a more understandable format that aids in assessing whether the economic and social costs of a project outweigh its benefits.

Although CBA aims to quantify all the measures in monetary terms to compare in a common unit, not all valuations are available to monetise. Thus, CBA uses market prices and predictions of future prices for certain valuations such as fuel prices. However, for impacts where there are no prices provided by the market, it may be derived from research for example, time saved in travel.

Although typically a CBA is conducted before a project is initiated, it can also be carried out on completion of a project. These are termed as ex-ante CBA and ex-post CBA. Ex-ante CBA is when the project is still under consideration and guides decision makers by appraising the costs and benefits of a project. Ex-post CBA on the other hand refers to a CBA conducted on completion of a project. The costs of this project are described as 'sunk' as they would have been invested. Hence, this type of CBA is normally conducted as a learning process and to gather information to assist decisions in future projects.

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[24] Romijn, G and Renes, G (2013) 'General Guidance for Cost-Benefit Analysis' , CPB Netherlands Bureau for Economic Policy Analysis and PBL Netherlands Environmental Assessment Agency

CBA is a useful tool that not only assists in deciding to proceed with a policy measure by assessing its benefits and costs, but can also be valuable in structuring the policy preparation itself.

Although CBA has many advantages, it has also faced several criticisms for failing to adequately address impacts of certain projects and being narrow in considering certain criteria. CBA especially is believed to pose certain challenges for large-scale transport projects as it is purported that as size increases, so does the uncertainty. This results in an inability to ascertain costs as the CBA is done early in the appraisal process (Cornet et al, 2018) [23][25].

In addition, decision makers cannot rely entirely on the CBA as there may be impacts to consider outside of this analysis. CBA focuses on providing the total costs and benefits in monetary terms and comparing it, this may result in certain impacts not being evaluated. Hence, it is also becoming imperative to consider certain projects in terms of their impact and effectiveness and the objectives they deliver. These may include reduction of pollution, new job creation, improving mobility or other quality of life. In these instances, it would also be useful to perform a cost-effectiveness analysis, either in addition to the CBA or instead.

5.5.2 CBA Analysis Framework

A CBA framework allows for a structure of the basic evaluation process. Clearly defining this framework early in the process is important as it provides stakeholders with an understanding of the process, consistency between evaluations and highlights the information that is required for the analysis Table 10 provides the framework with the key criteria and the factors for the CBA analysis.

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[25] Yannick Cornet, Merrill Jones Barradale, Henrik Gudmundsson, and Michael Bruhn Barfod, "Engaging Multiple Actors in Large-Scale Transport Infrastructure Project Appraisal: An Application of MAMCA to the Case of HS2 High-Speed Rail," Journal of Advanced Transportation, vol. 2018, Article ID 9267306, 22 pages, 2018. https://doi.org/10.1155/2018/9267306

Table 9 CBA Analysis framework key criteria and factors ((adapted from [26]))

Key Criteria	Factors
Project description	What will be done?
	Where?
	When?
	How?
	By whom?
Project objectives and impact	What is the problem or goal that the project is intended to address?
	What objectives and impacts should be considered in the economic evaluation?
Analysis Purpose	Will the analysis be used to determine if the project should be undertaken?
	Will it be used to determine which of a group of projects should be selected or which should have highest priority?
Perspective and scope	What are the agency's primary objectives?
	For whom are benefits being sought?
	Who will incur the direct and indirect costs?
Time period of analysis	Over what period of time should projects be evaluated?
Level of effort for the analysis	How much effort should be devoted to benefit-cost analysis and which aspects should receive the most attention?
Defining Alternatives	What is the base case (the conditions that will result if the project is not implemented
	What alternatives will be considered and compared with the project?
Type of economic analysis	What type of evaluation should be used i.e C-B ratio, NPV, rate of rturn, or a combination of these?
Project schedule	When will costs be incurred?
	When will benefits be realized?
Geographic scope of the anal	What area will be affected by the project?
	By its alternatives?
Performance indicators	What indicators will be used in the future to determine whether the project is achieving its objectives?
	What baseline data should be collected before the project is implemented.

The scope, perspective of the analysis must be established before starting the analysis. Any other groups outside the project to who the significant benefits and costs impact should be identified and accrued as they may potentially support or oppose the project. Costs and benefits for the groups must be evaluated, if any group has higher costs than benefits alternatively a group has higher benefits than costs, this has to be compensated.

5.5.3 Methodology of CBA

The structure of the deliverable will resemble the arrangement of tasks as described in the Description of Work, and the planning of work in this document. Based on WP4 and WP3 outcomes, a generic and robust (C-) ITS business case template will be validated in this task.

The core objectives of the business case, its areas of opportunity and improvement potential will determine the following business case factors to be validated:

- Enabling elements:
    Financial analysis
    Business modelling
- Core deliverables:
    Top-down business case: will enable definition of the template or framework
    Bottom-up benefits case: defines critical success factors and KPIs for implementation

This part of the methodology parallels with the steps as depicted in Figure 14.

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[26] Adapted from: http://bca.transportationeconomics.org/setup/purpose-of-the-analysis
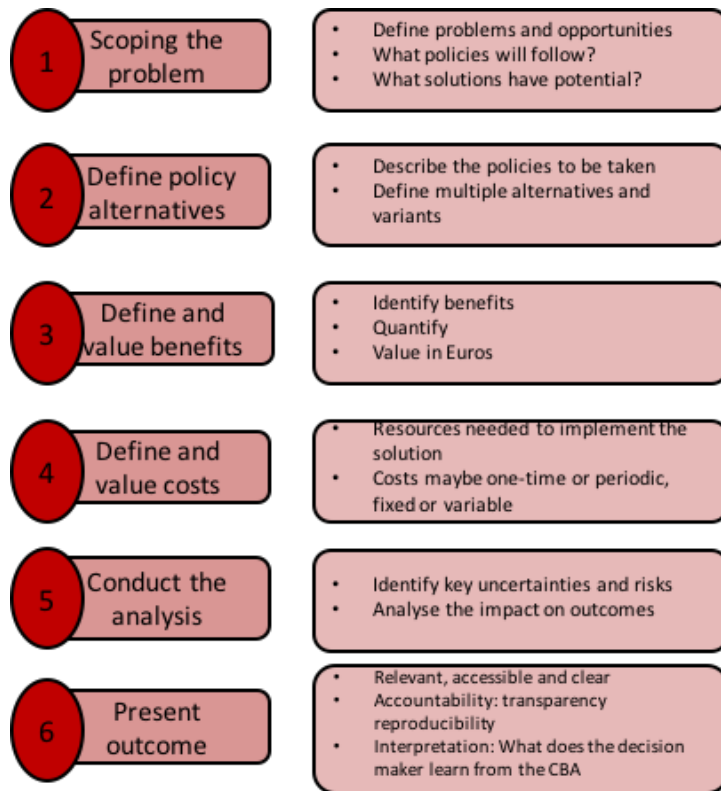
Figure 14 Methodological Approach of WP 5, Task 5.1

5.5.3.1 *Step 1: Scoping the problem*

The first step in the CBA methodology was to define the problem analysis that would define:

- The nature of the problem and how it may further develop
- Any governmental interventions
- Effective solutions for the problem

An efficient problem analysis should be carried out as early as possible as this contributes to a key part of decision-making. Although it may be argued that the problem analysis itself is not part of the CBA, this is advantageous to structure the analysis and contributes to the decision-making process.

5.5.3.2 *Step 2: Define policy alternatives*

The next step in the process is to define the alternatives, that is how the situation would develop if this project or measure was not implemented. An economic analysis would provide an evaluation of the benefits with an alternative scenario i.e. the no build or alternatively it may compare benefits with various alternatives. Hence, these alternatives have to be carefully defined for comparison as they would have significant impacts on CBA.

5.5.3.3 *Step 3: Define and value benefits*

Benefits are defined as the impacts a project has on the users of that project and may also include the society on a whole. The groups that are going to be benefited either directly or indirectly are to be identified. The next step would be to identify the benefits for each group and to quantify it in monetary terms. An assessment of the benefits to be predicted over the time horizon of the project must be conducted. Any social values of the benefit must also be

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estimated. Benefits may be described as tangible benefits or intangible benefits. An approach to quantify all the benefits must be evaluated. Benefits are measurable with an economic value and may include:

- Travel Time (reduction of congestion costs)
- Vehicle Costs
- Safety
- Emissions
- Reliability
- Noise/Pollution
- Economic Effects
- Community Impact

Benefits in transportation projects focus highly on reductions in transportation costs, but there are many other benefits to these projects. Some intangible benefits although may prove difficult to be monetised are critical to making a choice among other alternatives.

In particular, the CBA assessment of the NEWBITS case studies has shown that most of the benefits come from reduction in the external costs of transport, i.e. reduction of CO_2 emissions and air pollution.

Equity and Option Value impacts that result from projects increase transport system affordability and diversity.

Benefit-cost analysis does not generally include economic impact analysis, which is the study of all the indirect economic impacts of a project on the economy, including jobs and other impacts of construction. Also, it generally does not include minor impacts that are identified in an environmental impact study.

Travel Time (congestion)

Travel time is a value assigned to the cost of time spent of transport and includes costs to businesses when their employees or their vehicles spent on travel or costs to consumers of personal time spent on travel. The key benefit to most transport projects is the saving in travel time. Many studies have highlighted the reduction in travel time to justify congestion relief projects.

However, the assessment of congestion, i.e. evaluating the cost of time losses, is not straightforward, relying on the use and interpretation of models.

There are two basic models for the assessment of congestion externalities in the literature: the bottleneck model and the link model. The bottleneck model describes a situation where a group of users want to pass one bottleneck at a desired point in time. The bottleneck's capacity is given by the maximal flow, i.e. the number of vehicles per hour that can pass. Users dislike arriving early or late, after having passed the bottleneck. In equilibrium there is a queue, first growing and then gradually declining, such that all users are equally well off. Some do not wait for long in the queue, but arrive early or late, others arrive just in time but have to wait in the queue for longer periods. An optimal road price replaces the inconvenience of waiting with the inconvenience of paying the price. User's utility remains unchanged by introducing the price, but the revenue is a net gain of the society. Applying this model in practice is difficult because it is dynamic. Though dynamic network assignment

models are available in the literature (see e.g. Peeta and Ziliaskopoulos 2001) [24][27], standard practice in traffic assignment is still based on static peak hour assignment.

There is no doubt, however, that a dynamic approach would be highly desirable for estimating efficient charges (cost of congestion). Price differentiation across time, such as different charges for peak and off-peak hours, only very imperfectly takes account of the congestion dynamics because the required time schedule depends on the growth and decline of queues in different parts of the network that have their own respective patterns across time. There is, however, a recent attempt to use the bottleneck model in practice. De Palma and Lindsey (2006) [25][28] use a dynamic assignment model for calculating efficiency gains of a dynamic charging scheme. Unfortunately, the model does not allow for an explicit incorporation of dynamic charges. The authors therefore approximate a dynamic charging scheme by a simple but intuitive rule, namely by just charging travel time. As travel time depends on both distance and congestion, a charge on travel time turns out to be a fairly good approximation to an efficient dynamic charging scheme. The efficiency gain turns out to be considerable, and clearly much bigger than that of static link charges. The practical usefulness of this approach seems to be questionable, however. Acceptance problems for a scheme that makes users pay for time losses in queues when they are annoyed at getting stuck in a queue anyway are likely impregnable. Another problem is that if paying for travel time, road users are entrapped to drive faster, which would be a non-desirable implication of such a charging scheme. It is recommended to keep the issue of dynamic charging in mind and to support attempts to make dynamic assignment models fit for taking optimal charging schemes on board. An acceptable, practical and easily accessible solution, however, does not yet seem to be available.

The conventional static link model predicts flows along links in the network that depend on link speeds, which in turn depend on how close traffic flows come to the respective link capacities. The conventional congestion model for flows along links starts from the characteristic of a link as described by the so-called fundamental diagram. The diagram relates speed along a link to the flow. Alternatively, transformations of these variables are related to each other in a way encompassing the same information. Much effort in the literature over the last decades has gone into specifying functional forms of the diagram and estimating its parameters.

On the contrary, the conclusion is that a useful ad-hoc rule for an EMCC (Efficient Marginal Congestion Costs) just based on observations of flows or speeds does not exist in the conventional model. The essential information needed, namely the position of the demand curve, is not observable on the road link. It has to be obtained from a network assignment model. It is unlikely that any sensible number on the EMCC along a road could be obtained without calibrating such a model. This is also true because road links in a network interact: what is required to determine the EMCC is not the position of the demand curve under

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[27] Peeta and Ziliaskopoulos 2001 Peeta, S. and Ziliaskopoulos, A. (2001). Foundations of Dynamic Traffic Assignment: The Past, the Present and the Future. Networks and Spatial Economics, vol. 1, no. 3-4, pp. 233–265.
[28] De Palma and Lindsey (2006), "Modelling and evaluation of road pricing in Paris", Transport Policy 13, 115–126.

conditions of a decentralised inefficient equilibrium, but under the condition that on all links users are charged in an efficient way.

From (EC, 2014) [26][29], an alternative approach is based on empirical estimations of travel time (and congestion costs). The first method for the travel time assessment is to carry out specific empirical research and/or surveys to estimate both work and non‑work travel time. The approach consists of interviewing individuals using the stated preference method or conducting multi‑purpose household/business surveys using the revealed preference method and then to estimate a discrete choice model on these data.

As a second option, value of time can be estimated adopting the cost saving approach. In such a case, the underlying logic is that time spent for work‑related trips is a cost to the employer, who could have used the employee in an alternative productive way. The recommended process for valuing work time with the cost savings approach is as below.

- Establishing wage rates for a given country or region: the gross hourly labour cost (Euro per hour) must be derived from observed (or, in absence, from average national) wage rates. The main data source should be the national statistical office;
- Adjustment to reflect additional employee related costs: this would include paid holidays; employment taxes; other compulsory contributions (e.g. employer pension contributions) and an allowance for overheads required to keep someone employed. Social security payments and overheads paid by the employer shall therefore be computed and added to the estimated hourly labour cost.

Concerning the other transport modes [27][30], the existing literature did not reveal many sources of marginal congestion or scarcity cost estimates for rail, air, or water transport.

Jansson and Lang (2013) [28][31] have developed a methodology to evaluate the external delay costs in rail transport. In the application for passenger transport in Sweden, The authors estimate how the marginal cost-based charges (initially limited to external costs for wear and tear, maintenance, emissions etc.) would change if delays due to additional departures were also taken into account. For example, if an additional departure of a commuter train leads to a delay of two minutes in the network shared with high speed trains, the authors estimate the marginal external cost effect of this delay to correspond to a 25% increase in the commuter train fare for this additional journey, and a 5% increase in the fares for high speed trains.

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[29] EC, 2014 European Commission. "Guide to Cost-Benefit Analysis of Investment Projects. Economic appraisal tool for Cohesion Policy 2014-2020"

[30] Most of the information concerning the assessment of congestion costs are drawn from the RICARDO-AEA (2014) Handbook on the assessment of the external costs of transport. An update of the study is going to be delivered in April 2019 by the EC DG MOVE.

[31] Jansson and Lang (2013) Jansson, K., Lang, H. (2013) Rail infrastructure charging EU-directive, Swedish concerns and theory, Research in Transportation Economics 39, 285-293.

For air transport, EuroControl gathers data that allow delay costs to be calculated. Earlier, EuroControl published a report (Cook et al., 2004) [29][32] describing a methodology for evaluating true cost of flight delays. The methodology presents results detailing the cost to airlines of delays during various segments of a scheduled flight. The costs are divided into short delays (less than 15 min) and long delays (greater than 65 min). The report provides a cost factor (Euros per minute) for each flight segment. The types of delays considered include gate delay, access to runway delay (both taxi in and out delays), en-routes delays, and landing delays (circling or longer flight paths to overcome congestion while approaching the airport). The data used in the study consisted of data collected from European airlines, air traffic management as well as interviews and surveys conducted by the research team.

For inland waterway and maritime transport, no illustrative quantification of marginal congestion costs could be identified. According to sectoral forecasts, however, the problem of port capacity will likely become very important in the nearest future.

Maritime shipping: By considering cargo handling and port logistics (stevedoring) costs and wait time records at several international ports of the 1970s, the UNITE project (Doll, 2002) [30][33] concludes that there are no external congestion costs in seaport operations. The analysis of EU and US ports in the COMPETE project (Schade et al., 2006) [31][34], however, clearly shows that capacity in particular in North American ports is approaching its limits and that congestion at cargo handling and storage facilities is a priority issue. The GRACE D4 report (Meersman et al., 2006) [32][35] estimates the additional (marginal) crew costs of a vessel having to wait to call at a port at €185 per hour. However, as ports usually do not keep records of vessel waiting times the computation of price relevant marginal external congestion costs in maritime transport is not easy to carry out.

Inland navigation: COMPETE results suggest that European countries do not face any capacity problems in their inland waterway networks. However, the GRACE case studies found a number of local bottlenecks at locks, although they largely depend on local conditions. Delay times range between zero and 160 minutes, in the latter case passage costs per ship are found to increase by €50 in case demand increases by 1%. Besides lock capacity, the availability of sufficiently deep water levels to operate all vessel types is a problem, particularly in summer time. Based on the Low Water Surcharge, which has to be paid on the river Rhine when water levels fall below a certain value, GRACE estimates scarcity costs between €0.38 to €0.50/TEU*km at Kaub and €0.65 to €1.25/TEU*km at Duisburg.

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[32] Cook A., Tanner G. and Anderson S. (2004). Evaluating the true cost to airlines of one minute of airborne or ground delay, University of Westminster, for EUROCONTROL Performance Review Commission.

[33] Doll, C. (2002). Unification of Accounts and Marginal Costs for Transport Efficiency (UNITE) Deliverable 7: User Cost and Benefit Cast Studies. ITS, University of Leeds, Leeds, UK

[34] Schade et al., 2006 Schade, W. et al. (2006).

[35] Meersman, H. et al. (2006). Generalisation of Research on Accounts and Cost Estimation (GRACE) – Deliverable D4: Marginal Cost Case Studies for Air and Water Transport. University of Antwerp, Antwerp, NE.

Vehicle Costs

Vehicle operating costs refer to costs that vary with vehicle usage, including fuel, tires, maintenance, repairs, and mileage-dependent depreciation costs (Booz Allen & Hamilton, 1999). These may include projects that influence traffic speed and delay, impact the number of miles travelled, operating costs or even road surfaces. Where projects have significant impacts on the use of alternative modes of transport, it may affect the vehicle ownership costs. Factors that would influence vehicle costs include:

- Total vehicle miles travelled
- Changes in travel speeds
- Travel delays caused by road or traffic conditions
- Fuel prices, consumption and related operating costs
- Average vehicle ownership costs

Safety

Safety is a significant impact of transportation projects. The safety impact analysis on a project requires the information on how accidents are affected as a result of the project. The severity and frequency of crashes are also to be considered as these may vary from: property only damage, minor injuries or the more severe disability causing crashes or resulting in death.

Accidents also have additional impacts such as delays in traffic, responding emergency team costs, medical costs, productivity losses and psychological effects such as pain, suffering and/or grief.

All these impacts need to be monetised that would help making planning decisions for safety more consistent. However, monetising every impact may prove challenging. There have been several criticisms to monetise a human life as this may imply that human life is then a commodity. However, decision-makers have to evaluate decisions that require trade-offs between safety and other planning objectives. A CBA helps in identifying the most cost-effective projects that will enable robust decision making.

In terms of a taxonomy of the most important components for safety assessment is provided in (RICARDOI-AEA, 2014). The most important accident cost categories are medical costs, production losses, material damages, administrative costs, and the so-called risk value as a proxy to estimate pain, grief and suffering caused by traffic accidents in monetary values. Mainly the latter is not covered properly by the private insurance systems.

A comprehensive discussion of the methods and data used in the assessment of safety costs in transport can be found in the deliverables of the GRACE project (Lindberg et al., 2006) [33][36]. They also cover the dedicated case studies of accident costs carried out during the UNITE (1998-2002) project. These key sources are the basis for the recommended methodology in the 2008 Handbook and in the update study by CE Delft et al. (2011) [34][37].

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[36] Lindberg, G. et al. (2006). Marginal cost case studies for road and rail transport. Deliverable D3, GRACE project.

[37] CE Delft, Infras, Fraunhofer ISI (2011b), External Costs of Transport in Europe - Update study for 2008. CE Delft, Delft, NL

The core bottom-up methodology used there is stemming from Lindberg (2001) [35][38] and it remains the most widely used approach until now.

The approach of Lindberg (2001) [35] is quite intuitive. When an additional vehicle joins the traffic, the driver exposes himself/herself to the average accident risk, the historical value of which can be assessed by relating the number of accidents involving a given vehicle class to the traffic flow. Furthermore, an additional vehicle may change the accident risk of the other transport users. This effect is captured by the risk elasticity, for which various econometric estimates exist.

In order to obtain the marginal external cost value, the adjusted risk rate must be applied to the relevant accident cost value, whereby the internal cost elements must be excluded. The following costs are related to the accident risk:

- expected cost (of death and injury) due to an accident for the person exposed to risk,
- expected cost for the relatives and friends of the person exposed to risk,
- accident cost for the rest of the society (output loss, material costs, police and medical costs).

The first two cost elements are evaluated using the concept of willingness to pay for safety. The key indicator upon which the evaluation is carried out is the value of a statistical life (VSL). Usually, the assumption is made that the users internalise in their decisions the risk they expose themselves and their family to, valued as their willingness-to-pay for safety.

Emissions

Transportation projects contribute to air pollution impacts and a benefit-cost model can estimate changes in emissions to calculate any positive or negative benefit. Air pollution impacts for a project should be quantified and may include factors such as miles, time on trips and types of vehicles to then model the quantity and mix of air pollution. An appropriate value per emission is then applied to calculate any benefits.

Transportation is the fastest growing major contributor to global climate change and motor vehicles produce various harmful emissions that impact health and the environment. It is also purported that even electric vehicles contribute to emissions since electricity is often generated by fossil fuels such as coal or natural gas.

EIB (2012) [36][39] provides a useful manual and guidelines for environmental (emissions) impact assessment in infrastructure projects.

The above approach is similar to what is known as Impact-Pathway Approach (RICARDO-AEA, 2014) [27].

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[38] Lindberg, G. (2001). Traffic Insurance and Accident Externality Charges. Journal of Transport Economics and Policy, vol. 35, no. 3, pp. 399-416.

[39] EIB, 2012. European Investment Bank, "Induced GHG Footprint The carbon footprint of projects financed by the Bank. Methodologies for the Assessment of Project GHG Emissions and Emission Variations"
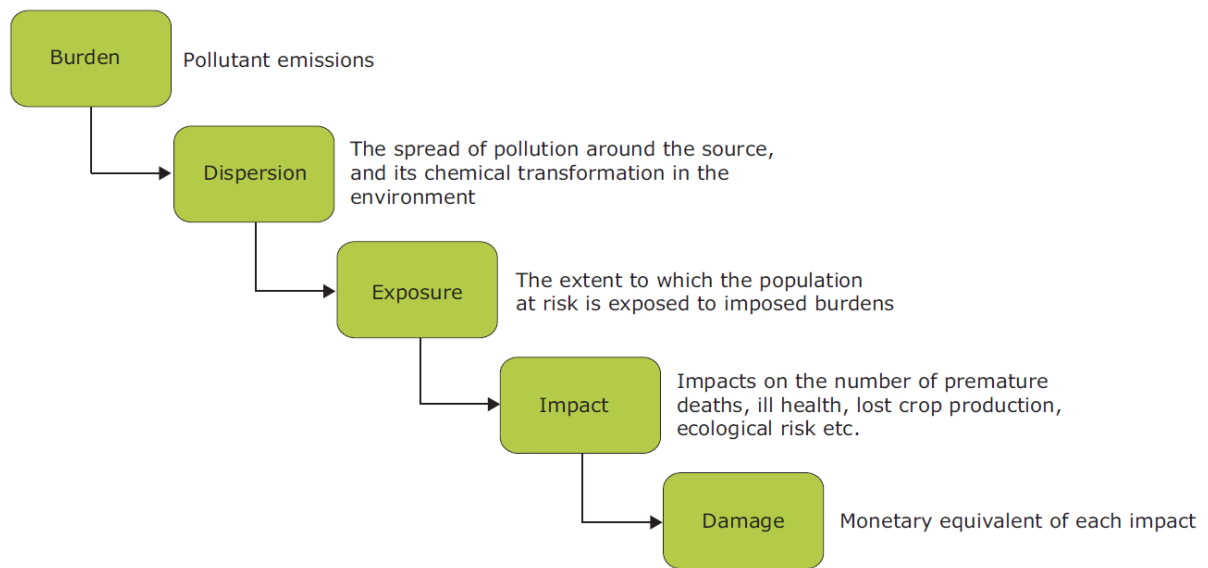
Figure 15: Impact Pathway Approach Source: RICARDO-AEA (2014)

The first step quantifies the burden of pollutant emissions e.g. by using vehicle emission factors. The dispersion of the pollutants around the source is modelled using atmospheric dispersion models, which are very complex and are not typically publicly available. The impacts of transport air pollutant emissions are highly location-specific and depend on many factors such as the local traffic conditions. The exposure assessment therefore relates to the population and the ecosystem being exposed to the air pollutant emissions. Spatially detailed information on population density must be available to allow proper assessment. The impacts caused by the emissions are determined by applying so-called exposure response functions that relate changes in human health and other environmental damages to unit changes in ambient concentrations of pollutants - the most important being particulate matter (PM) and nitrogen oxides (NOx). These exposure response relations are based on epidemiological studies. Finally, the impacts of the emissions on humans and the ecosystem must be evaluated and transformed into monetary values. This step is often based on valuation studies assessing e.g. the willingness to pay for reduced health risks.

This method focuses on the quantification of the explicit impact that the emissions have on human health, environment, economic activity, etc. Efforts undertaken in the last 20 years to develop standardised approaches involve a detailed analysis of the long chain of events preceding the final impact on the exposed population. The EU funded series of projects ExternE (finalised in Bickel and Friedrich (2005) [37][40] formalised this solution under the title Impact Pathway Approach (IPA).

Types of Emissions

Emissions from transport contain a mixture of organic and non-organic, gaseous and particulate components, differing in size, shape, chemical and physical properties. The general distinction is made between directly emitted or primary pollutants and secondary

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[40] ExternE (2005): Bickel, P. and Friedrich, R. (eds.), 2005. "Externalities of energy: Methodology 2005 Update". European Commission, Luxembourg

pollutants. Primary pollutants are direct products of (incomplete) fuel combustion. These mainly include carbonaceous soot (also referred to as black carbon), nitrogen oxides (NOx), sulphur dioxides (SO2), carbon monoxide (CO), toxic volatile organic compounds (VOC), in particular benzene and 1,3 butadiene, some polycyclic aromatic hydrocarbons (PAH), and heavy metals. Secondary pollutants arise through atmospheric chemistry. The main secondary pollutants are ground-level ozone (O3), nitrates and sulphates. Ozone is formed in the atmosphere through chemical reactions involving volatile organic compounds (VOC),

NOx (which are referred to as ozone precursor gases) and sunlight. Nitrates and sulphates arise through oxidation of NOx and SO2, respectively. Some vehicle emission components thus have both direct effects on health.

Although transport emission reduction has always been of primary importance, the scope of emissions considered are now expanding. In addition to the risks to human health, there is a growing concern now over emissions that cause environmental damage, in particular to climate change. It is increasingly believed that pollution has had a severe impact on average global temperature and also impact ecological functions. Although these may be difficult to monetise in a project, they must be considered while making policy decisions.

Concerning the CO2 and greenhouse gas (GHG) emissions, in general there are two main approaches to the evaluation of the cost of GHG emissions. The first is the damage cost approach, which can intuitively be explained as an evaluation of total costs under the assumption that no efforts are taken to reduce the pace of climate change. It implies the incorporation of various effects connected to changes in sea level, landscape, fresh water availability, vegetation, etc. The second is the abatement cost approach, which evaluates the cost of achieving a given amount of emissions reduction.

The estimation of full damage costs, although desirable from a scientific point of view (as it allows quantifying the external effects fully), is connected with extremely high uncertainty due to complex global pathways of various effects and long-time horizons involved. On the other hand, the use of abatement cost figures is a theoretically sound alternative, if the emission reduction targets adequately reflect the preferences of society and can thus be used in the context of determination of willingness-to-pay for a certain abatement level. Another argument for using avoidance cost estimates is the fact that many risks connected with future climate change cannot yet be identified and evaluated. For these reasons, the calculations of climate change costs below are based on the estimates of CO2 costs derived from an abatement cost approach.

Noise emissions

Noise emissions from traffic pose an environmental problem of growing importance. Noise exposure is not only a disutility in the sense that it disturbs people; it can also result in health impairments and lost productivity and leisure. The reason the problem is growing is a combined effect from greater urbanisation and an increase in traffic volume. Whereas the increase in traffic volume means higher noise levels, the urbanisation has led to more individuals being exposed to traffic noise.

Two major impacts are usually considered when assessing noise impacts:

- Annoyance, reflecting the disturbance which individuals experience when exposed to (traffic) noise.

- Health impacts, related to the long-term exposure to noise, mainly stress related health effects like hypertension and myocardial infarction.

It can be assumed that these two effects are independent, i.e. the potential long-term health risk is not taken into account in people's perceived noise annoyance.

The methodology for the assessment of the external costs of noise is based on the Impact-Pathway Approach (IPA), already discussed with reference to air pollution. The following table, adapted from RICARDO-AEA (2014), shows an example of the IPA application to the assessment of the transport external costs of noise emissions.

Table 10: Assessment of transport external costs of noise emissions

IPA steps	Description
Noise Emissions	The changed levels of noise are measured in terms of change in time, location, frequency, level and source of noise.
Noise Dispersion	
Exposure-Response Functions	These functions present a relationship between decibel levels and negative impacts of noise. Each impact has one or more endpoints. Using the information about the number of cases of each endpoint, the overall change in noise impact is calculated.
Economic Valuation	An economic value for a unit of each endpoint of the exposure-response functions is calculated either by transferring estimates from existing valuation studies or by conducting a new original study using environmental valuation techniques.
Overall assessment	Economic value of each unit of endpoint is multiplied by the corresponding impact and aggregated over all endpoints from exposure-response functions.

Travel Time Reliability

Travel time reliability is defined as the consistency of dependability in travel times and is measured day to day and/or across various times of the day. Any delays are considered in the measure of travel time reliability. Several factors impact reliability that may include:

- Vehicle characteristics
- Driver characteristics
- Interaction between drivers
- Traffic management systems
- Traffic regulations
- Weather

Travel time reliability thus is measured as a dispersion of the travel time that have significant economic benefits and are increasingly considered now in CBA. To include travel time reliability in CBA, it is vital to find a measure for travel time reliability, a value provided to it, a method to predict future reliability and also estimate any changes in reliability due to a project.

Economic Effects

While considering CBA for transportation projects, it is understood that these projects have a high impact on a community's economic development. These contribute to employment opportunities, business activities, employment, housing and productivity. Overall transport projects may be considered to improve accessibility to services, access education, employment, reduce transportation costs contributing to an increase in economic productivity and development. It is also important to monetise the full range of economic impacts and avoid double counting any impacts.

The Institute for Advanced Studies (2014) [38][41] provides guidelines for the financial analysis of infrastructure projects based on the following assumptions:

- Only cash inflows and outflows area considered and compared along a given time horizon;
- The incremental approach should be used to determine project cash flow;
- An appropriate financial discount rate has to be applied to aggregate cash flows of a period stretching across several years.

Concerning the economic analysis, the key concept is the use of shadow prices to reflect the social opportunity cost of goods and services, instead of prices observed in the market, which may be distorted. Sources of market distortions are manifold:

- non‑efficient markets where the public sector and/or operators exercise their power (e.g. subsidies for energy generation from renewable sources, prices including a mark‑up over the marginal cost in the case of monopoly, etc.);
- administered tariffs for utilities may fail to reflect the opportunity cost of inputs due to affordability and equity reasons;
- some prices include fiscal requirements (e.g. duties on import, excises, VAT and other indirect taxes, income taxation on wages, etc.);
- for some effects no market (and prices) are available (e.g. reduction of air pollution, time savings).

The standard approach, consistent with international practice, is to move from financial to economic analysis. Starting from the account for the return on investment calculation, the following adjustments should be:

- fiscal corrections;
- conversion from market to shadow prices;
- evaluation of non‑market impacts and correction for externalities.

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[41] The Institute for Advanced Studies 2014, "Guidelines for Cost-Benefit Analysis of Infrastructure Projects"

Step 4: Define and value costs

Costs are defined as the resources, such as land, labour, and material, expended on the project by the entity providing it. These "costs" are often referred to as "agency costs" and do not include any costs borne by the users of the project or the public at large.

They may include:

- Initial Costs
- Continuing Costs
- Rehabilitation Costs
- End of project costs

The following table provides the types of costs and their description.

Table 11 Type of costs and their descriptions

Type of costs	Description
Initial Costs	Planning, preliminary engineering, and project design
	Environmental impact report
	Project-related staff training
	Final engineering
	Land acquisition
	Construction costs, including improvements to existing facilities
	Equipment and vehicle purchases
	Equipment required for project operation
	Decommissioning costs for facilities that are no longer needed
Continuing Costs	Operations
	Maintenance
	Rehabilitation
Rehabilitation Costs	Future cost of repairs and improvements
End of project costs	Residual value - Estimated value at the end of the period of analysis
	Salvage value - Estimated value in case of selling the asset
	Close-out - costs incurred at the end of the project's operation

Initial costs are those that incur at the design and construction phase. If projects have any additional phases, only the first phase of the project should be considered, as there is no guarantee on the implementation of the other phases. However, this phase can be used to compare other phases that will enable decision-makers an overall view of the project. A sensitivity analysis will also aid in determining how higher costs may affect the efficiency of the project.

Continuing costs occur when the initial phase of the project is completed but is still in use. The typical examples of these costs include labour, material and supplies, maintenance equipment, utilities and rent. Depreciation is not normally included in these costs, only future costs.

End of project costs occur at the close of the project. This may not be applicable to all transportation projects as some projects do not 'end'. End of project costs are discounted in the same manner as other costs.

5.5.3.5 *Step 5: Conduct the Cost Benefit Analysis*

The cost benefit analysis is conducted by dividing the total discounted benefits by the total discounted costs. The benefits of the project are then assessed by the B-C ratio, where a ratio higher than 1 suggests that the project has more benefits than costs. Higher the B-C ratio, greater the benefits of the project in relation to its costs.

5.5.3.6 *Step 6: Present Outcomes*

Results of the CBA must be presented in a clear, concise and user friendly manner. The most important results must be highlighted, the associated benefits of the project, the costs and any variants. Any benefits that were not monetised must also be presented with clear explanatory notes. This would guide policy makers with effective decision making in formulating policies and with a clear analysis to consider while making their decision.

5.5.3.7 *Summary of steps*

1. Problem Analysis:
   - What is the problem and how is it expected to develop?
   - What is the most promising option?

2. Establish the Policy Alternative:
   - Describe the measures to be taken
   - Most likely scenario in the absence of a policy

3. Determine Benefits:
   - Identify the benefits
   - Quantify the benefits
   - Value (monetise) benefits
4. Determine Costs:
   - Resources consumed to implement the solution
   - Costs may be one-off or recurring, fixed or variable

5. Overview of costs and benefits
   - Calculate all costs and benefits discounted to the same base year and calculate the balance
   - Present all benefits, including non-quantified and/or non-monetised effects

6. Present Outcomes:
   - Relevant, understandable and clear
   - Explain: transparency and reproducibility
   - Interpret: what can the decision-maker learn from the CBA?

5.5.4 CBA Modelling

A Microsoft Excel based model was used to perform the cost benefit analysis. Initially all the costs were inputted as well as benefits for the time period under consideration. The model also calculated discounted rates for the CBA using sensitivity analysis. The model also allowed for calculating horizon values. A typical CBA considers costs and benefits at the initiation of a project, horizon values are when costs and benefits are considered into the future of the project i.e. horizon. The results of the CBA are presented in two methods: Net Present Value (NPV) and Benefit Cost Ratio (BCR).

5.5.4.1 *Discounting to present value*

The present value of money or goods is perceived to be higher than the expected value of returns in the future due to effects of inflation etc. Hence, the potential value of benefit or cost in the future may not be representative of the present actual value of cost or benefit. It is therefore essential when considering a long term of the project to discount all future costs and benefits to a common present value. This concept is termed as discounting and allows calculation of the Net Present Value (NPV) of a project.

Using a discount rate, the current equivalent monetary value of a benefit or cost that occurs in the future is calculated. The formula used to calculate the NPV of a future benefit or cost is:

$$PV = \frac{F}{(1+r)^n}$$

Where,

PV = Present Value
F = Future Value of the benefit or cost, in monetary terms
r = Rate of Discount
n = number of periods under consideration, for example number of years

For example, if the costs of a product/service is €20,000 and the discount rate is 5% (entered as a decimal 0.05), the NPV for a one year period is calculated by:

$$PV = \frac{20000}{(1+0.05)^1}$$

The PV therefore is €19,047.62, hence the future costs are almost a €1000 lower in monetary terms than in present terms.

5.5.4.2 *Discounting over multiple years*

For projects where the CBA is calculated for a longer period of time i.e. over multiple years, discounting becomes important to provide an accurate representation of the net present value. The formula for calculating the net present value of the future benefits or costs is:

$$P = \frac{F}{(1+r)^0} + \frac{F}{(1+r)^1} + \frac{F}{(1+r)^2} + \ldots + \frac{F}{(1+r)^n}$$

Or

$$PV = \Sigma \frac{F}{(1+r)^n}$$

5.5.4.3 *Discounting Rates*

Discount rates are a decisive parameter in the CBA and it is acknowledged that these differ for various projects. For instance, in the UK, the Greenbook (Treasury of the United Kingdom, 2003) establishes the discount rate. They recommend a discount rate of 3.5% and use the following equation for generating the discount rate:

$$r = \rho + \mu g$$

Where:
r = discount rate
ρ = pure time preference (on the basis that there is no change in expected per capita consumption)
μ = elasticity of marginal utility of consumption
g= annual growth in per capita consumption

HM Treasury calculate r assuming values for ρ=1.5%, μ=1 and g=2%

$$r = 0.015 + (1 * 0.02)$$

Hence the discount rate of 3.5% is used in the UK for an evaluation of CBA for the purposes of public sector projects.

5.5.4.4 *Future Values or Compounding*

In certain instances, the present values of costs or benefits may be known and future values may have to be calculated. For example, if an investment has been made, its value in a year's time has to be estimated with a known rate of interest. This can be calculated by using the equation as follows:

$$FV = PV(1 + r)^n$$

Where:
FV = Future Value
PV = Present Value of cost or benefit in monetary terms
r = rate of discount
n = period under consideration (e.g. years)

5.5.4.5 *Long-term projects and Horizon Values*

Although discounting is applied to costs and benefits to discount for present values even for projects over multiple years, it is not always practical to calculate over a long period of time using the standard equation. In these cases, a horizon value maybe used to separately consider costs and benefits occurring in the far future or horizon. The following equation is used for calculating horizon values:

$$FV = \sum \frac{P}{(1+r)^n} + PV\,(H_n)$$

Where:
FV = Future Value
PV = Present Value of cost or benefit in monetary terms
r = rate of discount
n = period under consideration (e.g. years)
PV (H_n) = present value of the horizon value

There are different methods for estimating horizon values, these are:

- Simple projections
- Liquidation or Scrap value
- Depreciated value
- Initial Construction cost
- Horizon value equal to zero

Simple projection method is similar to the standard discounting over multiple years, but has a distinction between the near and far future. While standard discounting is used for the near future, the far future is based on an assumption that the benefit or cost will grow or decline as a constant rate. Liquidation or scrap value is used when no other benefits or costs arise beyond the discounting period, and the project comes to an end. Depreciated value method is used to estimate the current value of an asset by subtracting its depreciation from its initial value. The initial construction cost method estimates the horizon value as a fraction of the original construction cost. The horizon value equal to zero method is used to employ a long "near future" discounting period assuming no costs or benefits beyond this period and is equivalent to assuming a zero-horizon value. Care has to be taken to use the zero-value method as overlooking any impacts may result in important costs or benefits being excluded from the CBA.

5.5.4.6 *Sensitivity Analysis and Discounting*

Sensitivity analysis demonstrates how net benefits will be influenced if the specified parameters deviate from the anticipated values. It has to be ensured that the discount rate used is appropriate and not solely responsible for the outcome of the appraisal. Performing a sensitivity analysis ensures that the robustness of the CBA is improved, especially when there is uncertainty over the discount rate. The following example[42], Figure 16, demonstrates the NPV of a project with different discount rates.

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[42] Source: http://www.cbabuilder.co.uk/Discount3.html

> **Example**
> Consider a construction project with initial costs of £1.5m. Benefits arising from this project are £100,000 at the end of year 1, £200,000 at the end of year 2, £500,000 at the end of year 3, and £1m at the end of year 4.
> With no discounting the NPV of this project is as follows:
> NPV = Benefits - Costs
> NPV = £1.7m - £1.5m
> NPV = £200,000
>
> With a discount rate of 5% the NPV of the project is as follows:
> £95,238.10 + £181,405.90 + £431,918.8 + £822,702.47
> NPV (B) = £1,531,265.30
> NPV = £1,531,265.30 - £1.5m
> NPV = £31,265.30
>
> With a discount rate of 10% however the NPV of the project is as follows:
> £90,909.09 + £165,289.26 + £375,657.40 + £683,013.46
> NPV (B) = £1,314,869.20
> NPV = £1,314,869.20 - £1.5m
> NPV = -£185,130.79
>
> In this example without discounting there is economic justification for the project to go ahead. With a discount rate of 5% similarly there is justification for the project to go ahead. However, with a higher discount rate of 10% the costs outweigh the discounted benefits by almost £200,000, suggesting the project should not go ahead. In this case the choice of discount rate could have a significant impact on the viability of the construction project.
>
> Plotting the various outcomes for different discount rates can allow a researcher to arrive at the *break even* discount rate. This is the rate at which the NPV is equal to zero. This break even rate is, however, influenced by the horizon value. With a horizon value of zero, the break even rate will be naturally lower than with a higher horizon value. In this example, if the project has a horizon value of £200,000 then even a discount rate of 10% will produce a positive NPV.
>
> With a discount rate of 10% and a horizon value of £200,000, the NPV of the project is as follows:
> NPV = PV (B) – PV (C) + PV (H)
> NPV = £1,314,869.20 - £1.5m + £200,000
> NPV = £14,869.21

Figure 16 Example to demonstrate NPV

5.5.4.7 *Obtaining and Presenting Results*

The results of the CBA are presented in two methods:
- Net Present Value (NPV)
- Benefit Cost Ratio (BCR)

Net Present Value

The Net Present Value (NPV) provides the difference between the present value of the benefits and the present value of the costs and is expressed using the following equation:

$$NPV = \sum PV\,(B) - \sum PV\,(C)$$

Where:
NPV = net present value
PV (B) = present value of the benefits
PV (C) = present value of the costs

This equation is also expressed as:
NPV = ∑ present value of total future benefits - ∑present value of total future costs

The NPV signifies that for value of NPV>0, the project has the economic justification to proceed, denoting that if the sum of the NPV of benefits is greater than the NPV of costs.

Benefit Cost Ratio

The Benefit Cost ration provides the results of the CBA as a ratio. This is achieved by calculating the sum of the NPV of benefits and comparing them against the sum of the NPV of costs and providing the ratio. The Benefit-Cost Ratio is expressed by the following equation:

$$BCR = \frac{\sum PV\ (B)}{\sum PV\ (C)}$$

Where,
BCR = benefit cost ratio
PV (B) = present value of the benefits
PV (C) = present value of the costs

It is also commonly expressed as:

$$BCR = \frac{\sum present\ value\ of\ total\ future\ benefits}{\sum present\ value\ of\ total\ future\ costs}$$

If the B-C ratio is below 1, it is interpreted that the costs outweigh the benefits of the project and hence should not proceed. Higher the ratio above 1 suggests that the benefits associated with the project are higher.

5.6 Performing CBA on the four NEWBITS case studies

5.6.1 CS1: ITS intelligent carpooling system for daily mobility VAOPoint Introduction

The University's VAOPoint Mobility case study (CS1) aims to increase average occupancy and achieve rational use of automobiles, while reducing the number of vehicles used in a university environment with high levels of daily inflow of private vehicles. It offers an intelligent carpooling service for daily mobility to the campus, where members of the university community can access numerous carpooling offers. In addition to traditional cost savings on sharing transportation expenses, VAOPoint promotes the reduction of users' carbon footprint and decrease traffic congestion by promoting high-occupancy vehicles.

VAOPoint has already been piloted at the UAB whose mobility plan includes promoting collective transport, journeys by bicycles as well as achieving more rational use of private vehicles matching the goals of VAOPoint.

5.6.1.1 *Scoping the problem*

UAB campus get filled up with over 13,000 vehicles of a very low occupation index: 1.2 people per vehicle - the same average as that of the metropolitan region of Barcelona. On a normal day there is a peak of 8,000 concurrent cars while there are only 7,000 parking spaces. While the UAB does not have sanctioning capacity, badly parked vehicles generate serious mobility problems such as blocking roads, invasion of unauthorized spaces, hindering mobility of pedestrians and service vehicles, etc.

- For the UAB it means having infrastructures that require constant investment and maintenance, as well as having a space that could be used for other, more productive uses
- For system users, the main problem is the time, cost and quality of the trip to and from the university
- With regard to society, in general, there is unnecessary pollution and an increase in congestion of the road network.

5.6.1.2 *Policy alternatives*

An alternative is to change the free parking system to a system of paid parking. This is, include a new rate to discourage the use of the private vehicle from the point of view of the economy of the users. Given the current context of economic post-crisis after a few years of reduction of benefits and complementary services to employees and increase in the prices of study fees, any incitement of this kind would, a priori, have a very high political cost due to the protests of all kinds that could generate. Also, in the university context where governance is in the hands of those who would be the users, it makes it very complex to have this alternative even high-occupancy private vehicles were free of charge.

A variant of this alternative would be to increase or reward the use of high occupancy vehicles or alternative transport systems, for example, if a salary supplement or a transport grant is set for a certain amount equivalent to the cost of parking so that whoever uses a car private see his income unchanged but whoever uses public transport, bicycle, or other accepted system, will see their income increased (or their costs reduced). However, this option is very complex to manage because the budgets of the university, at least today, would not be able to absorb it.

Doing nothing could be another alternative but in this case, due to the simple vegetative growth, the situation, which is already complex today, would worsen over time, generating more inefficiency and discontent, reducing the quality of life of the users and, in part, the attraction of the university to attract students. Perhaps waiting for the deployment of technological advances with a high impact on mobility, such as the use of shared autonomous cars or an increase in the capacity and quality of public transport or the adaptation of alternative transportation systems, would allow the alternative "Do nothing" a chance to be considered but, in any case, it would not rule out the use of the VAOPoint system in the meantime.

5.6.1.3 *Costs and Benefits of the carpooling system*

The benefits and costs of having a fully functional carpooling system compared to the current situation, where it does not exist, cannot be known. Nevertheless, the current level of development of the system allows us to have a very accurate estimation of the costs and can infer, with a little more uncertainty, the benefits.

Costs

The project initiated by an SME Technology Based Company (a university spin-off company) has been piloted in its first city trial/deployment to members of the university community for access to the campus. For this, a prototype of an app and the corresponding back end software were created to connect users and control the entire carpooling system that would allow identifying the used vehicle and giving access to reserved parking areas. Later on, and incorporating the lessons learned in the pilot, a definitive version of all the software would be developed. Currently, the development of the final version has been tendered and awarded.

The implementation or the one-off costs included the following:

Table 12: Case Study 1 - Implementation Costs

One-time costs	Amount	Source
Project Management Staff	€ 19,080.00	cost of the pilot project
Technical staff	€ 40,040.00	cost of the pilot project
Commercial/marketing Staff	€ 11,460.00	cost of the pilot project
Administrative /support staff	€ 1,660.00	cost of the pilot project
per diem	€ 1,080.00	cost of the pilot project
travels	€ 16,800.00	cost of the pilot project
Equipment and supplies	€ 8,450.00	cost of the pilot project
Graphic design marketing Id	€ 3,000.00	cost of the pilot project
Marketing campaign	€ 14,880.00	cost of the pilot project
Provision for contingence reserve	€ 5,814.00	cost of the pilot project
Administrative costs	€ 8,557.00	cost of the pilot project

Convert prototype into definitive software	€ 28,000.00	Actual contract
Servers	€ 750.00	current internal cost of a server with similar characteristics in UAB
Cost of barriers and sensors for parking spaces	€ 75,000.00	Estimation of UAB Mobility Unit
TOTAL NON-RECURRING COSTS	€ 234,571.00	

Table 13: Case Study 1 - Operation Costs

Periodic costs (Operation and maintenance)	Amount	Periodicity	Comments
Hardware hosting	€ 216	Per year	Estimation by UAB based on input stakeholders
Software maintenance	€ 7,500	Per Year	Estimation by UAB based on input stakeholders
Infraestructure Maintenance	€ 3,000	Per Year*	a non-routine maintenance with replacement of some elements estimated at € 6,000 is foreseen in the third year
Social Network Monitoring	€ 5,220	Per year	Estimation of costs for receiving AIS, GPS and traffic data (estimated based on Fleetmon website, NDW website and stakeholder consultation).
Software Major Revision and Upgrade	€ 30,000	4th year only	Based on complaints and suggestions from users, technological adaptation, new functionalities, etc. a full software revision is planned for the fourth year

Benefits

As a system that does not incorporate any type of payment by users, there is no monetary income of any kind, therefore we cannot talk about revenues, which does not mean that the system has no benefits, but that all of them are intangible.

The most relevant quantifiable benefit comes from savings in CO_2 emissions. The main objective of the entire project is to reduce 2000 cars in 3 years. We will assume a reduction of 750 vehicles the first year, 1500 the second and 2000 the third and subsequent years.

However, this reduction of vehicles will not occur 365 days a year. We do not have direct data of daily arrival of vehicles but we can obtain an indirect reference that is the monthly number of passengers in public transport (data provided by the operators and collected in the mobility plan of the UAB). As results there are 9 months of high activity (coinciding with the academic period), two of medium occupation (June and July) and one of very low occupation (August). Attending also that the maximum affluence takes place between Monday and

Friday allows us to estimate of very conservative way that the saving will take place in 200 days a year (10 months * 20 days/month).

From the mobility plan of the UAB [39][43], and taking into account the city of residence of those who daily arrive at the university, we can infer that the average displacement is 23km (46 round trip).

From Eurostat [40][44] we can see what the average CO_2 emissions of a new vehicle are in Spain. If we cross this information with the average age of the cars in Catalonia (data from the mobility observatory of the Generalitat de Catalunya [41][45]) we can obtain what is the average emission of a standard vehicle in Catalonia (148gr/km), which multiplied by the number of vehicles allows us to obtain the CO_2 savings.

Table 14: Average CO2 emissions of a new vehicle in Spain

Oldness of the vehicle (Years)	% Cat.	Co2 emissions	%Cat*CO2
1	4,30%	114,40	4,92
2	4,00%	115,30	4,61
3	4,90%	118,60	5,81
4	7,10%	122,40	8,69
5	7,30%	128,70	9,40
6	7,10%	133,80	9,50
7	6,40%	137,90	8,83
8	5,50%	142,20	7,82
9	5,20%	148,20	7,71
10	5,90%	153,20	9,04
11	6,30%	155,60	9,80
12	5,40%	155,30	8,39
13	3,80%	155,30	5,90
14	2,80%	157,00	4,40
15 or more	24,00%	180,00	43,20
			148,01

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[43] Available at https://www.uab.cat/web/la-movilidad-en-la-uab/plan-de-movilidad-1273127157967.html Accessed on Nov. 2018

[44] Available at http://ec.europa.eu/eurostat/cache/metadata/en/sdg_12_30_esmsip2.htm Accessed on Nov. 2018

[45] Available at
http://territori.gencat.cat/ca/01_departament/06_estadistica/06_observatori_de_mobilitat/indicadors/arees_tematiques/transit/antiguitat_del_parc_de_vehicles/ Accessed on Nov. 2018

We will use the same assumptions as in the "Update of the Handbook on External Costs of Transport" (European Commission, 2014) [42][46] that uses as a reference value for climate costs per ton of CO2 at € 90

So, if we take the annual reductions of vehicles multiplied by the distance, we calculate their emissions and convert them into euros, the saving for each year is 122.756 € for the first year, 184.135 € for the second and 245.513 € for the third and subsequent year.

Intangible benefits:

There are more benefits associated with the development of the project that justify the existence of a business case, but they are mainly strategic in nature, absolutely intangible and of a very high estimation complexity that we considered unnecessary to carry out.

- Reduction of stress (increase of tranquillity, reduction of uncertainty) considering that you have the security of finding an unoccupied car park without having to look for it
- Reducing 15% the influx of vehicles leads to a considerable reduction in traffic accidents
- Time to find a parking space close to zero, in peak hours could be more than 10 minutes
- Data acquisition. System will provide a big data on users' mobility habits
- Reduction of vehicles parked inappropriately. Improvement of internal mobility and safety in University campus
- Promotion of interaction between users of different centres.
- Promotion of multidisciplinary groups and initiatives. Aligned to the corporate objective of promoting multidisciplinary innovation initiatives on campus

5.6.1.4 *Results*

5.6.1.5 *Net Present Value costs and benefits*
Based on the data from the previous section we have estimated the NPV of the costs and benefits of the carpooling system. We followed the suggestion of the European Commission to use a discount rate of 5%

NPV of Estimated costs:

For years 0-4, the following net present costs were computed: (all figures in €)

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[46] European Commision, DG-MOVE (2014), Update of the Handbook on External Costs of Transport, Available on: https://ec.europa.eu/transport/sites/transport/files/themes/sustainable/studies/doc/2014-handbook-external-costs-transport.pdf Accessed on Nov. 2018

Table 15: Case Study 1- NPV of Costs

Costs On Multiple Years						
Year		Year 0	Year 1	Year 2	Year 3	Year 4
Software maintenance (per year)	Monetary Value		7500	7500	7500	7500
	NPV		7142	6802.72	6478.78	6170.27
Hardware maintenance & operation	Monetary Value	216	216	216	216	216
	NPV		205.71	195.92	186.59	177.7
Infrastructure maintenance	Monetary Value		3000	3000	3000	3000
	NPV		2857.14	2721.09	2591.51	2468.11
Social network monitoring	Monetary Value	5220	5220	5220	5220	5220
	NPV		4971.43	4734.69	4509.23	4294.51
Software Major revision & upgrade	Monetary Value				30000	
	NPV				25915.13	

The Total Net Present Value of Costs = €322,430.40

The benefits were inputted into the model and the net present value for the years under consideration were calculated. This is presented in table 8.

Table 16: Case Study 1 - NPV of Benefits

Benefits occuring on Multiple Years						
Year		Year 1	Year 2	Year 3	Year 4	Year 5
CO2 savings	Monetary Value	122756	184135	245513	245513	245513
	NPV	116910	167016	212083	201984	192366

The Total Net Present Value of Benefits = €890,359.72

5.6.1.6 *Net Present Value*
The overall net present value of the CS1-Vaopoint carpooling system as the difference between the NPV of the benefits and costs is **€ 567,929.32.** Seen in another way the investment is recovered at the beginning of year 3.

5.6.1.7 *Benefit Cost Ratio*
The Benefit Cost Ratio **BCR** (Benefits/ costs) has been calculated and amounts **2.76**. As the BCR is above 1, it can be concluded that the benefits of the project (significantly) outweigh the costs.

5.6.1.8 *Conclusion and recommendations*
After carrying out a cost-benefit analysis for CS1, we were able to identify the costs quite accurately, although the current development of the project does not allow us to accurately quantify the benefits. In addition, in the "Benefits" section we have only been able to include with sufficient guarantee the estimated savings of emissions derived from the planned reduction of vehicles. The complexity of calculating the rest of the intangible benefits identified and the unreliability of the results that could be obtained led us to make the decision not to include them in the analysis, especially when they were not necessary to demonstrate the interest of the project. A subsequent CBA should be performed with real data in terms of reduction of vehicles after implementation to corroborate that the results are satisfactory although everything suggests that even if the expected impact is not achieved, the project remains intellectually interesting.

The University's VAOPoint Mobility case study aims to increase average occupancy and achieve rational use of automobiles, while reducing the number of vehicles used in a university environment with high levels of daily inflow of private vehicles. It offers an intelligent carpooling service for daily mobility to the campus, where members of the university community can access numerous carpooling offers. In addition to traditional cost savings on sharing transportation expenses, VAOPoint promotes the reduction of users' carbon footprint and decrease traffic congestion by promoting high-occupancy vehicles.

VAOPoint has already been piloted at the UAB whose mobility plan includes promoting collective transport, journeys by bicycles as well as achieving more rational use of private vehicles matching the goals of VAOPoint.

5.6.2 CS2: C-ITS to manage the drivers' behaviour crossing traffic lights intersections

The European project Compass4D focused on the design implementation and evaluation of C-ITS services in several European Cities (Bordeaux, Copenhagen, Helmond, Newcastle, Thessaloniki, Verona and Vigo) which resulted in increased drivers' safety and comfort (by reducing the number and severity of road accidents and avoiding queues and traffic jams) and positive environmental impacts (by reducing vehicles' CO_2 emissions and fuel consumption).

Being part of the piloting activities undertaken in Compass4D, the C-ITS service deployed in Verona, also known as Traffic Light Assistance (TLA) service (falling under the so-called day one C-ITS services identified by the European Commission), aimed at providing road drivers with the information needed to take corrective driving actions to avoid unnecessary stops and waiting times at urban signalized traffic intersections. This produced concrete traffic congestion improvements and environmental and health-related benefits.

TLA service is organised in a way that when a driver is approaching an intersection (or alternatively driving through a series of closely-spaced intersections on an equipped urban corridor) he/she receives the information of the time remaining to the appearance of the green light at the next intersection as well as the optimal driving speed in order to reach the next intersections during the green time period, thus avoiding to come to a complete stop.

The realisation of this technological service is enabled by a continuous communication between vehicles and traffic lights and the information to users (i.e. private road drivers, bus drivers or commercial fleet drivers) can be provided through various means of communication, such as via smartphone or it can be directly projected in the car dashboard (Figure 17).
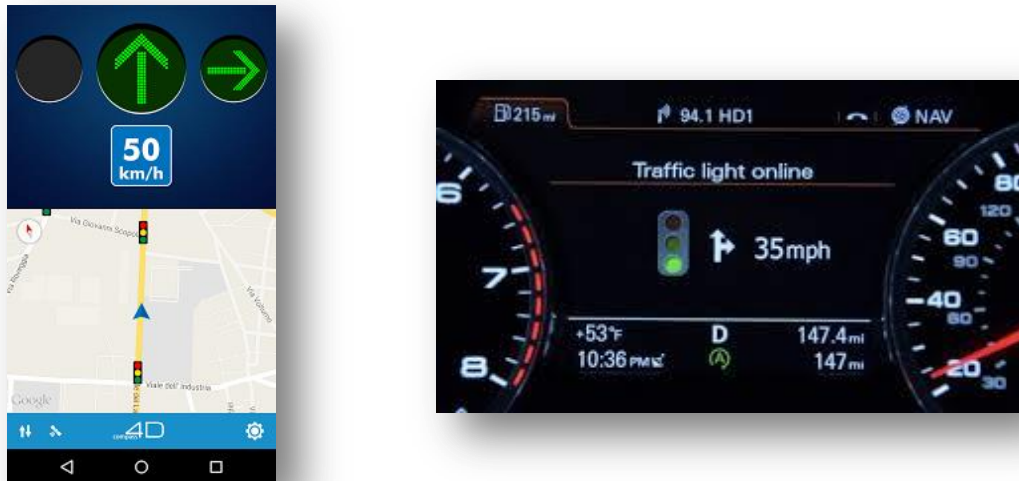
The TLA service can provide the following types of information to users:

GLOSA (Green Light Optimised Speed Advice) – the information about the speed driver must take in order to reach the next traffic light during the green light period; and

TTG (Time to Green) – the information about the time to be waited until the traffic light switches back to green.

Whilst the Compass4D project lasted for three years (between 2013 and 2015), the Verona pilot operation was carried out over a period of 12 months, divided into 3 months 'baseline' operation (to collect data without Compass4D services), and 9 months 'functional' operation (to collect data with Compass4D services in use).

Large scale deployment (i.e. the whole city of Verona) was the main focus of the pilot site, as demonstrated by the pilot stats below:

- No. of cars   30
- No. of buses   10
- No. of drivers   50
- No. of traffic lights   150

For ease of reference, here is a summary of the NEWBITS Case Study (CS) 2 value proposition:

TLA service allows drivers to avoid unnecessary stops and waiting times at urban signalised intersections by undertaking corrective driving actions aimed at regulating current cruise speed; such corrective actions are informed by the speed advice and the information on remaining time to catch up green light at next signalised intersection, which are both delivered to end-users (either through a smartphone application or directly projected on the car dashboard).

CS2's UVP lies in opportunity to travel along congested urban corridors at a minimum cost, with a reduced travel time and improved comfort level, while allowing drivers to generate a much lower environmental impact, thus contributing to the realisation of a greener, more efficient and sustainable mobility.

The TLA service, which can be implemented for any type of road vehicle (i.e. private cars, public transport vehicles, emergency vehicles, commercial vehicular fleet, etc.), it may also increase sustainability and environmental awareness as well as promote the development of eco-friendly communities in European cities.

5.6.2.1 Scoping the problem

The urbanisation phenomenon in association with demographic changes (i.e. relating to population growth, structure and ageing) are driving policy makers to look out for new innovative solutions to solve outdated traffic congestion issues in and around European cities and deliver sustainable urban environments for their citizens.

C-ITS is being progressively promoted by policy makers as a valuable solution to avoid unnecessary traffic delays and road accidents at urban signalised intersections by offering smart, connected, safe and clean solutions meeting the diverse needs of users driving in congested traffic environments. These systems, coupled with urban planning practices, intermodal transport measures and cleaner vehicles, can make modern cities more sustainable, while enhancing the users' travel experience and improve the overall accessibility levels for running economic activities more smoothly.

In the Compass4D project, seven cities industry and research organisations have joined forces to pilot C-ITS services in real-life traffic environments with the ultimate aim to ensure sustainable deployment of C-ITS services beyond the project life-cycle. The Compass4D project proved that there is no one-size-fits-all solution, but it has extensively trialled various C-ITS services tailored to local needs and in line with local mobility policy goals. While Copenhagen focused on improving public transport traffic flows, Helmond demonstrated the benefits of using C-ITS for improving traffic congestion and the driving experience of emergency vehicles and urban freight. On the other hand, Thessaloniki, Verona and Vigo concentrated their efforts on assessing the effects for private drivers, taxi fleets and freight transport.

5.6.2.2 Reference and policy alternatives

The cost-benefit analysis of CS 2 will assess a situation with the TLA service used by road users (policy alternative) as compared to situation without the service being used (reference alternative).

The scale of implementation of the service in the pilot phase is relatively small and does not offer a representative market situation for the cost-benefit analysis. In principle, the service is of interest to private road drivers, emergency vehicle fleet operators, hauliers, etc. Therefore, a scenario is proposed based on the Verona pilot situation where 40 vehicles (and 50 drivers) were equipped with on-board units (OBUs) to allow direct communication exchanges between the vehicles and road-side devices installed at 150 signal-controlled intersections.

5.6.2.3 Benefits / Income

The TLA service, by establishing a continuous communication between vehicles/drivers (through On-board Units, OBUs), the city-wide ITS platform and road-side units (RSUs),

enables drivers to take corrective driving actions to avoid unnecessary stops and waiting times at urban intersections. This results in concrete safety and traffic congestion improvements as well as environmental and health-related benefits.

Through the reduction of the number of vehicle stops at urban intersections, the following benefits can be achieved:

- Reduction of fuel consumption and vehicle emissions at signalised intersections by regularising individual vehicle movements and platoon progression;
- Improvements to safety and traffic efficiency by controlling engine activity and reducing number of stops at intersections;
- Optimisation of junction throughput by minimising time loss at the start of green light (from technical literature, 2-3 sec at the start of green are generally "wasted");
- Improvement to travel times and commercial speed/speed of selected vehicles (emergency, public transport fleet, heavy good vehicles).

However, in the Compass4D project benefits were only assessed in terms of improvements in the length of time needed to cross an intersection, emissions and fuel consumption either directly measured from the vehicle or modelled, number of stops experienced by a vehicle crossing an intersection; the reason being that some of the above benefits could not be estimated directly (such as in the case of road accidents); in such instances the impact of the TLA service could not be directly estimated in real-life traffic conditions but only in controlled or simulated environments presenting non-safety critical conditions.

One of the main conclusions of the COMPASS4D project was that travel time and fuel consumption improvements depend heavily on the expansion of the system in terms of number of equipped vehicles and intersections. Therefore, the multiplication of benefits for all vehicle categories is directly associated with the number of vehicles and the extent of the infrastructure equipped with OBUs and RSUs respectively.

The actual availability of benefit-related data will have to be confirmed in due course with former Compass4D project partners.

Benefits estimation

The Compass4D project faced a unique data collection challenge for the Verona pilot site which was brought up by the limited number of journeys logged by the system across the site and the low frequency of data recorded within those journeys. As a result, the statistical unreliability of data collected meant that robust conclusions could not be drawn for Verona pilot site (although the technology was successfully evaluated in other pilots).

In the remainder of Section 5.3.2 of this Deliverable, an overview is given of the identified cost and benefit items which have been estimated based upon interactions with key stakeholders (namely the Municipality of Verona) and on a number of assumptions which are herewith discussed.

As a result, it should be noticed that the level of uncertainty in these figures is rather high and that they should be considered as illustrative.

Taking these limitations into account, below is the evaluation data available from the publicly available Evaluation report of the Compass4D project. The metrics used can be interpreted as follows:

- **Distance**: The distance metric is the total distance driven by a vehicle starting from the time it enters an intersection to the time it leaves that intersection.
- **Duration**: The duration is the time taken for a vehicle to enter and then exit a particular intersection.
- **Speed**: The speed is a function of the previously created distance and duration and, like duration, will probably see a large systematic variation across intersection, trajectories and congestion levels.
- **Emissions**: The emissions within this system are defined as the gCO_2 emitted by the vehicle across each separate journey. The emissions have been calculated from the Panis Emissions model. It is expected a systematic variation in emission across the different vehicle types and hence it would be necessary to analyse each vehicle type separately.
- **Efficiency**: The efficiency is calculated from the total emissions and the total distance over each journey. It is normally expressed in units of gCO_2/km and serves as a useful indicator for the improvement (or otherwise) in a journey. It is more useful than emissions as it is naturally averaged by the distance, whilst the emissions from a journey will contain the variation in the distance, which can be affected by logging drop out.

Table 17 CS2 Compass4D evaluation results for Verona pilot site.

	Duration	Distance	Speed	Emission	Efficiency
	Secs	M	M/S	gCO_2	gCO_2/km
Route 1	-10.6	-29.4	0.103	-34.1	-0.077
Route 2	6.76	39.1	-1.17	-22.5	-0.0564
Route 3	32.6	-38.4	-5.53	-92.0	-1.18
Route 4	52.8	-45.4	-0.626	-92.7	-0.0769

NB: it should be noted that the number and vehicle types used for each route is unknown. The total distance driven by the 40 vehicles used in the demonstration trials can be derived from values above, i.e. 2,125km.

The net reduction of gCO2 per vehicle (i.e. 'Efficiency' metric) is used to estimate savings of climate change costs. It is worth considering that all publications available in the technical literature require CO2-equivalent or measurement of other pollutants as data inputs to estimate air pollution savings, i.e. particulate matter etc., which are therefore not considered in the calculations below.

According to the "Update of the Handbook on External Costs of Transport" (Ricardo, 2014), considering a unit climate change cost of 90€/tonne the resulting climate change savings would be marginal (CS2 is only a pilot demonstration). Therefore, the average reduction of CO2, i.e. 0,35 gCO2/veh km, is used to infer the total resulting cost savings obtainable for the entire vehicular fleet circulating in Verona, if the CS2 service was deployed throughout the city.

Table 18 Total yearly cost savings from emissions reductions.

	City of Verona	Metropolitan area	Reference or comments	
Vehicular fleet	164.336	576.441	SUMP Observatory https://www.osservatoriopums.it/verona	Automobile Club d'Italia statistics (2014) http://www.aci.it/laci/studi-e-ricerche/dati-e-statistiche/consistenza-parco-veicoli/2014.html
Total daily trips (*)	130.288	455.388 (576.441 *0,79)		-
Total daily trips to vehicular fleet	0,79	-	-	
Average distance travelled (km)	4	11,6	UNRAE, Censis joint research report (May 2018) – "La mobilità in transizione: L'esigenza di un accompagnamento consapevole ed evoluto" http://www.unrae.it/files/Studio%20CENSIS_5af9838c387f9.pdf	
Average CO2 reduction (gCO2/veh*km)	0,35	0,35	From Table 1	
Climate change cost (€/tonne)	90	90	https://ec.europa.eu/transport/sites/transport/files/handbook_on_external_costs_of_transport_2014_0.pdf	
Average working days per year	250	250	-	
Total cost savings per year (€)	4,515	45,760	**City:** (130.288 * 4 * 0,35 * 90 * 250) **Metropolitan**: ((576,441 * 0,79) * 11,6 * 0,35 * 90 * 250)	

(*) only journey purposes considered are: home to education and home to work

Regarding travel time improvements, these could be derived from a traffic microsimulation study [43][47] undertaken for Verona within the framework of the Compass4D project. It should however be noted that the network modelled only 4 included junctions totaling up to 1km in length. Choosing a normal traffic scenario and a 50% vehicle penetration rate, there would be a 9s travel time improvement (per vehicle) on average. Using a National reference value for the value of time parameter (ca. 4.5 €/h), another marginal improvement derives.

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[47] Compass4D project (2015), Deliverable 4.2 Final Results Report

As a result, it is considered such travel time changes are only theoretic since in real-world environments they would be highly dependent on the extent of the network considered, the specific traffic conditions dominating the transport network throughout the day as well as the penetration rate of vehicles equipped with OBUs. Therefore, the monetary effects of travel time improvements are no further considered.

Additional benefits that could not be quantified are:

- Air pollution improvements
- Improvement to travel times and commercial speed/speed of selected vehicles
- Improvements to road safety and traffic efficiency by controlling engine activity and reducing number of stops at intersections;
- Optimisation of junction throughput by minimising time loss at the start of green light
- Improved driving experience
- Mental health (stress reduction)

5.6.2.4 *Costs*

Typical cost categories associated with the provision of any type of ITS service are:

1) **Implementation costs**: project management staff, technical development staff, office space & telematics platform (such as the Verona's proprietary ITS platform which supervises traffic operations across the City, OBUs and RSUs);
2) **Operation & maintenance costs**: management and customer services staff, technical development staff, property operating expenses, employee training and assistance costs, specific supplier expenses (IT equipment and tools, financing, insurance, legal, training delivery, etc.); and
3) **Other costs** (organizational and bureaucratic costs).

Following a meeting with Verona Municipality held on 4th December 2018, which acts as the sole orchestrator of mobility services in the city of Verona, it was understood that costs incurred to operate the TLA service are only related to the upgrade and renewal of IT and road-based infrastructure as well as upgrading of database and software tools.

The overall spend was €600,000 (namely, €200,000 a year and with a 50% funding provided by the European Commission as part of the Compass4D activities) spread over three years of project funding.

Costs estimation

With reference to the cast categories introduced above, a summary of implementing and operating costs is shown in Table 1 and 2.

<div align="center">Table 19 CS2 Total non-recurring costs</div>

Implementation		
Project Management Staff		
Team Leader	€0,00	Whilst these cost categories are typical for running and managing ITS services, project management staff had already been employed at the Verona Traffic Control Centre (which hosts the TLA-related infrastructure) when the Compass4D project started; therefore there was no need for additional human resources.
Assistant 1	€0,00	

Technical Development Staff		
IT Team Leader	€0,00	Whilst these cost categories are typical for running and managing ITS services, project management staff had already been employed at the Verona Traffic Control Centre (which hosts the TLA-related infrastructure) when the Compass4D project started; therefore there was no need for additional human resources.
IT Assistant 1	€0,00	
Office Space & IT Platform		
Office space and Communication room	€0,00	All equipment is hosted within the Verona Municipality Traffic Control Centre
IT platform and operation	€100.000,00	Rough estimate to install RSU, OBU and progressively update existing IT infrastructure and SW tools
Data Purchase		
Mapping, Transport Infrastructure & Traffic Data	€0,00	No need for this as Verona owns the data
Location data (GPS)	€0,00	to acquire vehicle location data for a year from a vehicle manufacturer
Accounting and legal services	€0,00	assumed in Compass4D was dealt by internally
Marketing Campaign	€0,00	assumed there was no need to market this
Total non-recurring costs	**€100.000,00**	

Table 20 CS2 Total recurring costs

Operation and Maintenance		
Management & Customer Service staff		
Team Leader	€0,00	
Assistant 1 / Customer Service	€0,00	
Technical Development Staff		
IT Leader	€0,00	
IT Assistant	€0,00	
Office Space & IT Platform	€60.000,00	Rough estimate to install RSU, OBU and progressively update existing IT infrastructure and SW tools
Data Purchase	€40.000,00	yearly cost, to acquire vehicle location data (for a year) from a vehicle manufacturer
Accounting and legal advice	€0,00	assumed in Compass4D was dealt by internally
Marketing campaign	€0,00	assumed there was no need to market this sinceCS2 is a pilot project.
Total recurring costs	**€100.000,00**	

5.6.2.5 *The CBA modelling*

The implementation or the one-off costs included the following:

Table 21 CS2 Implementation costs

IMPLEMENTATION COSTS	
Team Leader	€ 60,000.00
Assistant 1	€ 30,000.00
IT Team Leader	€ 40,000.00
IT Assistant 1	€ 20,000.00
IT platform and operation	€ 10,000.00
Location data (GPS)	€ 40,000.00
TOTAL NON-RECURRING COSTS	€ 200,000.00

Table 22 CS2 Operation and maintenance costs

OPERATION AND MAINTENANCE COSTS	
Office Space & IT Platform	€ 10,000.00
Data Purchase	€ 40,000.00
TOTAL NON-RECURRING COSTS	€ 50,000.00

On entering the costs in the model, the NPV was calculated for the recurring costs. The European Commission's suggestion of a discounting rate of 5% was used. For years 0-4, the following net present costs were computed:

The Total Net Present Value of Costs = €387,297.53

Table 23 CS2 Benefits Occurring on Multiple Years

Benefits Occurring on Multiple Years						
Year		Year 0	Year 1	Year 2	Year 3	Year 4
Climate change cost savings due to emission reductions (city level)	Monetary Value	4515	4515	4515	4515	4515
	NPV		4300	4095.24	3900.23	3714.5
Climate change cost savings due to emission reductions (metropolitan area)	Monetary Value	45760	45760	45760	45760	45760
	NPV		43,580.95	41505.67	39529.21	37646.87

The Total Net Present Value of Benefits = €228,547.66

Net Present Value

The net present value for case study 1 using:

$$NPV = \sum PV\,(B) - \sum PV\,(C)$$

NPV = -€158,749.86

The net present value with horizon value was:

$$NPV = PV(B) - PV(C) + PV(H)$$

NPV = -€131,872.40

Benefit Cost Ratio

The Benefit Cost Ratio:

$$BCR = \frac{\sum PV(B)}{\sum PV(C)}$$

BCR = 0.59

Generally, if a project's BCR is less than 1, the project's costs outweigh the benefits and it should not be considered.

A sensitivity analysis was carried out for different values of discount rates, this is presented in the table 16 below:

Table 24 CS2 sensitivity analysis

		NPV	NPV + H
Discount Rate (-)	-10.0	-£168,472.44	£77,165.58
	-9.0	-£168,505.54	£26,263.10
	-8.0	-£168,537.28	-£13,711.27
	-7.0	-£168,567.72	-£45,187.27
	-6.0	-£168,596.94	-£70,036.34
	-5.0	-£168,625.00	-£89,704.00
	-4.0	-£168,651.96	-£105,309.87
	-3.0	-£168,677.87	-£117,723.45
	-2.0	-£168,702.80	-£127,621.83
	-1.0	-£168,726.78	-£135,533.57
	0.0	-£168,749.86	-£141,872.40
Discount Rate (+)	1.0	-£168,772.10	-£146,962.91
	2.0	-£168,793.52	-£151,060.42
	3.0	-£168,814.17	-£154,366.20
	4.0	-£168,834.08	-£157,039.34
	5.0	-£168,853.29	-£159,205.83
	6.0	-£168,871.83	-£160,965.68
	7.0	-£168,889.73	-£162,398.47
	8.0	-£168,907.02	-£163,567.66
	9.0	-£168,923.73	-£164,523.94
	10.0	-£168,939.88	-£165,307.91

The model indicated that the project will break even in the horizon (period 20 years) at a discount rate of -10 or -9.

Intangible benefits (Societal and economic benefits)
- The impacted business would be OEMs, public transport operators, telecom operators, road freight operators;

- Road accidents likely to be avoided given the reduction in the number of stops at signalised junctions enabled by the system;
- Although they could not be quantified due to the lack of available data, travel time savings could also result from the system since users would drive on corridors equipped with road-side units aimed at communicating the optimal driving speed (and remaining time to red signal) to avoid stops at downstream junctions;
- Improved driving experience and stress reduction (from traffic).

5.6.2.6 *Conclusion and recommendations*

The pilot demonstrator for delivering the TLA service involved a local authority, public transport and fleet operators and ICT/ITS developers, which seems quite vital to support knowledge exchange among many different stakeholders, and develop a system characterized by secure information exchange in a trusted working environment.

A framework for the cost-benefits analysis of CS2 has been developed to assess the socio-economic sustainability of a TLA-related investment.

Different cost and benefit items have been identified for CS2, however these were strongly affected by insufficient amount of pilot-based data as discussed above. A first principles cost-benefits estimation has therefore been performed based on assumptions made by the case study leader (TTS Italia) and on consultations with the CS2 stakeholders.

According to the exercise results, investment costs are relatively high; the results of the CBA indicate that implementation of the TLA service may not lead to self-sustaining socio-economic benefits, when it is implemented at city-level scale, given the CBR is less than 1.

However, it should be reminded that the Verona pilot lacked robust evidence to assess the effects of the TLA on travel time changes across the city, as detailed earlier in this document. At the scale of a city, even a small amount of travel time saving achieved as a result of giving green light priority at urban signalized junctions (to public transport or emergency vehicles) of the order of 2-4% can show a significant annual return, in the order of millions of Euros, as well as deliver safety-related benefits.

In light of these considerations, it may be considered that the CBR will improve significantly as time saving benefits are entered into the calculations and a more precise cost estimate is inputted into the CBA model.

Based on the positive results for users and cities obtained across the seven Compass4D pilots, these decided to continue operating the Compass4D C-ITS services in 2016 regardless of European funding opportunities. Therefore, upon relying on the strong commitment of both public and private stakeholders, representatives from the cities were firmly convinced that C-ITS will help them to reduce road transport-related emissions as well as improve traffic flows and road safety conditions; this clearly demonstrates the true commitment shown by cities to further deploy C-ITS across Europe.

5.6.3 CS3: New ICT method to increase efficiency in logistic chain of ports

Case study 3 is about a track-and-trace service for container transport from the sea port to the hinterlands by inland waterway and truck (for the last mile of the container to the warehouse or further in case of delays). The service visualises in a dashboard the real-time status, location and Estimated Time of Arrival (ETA) of containers from the moment the sea port is approached up to the moment at which the container reaches the warehouse where the container is unpacked, providing the following information:

- A centralised overview of the container planning.
- Continuously updated ETA.
- Actual Time of Arrival (ATA).
- Container status (e.g. customs information, commercial release).

This information stems from several sources, such as the individual participants' planning and monitoring systems as well as public sources for ship positioning and proprietary ETA predicting engines. The information is aggregated to complete an end-to-end view of the container, following an open standard for trip specification.

At the moment the project is in a pilot phase in which the containers are followed for a single logistics chain from Rotterdam to a warehouse in Limburg. During this pilot the system will be tested and the different partners will experience some of the cost and benefits generated by the service. The logistic chain involves a shipper, a warehouse operator and an inland terminal. The latter also takes care of the barge and truck transport on the corridor deep sea terminal – inland terminal – warehouse. In a fully operational phase the system can be applied to many more logistic chains and other cross cost and benefits may be revealed than for a single logistic chain.

5.6.3.1 *Scoping the problem*
In container transport from overseas origins to destinations in the hinterland of sea ports, often many logistic companies are involved such as shippers, shipping companies, sea terminal operators, sea port authorities, inland terminal operators, freight forwarders, carriers and warehouse operators. A lot of communication is necessary between these parties to make this transport happen.

The planning of the hinterland logistics very much depends on the processes in the sea port: the arrival of the sea ship, the unloading of the ship, the release of the containers by customs and shipping company and finally the barge planning. The time of arrival (and release) of the container in the sea port has a relatively high uncertainty (e.g. due to weather conditions, delays caused by intermediate stops at other sea ports, etc.) and the estimated time of arrival can change often before the actual time of arrival. In addition, in hinterland transport events can occur that influence the predicted time of arrival, such as longer waiting time at locks and congestion at roads. For the logistic partners in hinterland transport it is important to have up-to-date information on the container status in order to plan their resources efficiently (e.g. by responding adequately and minimizing efforts for coordination and communication in case of delays). However, currently this information is not provided with high frequency and is not shared automatically with all logistic partners involved. Any changes with respect to the original planning or experienced delays therefore lead to a lot of ad-hoc communication.

The track-and-trace platform developed in the case study makes it possible to share the real-time information of the containers between all involved logistic parties. This will, first of all, reduce communication on updates between the involved parties. In addition to this main initial objective of the service, the track-and-trace platform may also provide the agents in the logistic chain to better plan their recourses and deliver better services.

5.6.3.2 *Reference and policy alternative*
The cost-benefit analysis of case study 3 will assess a situation with the track-and-trace used by logistic parties in the transport process (policy alternative) as compared to situation without the track-and-trace system being used (reference alternative).

The scale of implementation of the service in the pilot phase is relatively small and does not offer a representative (long-term) market situation for the cost-benefit analysis. In principle, the system is of interest for all logistic organisations in container transport, particularly from sea ports. Therefore, a scenario is proposed based on a situation in which 200.000 containers per year are track-and-traced belonging to 222 shippers (assuming 900 containers per shipper) and involving 30 different logistic service providers (warehouses, inland terminals, forwarders etc.) involved in the transport. The number of containers roughly equals about 20% of loaded containers that are transported per barge from Rotterdam to the hinterland (see market analysis in D3.3). At this larger scale the service might not only provide benefits to a single logistic chain, but also cross-chain benefits, such as optimization in the planning of barges.

Notice that the definition of the policy alternative is in line with a potential market situation on the medium to long term. At the short term, the market penetration of the service will be lower, covering less containers. In order to assess the impact of the market size (i.e. number of containers covered) on the costs and benefits of the services, a sensitivity analysis is carried out in Section 5.6.3.7.

5.6.3.3 *Inventory Costs and benefits of the track-and-trace service*
The costs and benefits of having the track-and-trace system as compared to the situation without are currently not known. However, an inventory of expected cost and benefit items have been identified during the project (see also D3.1 and D4.2). In the sections below an overview is given of the identified cost and benefit items. As a first exercise, costs and benefits have been estimated offering a CBA framework for case study 3. The CBA figures can, after the pilot period, be updated with more actual figures with the stakeholders of case study 3.

The figures used in the exercise (with large ranges to show the uncertainty in these figures) are merely based on an expert guess by the case study leader (CE Delft), and sometimes based on input from the stakeholder at an earlier stage of the project. It should be noticed that the level of uncertainty in these figures is rather high and that they should be considered illustrative. As mentioned before, the CBA should preferably be updated with more robust figures once the pilot period is finished.

Costs
The costs of implementing the track-and-trace service mainly exist of one-time or non-recurring costs (e.g. developing costs, learning costs) and periodic or recurring costs (e.g. operation costs). An overview of the non-recurring and recurring costs is given in the tables

below. For each cost item a range of the estimated value is given. Furthermore, the sources (and/or assumptions) used to estimate the various costs are presented.

Table 25: CS3 Costs

One-time costs	Min	Max	Source
Development of the service in pilot phase	€ 400,000	€ 1,000,000	Estimation by CE Delft.
Investment in developing the system to a commercial product	€ 150,000	€ 250,000	Estimation by CE Delft based on input stakeholders
Costs for developing API	€ 15,000	€ 280,000	Estimation by CE Delft based on input stakeholders. Assumption used:1 -14 man-days per API against average wage costs of € 125, -/h. Maximum 15-20 different API to develop (assuming that the stakeholders use 15-20 different types of logistic management systems and once API are developed for these different systems additional costs are marginal).
Costs ITS developer to connect clients to the track-and-trace system	€ 63,056	€ 126,111	Estimation by CE : 2-4 hours per connection (Given a developed API).
Cost for users to implement the track-and-trace system (learning costs)	€ 201,778	€ 403,556	Estimation by CE Delft based on 8 - 16 hours per customer against average wage costs of €100,-/ h
Total non-recurring costs	€ 829,833	€ 2,059,667	

Table 26: CS3 Operation Costs

Periodic costs (Operation and maintenance) (yearly)	Min	Max	Comments
Hardware hosting	€ 2,400	€ 4,800	Estimation by CE Delft based on input stakeholders
Software maintenance	€ 15,000	€ 25,000	Estimation by CE Delft based on input stakeholders. Assumption: software maintenance costs are equal to 10% of investment cost in developing to commercial product
8/7 (minimum variant) or 24/7 (maximum variant) help desk service	€ 219,000	€ 657,000	Estimation by CE Delft based on input stakeholders. Assumption: 8 or 24 manhours per day, against average wage costs of €75,-/h.
Data costs (from external sources like road traffic, AIS)	€ 7,200	€ 21,600	Estimation of costs for receiving AIS, GPS and traffic data (estimated based on Fleetmon website, NDW website and stakeholder consultation).

Total recurring costs	€ 251,100	€ 720,900	

Benefits

As the track-and-trace system gives better insight in the status and expected time of arrival of the container, it allows to streamline the hinterland process. It is expected that this will reduce time spent on communication (mainly between inland terminal operator and warehouse operator), will reduce ad-hoc trucking for delayed containers, and will allow the warehouse to better plan the work-forces for unpacking the containers (i.e. higher productivity of workforces at warehouses). In addition, the streamlining of the process might partly lead to earlier sales of the containers' content and the contractual rental period of the container might be reduced as the slack in the planning will be reduced. Finally, when information on estimated time of arrival and release time at the sea port is improved for a large share of the containers in Rotterdam, the barge planning might be improved leading to reduced kilometres in the Port of Rotterdam between terminals and/ or higher load factors of barges. This increased transport efficiency leads to cost savings, which can be regarded a benefit of the track-and-trace system. Furthermore, it may lead to a reduction in emissions (of trucks and barges).

An overview of the benefits is given in the tables below. For each cost item a range of the estimated value is given. Furthermore, the sources (and/or assumptions) used to estimate the various costs are presented.

BENEFITS (recurring) (yearly)	Min	Max	Comments
Reduced communication Warehouse	€ 333,333	€ 666,667	Estimation by CE Delft: Assumption: for 5- 10% of containers 20 minutes less communication per container is required. By assuming an average wage costs of € 100,-/h, the total savings on labour costs are calculated.
Reduced communication inland terminal operator	€ 333,333	€ 666,667	Estimated CE Delft: Assumption: for 5- 10% of containers 20 minutes less communication per container is required. By assuming an average wage costs of 100,-/h, the total savings on labour costs are calculated.
Reduced trucking	€ 300,000	€ 400,000	Estimation by CE Delft based on input stakeholders. Extra costs trucking 100,- per event. From total containers 3-4 % is trucked because of delay; 50% of these delays will be prevented by ITS solution.
Higher productivity workforces at warehouse (less hours per container)	€ 320,000	€ 800,000	Estimate CE Delft: In the reference alternative 2 hours per container was required to unpack containers. In policy alternative, 2-5% less time needed to unpack containers. The savings in labour costs are estimated by multiplying time savings with average wage costs of 40,-/h.
Earlier sales of goods (opportunity costs)	€ 342,466	€ 2,739,726	Estimation by CE Delft based on input stakeholders. Value content of container is €125.000-€1.000.000; 5% of containers delivered one day earlier, opportunity costs rent: 10%
Reduction in container rental period	€ 1,000,000	€ 4,000,000	Estimation by CE Delft based on input stakeholders. Container rent costs are €5-€10 per day. In contract (longer term) rental period might be reduced by 1-2 days if general lead time is reduced.
Increased transport efficency (km/tkm) barges in port	€ 230,400	€ 460,800	CE Delft assumption: Cost barge 1.15 Euro/container-km, 100 km average distance to inland terminal, 1%-2% reduction in costs due to higher efficiency
Environmetal benefits of reduced trucking	€ 36,794	€ 49,058	CE Delft assumption: The emission of truck transport are replaced by emissions of transport by barge (see details in annex)
Environmetal benefits of increased efficency barging	€ 36,386	€ 72,771	CE Delft assumption; The track and trace system allow barges to improve their efficiency in the sea port; optimization of terminal calls at sea port and capacity utilization (see annex for details).
Total Benefits	€ 2,859,532	€ 9,733,859	

5.6.3.4 *Results*

Net Present Value cost and benefits

Based on the figures presented in the previous section for total non-recurring costs and annual recurring costs, the NPV for all costs of the track-and-trace service was estimated. The European Commission's suggestion of a discounting rate of 5% was used. Furthermore, we only include the costs (and benefits) for the first five years for which the service is running. This will probably result in a conservative estimate of the Cost-Benefit ratio, as most costs occur in the first year of the project, while benefits are expected for the whole period the service is running.

The following net present costs were computed for the minimum and maximum of the range. We show both the NPV per year and the total NPV for the entire period.

Table 28: CS3 NPV of Minimum Costs

NPV of Minimum estimated costs	year 1	year 2	year 3	year 4	year 5	Total 1-5
Development of the service in pilot phase	400,000	-	-	-	-	400,000
Investment in developing the system to a commercial product	150,000	-	-	-	-	150,000
Costs for developing API	15,000	-	-	-	-	15,000
Costs ITS developer to connect clients to the track-and-trace system	63,056					63,056
Cost for users to implement the track-and-trace system (learning costs)	201,778	-	-	-	-	201,778
Hardware hosting	2,400	2,286	2,177	2,073	1,974	10,910
Software maintenance	22,500	21,429	20,408	19,436	18,511	102,284
8/7 help desk service	219,000	208,571	198,639	189,180	180,172	995,563
Data costs	7,200	6,857	6,531	6,220	5,923	32,731
Total	1,080,933	239,143	227,755	216,910	206,581	1,971,322

Table 29: NPV of Maximum Costs

NPV of Maximum estimated costs	year 1	year 2	year 3	year 4	year 5	Total 1-5

Developement in pilot phase	1,000,000	-	-	-	-	1,000,000
Investement to commercialize service	250,000	-	-	-	-	250,000
Costs per client for connecting (developing API)	280,000	-	-	-	-	280,000
Cost for user to adapt to T&T system	126,111	-	-	-	-	126,111
Hardware hosting	4,800	4,571	4,354	4,146	3,949	21,821
Software maintenance	37,500	35,714	34,014	32,394	30,851	170,473
24/7 help desk service	657,000	625,714	595,918	567,541	540,516	2,986,689
Data costs	21,600	20,571	19,592	18,659	17,770	98,193
Total	2,780,567	686,571	653,878	622,741	593,086	5,336,842

The total net present value of the costs is in the range of **€2.0- €5.3 million**. These costs consist for 39% of non-recurring costs.

The NPV of the benefits were computed as below for both the minimum and maximum estimation. Again, we have shown the annual NPVs as well as the total NPV for the entire 5-year period.

Table 30: CS3 NPV Minimum Benefits

NPV of Minimum estimated benefits	year 1	year 2	year 3	year 4	year 5	Total 1-5
Reduced communication Warehouse	333,333	317,460	302,343	287,946	274,234	1,515,317
Reduced communication at ITO	333,333	317,460	302,343	287,946	274,234	1,515,317
Higher productivity workforces at warehouse (less hours per container)	320,000	304,762	290,249	276,428	263,265	1,454,704
Earlier sales of goods (opportunity costs)	342,466	326,158	310,627	295,835	281,747	1,556,832
Reduced trucking	300,000	285,714	272,109	259,151	246,811	1,363,785
Reduction in container rental period	1,000,000	952,381	907,029	863,838	822,702	4,545,951
Increased transport efficiency (km/tkm) barges in port	230,400	219,429	208,980	199,028	189,551	1,047,387
Environmental benefits of reduced trucking	36,794	35,042	33,373	31,784	30,270	167,262
Environmental benefits of increased efficiency barges	36,386	34,653	33,003	31,431	29,935	165,407
Total	2,932,712	2,793,059	2,660,056	2,533,387	2,412,749	13,331,962

Table 31: CS3 NPV of Maximum Benefits

NPV of Maximum estimated benefits	year 1	year 2	year 3	year 4	year 5	Total 1-5
Reduced communication Warehouse	666,667	634,921	604,686	575,892	548,468	3,030,634
Reduced communication at ITO	666,667	634,921	604,686	575,892	548,468	3,030,634
Higher productivity workforces at warehouse (less hours per container)	800,000	761,905	725,624	691,070	658,162	3,636,760
Earlier sales of goods (opportunity costs)	2,739,726	2,609,263	2,485,012	2,366,678	2,253,979	12,454,659
Reduced trucking	400,000	380,952	362,812	345,535	329,081	1,818,380
Reduction in container rental period	4,000,000	3,809,524	3,628,118	3,455,350	3,290,810	18,183,802
Increased transport efficiency (km/tkm) barges in port	460,800	438,857	417,959	398,056	379,101	2,094,774
Environmental benefits of reduced trucking	49,058	46,722	44,497	42,378	40,360	223,016
Environmental benefits of increased efficiency barges	72,771	69,306	66,006	62,863	59,869	330,815
Total	**9,855,689**	**9,386,370**	**8,939,400**	**8,513,715**	**8,108,300**	**44,803,473**

The total NPV of the benefits range from **€13.3 million to €44.8 million**. Earlier sales of goods and reductions in the rental period of containers contribute significantly to these total benefits (12%-28% and 34-41%, respectively). But also reduced communication costs, higher productivity of workforces at warehouses and cost savings due to reduced trucking seems to be significant benefits of this service.

5.6.3.5 *Net Present Value*

The overall net present value of the track-and-trace system is the difference between de NPV of the benefits and costs. (Benefits-costs).

When taking the values for the minimum cost and benefits the NPV equals **€11.4 million,** for the maximum values it is €**39.3 million.** It should be noticed that even when only the reduction in communication costs (the main initial objective of the service) are considered, benefits do exceed costs resulting in a NPV of € 0.7 to € 1 million.

5.6.3.6 *Benefit Cost Ratio*

The Benefit Cost Ratio **BCR** (Benefits/ costs) has been calculated and amounts **6.8** for minimum values and **8.4** for maximum values. As the BCR is above 1, it can be concluded that the benefits of the project (significantly) outweigh the costs.

5.6.3.7 *Sensitivity analysis*

Two types of sensitivity analyses are carried out in order to test the robustness of the results found in the previous sections. First, we compared the minimum benefits and maximum costs of implementing the track-and-trace system. Even in this case, the benefits outweigh the costs with a NPV of €9.0 million and a BCR of 2.5.

Additionally, a sensitivity analysis was carried out for different number of containers (see figure below). Minimum estimated cost and benefits are in balance at a volume of 26.500 containers per year. For maximum costs and benefits this is 22.000 containers per year. Comparing the maximum cost with the minimum benefits the BCR becomes positive above 76.000 containers per year. So, even at a more premature phase of the market penetration of the service the benefits exceed the costs.
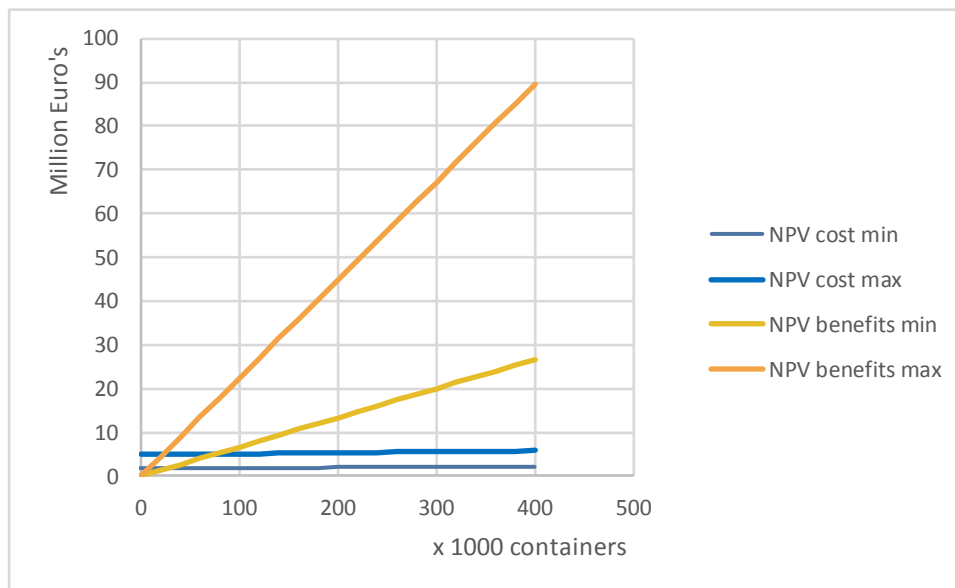
Figure 18: CS3 Sensitivity Analysis

5.6.3.8 *Conclusion and recommendations*

A framework for the social cost-benefit analysis of case study 3 has been developed. Different cost and benefit items have been identified. As the case study is still in a pilot phase, it is too early to quantify the costs and benefits. However, a first exercise has been performed based on cost and benefits estimates made by the case study leader (CE Delft). The results of this exercise indicate that implementation of the track-and-trace system may lead to net social benefits when it is implemented at a scale above 25.000 containers. Furthermore, it is shown that at a scale of 200,000 containers, only the reduced communication costs (the main initial objective of the service) are sufficient to cover the costs. A further elaboration of the social cost-benefit analysis should be performed to confirm and elaborate these conclusions. This can possibly be done after the pilot period, as then more evidence on costs and benefits will be available.

As mentioned above, the social cost-benefit analysis has been carried out for a possible medium to long term scale of 200,000 containers. At the initial phase of the project, the BCR will be lower, as most costs occur at the development and implementation phase, while benefits occur over the entire lifetime of the service. It would be recommended to assess a

policy alternative that considers a growth path of the scale of the service, as this will show the BCR at the first, less profitable years. Furthermore, such an analysis will show when the service will become profitable (from a social point of view).

The current social cost benefits analysis gives no information on the business cases of the individual parties in the system. To bring the track-and-trace system to the market it is important to create net benefits for all individual partners. Therefore, it is recommended to assess which stakeholders will bear the costs and benefits of implementing this system (in relation to the networked business model). Alternatively, the stakeholders that are also the actors of this network are in a position to develop cost-sharing schemes between themselves in order to bear the costs fairly equal.

According to the exercise results, investment costs are relatively high, including the cost for the pilot. The pilot for such a service that includes many different stakeholders, seems vital to support knowledge exchange between logistic and ICT stakeholders, to develop a system for secure information exchange in a trusted business environment and to advance the technological developments together.

A government grant to start a pilot can be very helpful to bring these stakeholders together. As there are net social benefits expected, such a grant is legitimate.

5.6.4 CS4: KEEP SAFE - A Knowledge-based approach to understanding railway safety

5.6.4.1 *Introduction*
Case study 4 is about the use of experts' knowledge to make data-informed decision making for transport safety, with focus on the British railway.

The project addressed the following challenges within the railway industry:

- Safety of passengers, staff and communities
- Relationship between data security and railway safety
- Predictive maintenance of railway infrastructure.

These three areas were addressed by collecting knowledge from a range of areas across the industry to understand the relationships between railway data and railway safety. A series of knowledge models were created to support data-driven decision making.

Key stakeholders in this project included:

From within the railway industry:

- Train manufacturers: Alstom Transport
- Train owners: Network Rail
- Train operators: Virgin Trains
- Railway regulatory bodies: Office of Rail and Road (orr.gov.uk)

From outside the industry:

- Government: Railway Safety and Standards Board
- Citizens (staff, passengers, communities): ultimately beneficiaries from an increased safety

5.6.4.2 *Scoping the problem*

A vast range of data exists within the railway industry, and their availability continues to increase as a result of uninterrupted data collection processes across the industry.

Continuous data collection processes from several sources provide the railway industry with regular snapshots of the situation and usage of their infrastructure and capabilities. However, despite the current use of those heterogeneous and sometimes contradictory data streams by specific stakeholders, the railway as an industry is still to realise the full potential of all the data available and understand their growing value for the future of the railway.

A joint view of those data resources could lead to a wide consensus on its value, sharing and use by key stakeholders. This would have countless benefits for the railway industry. This project focuses on how the data available can help in designing and putting in place mechanisms to assure safety and security of customers and staff in an industry where the interdependence between physical and digital environments is set to grow exponentially over the next few years. This is particularly important as an additional risk emerges: the physical security of individuals is increasingly influenced by the security of the data that the railway industry holds.

5.6.4.3 *Reference and policy alternative*

When considered in the wider context of transport this project represents a differential innovation as it combines aspects already in use in sectors such as aerospace and to some extent automotive in order to apply its benefits in the context of the railway industry.

However, when looked from the perspective of the railway industry as a separate part of the transport sector, this project represents a radical innovation. This is because the project paved the way for practical implementations such as the turning of every train into an infrastructure monitoring train for the purpose of predictive maintenance. In this case, with support from a major train manufacturer, a train owner and a train operator company in the UK, this vehicle-to-infrastructure system has adopted the principles of KEEP SAFE to fit a number of sensors in trains to measure the overhead electrification system for the purpose of informing a predictive maintenance strategy that ultimately results in an improved safety.

The cost-benefit analysis of case study 4 will use existing data from the (pilot) project cost and extrapolate to a wider initiative whereby the same project is implemented at a wider level. The resulting cost (estimate) will then be used to estimate the benefits received in comparison to available statistics from previous years.

This approach is justified by the fact that the scale of the initial implementation was relatively small, consisting of:

(1) the theoretical background and development conducted by Coventry University with funding from the UK Railway Safety and Standards Board (RSSB) with the following objectives:
   a. Create a basic, high-level Information Architecture for the GB Railway.
   b. Use the high-level information architecture to create metadata-driven, safety-focused models of railway operation and performance.

  c. Develop a prototype software tool that will use the metadata models for the prediction of safety-related faults.

 (2) the pilot implementation using one train for a period of three months, with funding from Network Rail and support from other stakeholders (listed above), with the aim of:
  a. Collecting infrastructure data using passenger trains
  b. Modelling the data to inform predictive maintenance and decision making.

This approach is also justified by the often qualitative nature of the project KPIs, which have been perceived by its stakeholders as follows:

1. Increased safety, leading to:
  a. Positive social impact
  b. Improved customer satisfaction
  c. Improved levels of compliance
  d. Improved business performance

2. Reduction of unplanned maintenance and repairs, leading to:
  a. Less cancellations and delays
  b. An increased availability of service
  c. Increase customer satisfaction
  d. Improved levels of compliance
  e. Improved business performance

This analysis will provide an overall estimate of the cost-benefit balance for the implementation of the system, which can be used to inform future implementations.

5.6.4.4 *Costs and benefits of the use of infrastructure data to manage safety in railway*

As with other NEWBIT cases, the scale of implementation of the service in the pilot phase is relatively small and does not offer a representative market situation for the cost-benefit analysis. While the theoretical developments were sufficient for initial testing, the practical implementation as limited to one train running on one line in England. In principle, our approach could be implemented across the railway network and using several trains.

In the sections below an overview is given of the identified cost and benefit items. As a first exercise, costs and benefits have been estimated offering a CBA framework for case study 4. The CBA figures can, after the pilot period, be based on more actual figures with the stakeholders of case study 4.

The figures used in the exercise (with large ranges to show the uncertainty in these figures) are merely based on an expert guess by the case study leader (CUE), as well as overall costs related to the British railway for previous years, obtained from the RSSB website. Sometimes the analysis uses inputs from stakeholders during the implementation of the project. It should be noticed that the level of uncertainty in these figures is rather high and that they should be considered illustrative. As mentioned before, the CBA should preferably be updated with more robust figures once data is available from a more extensive implementation.

Costs

The costs of the theoretical developments mainly exist as a one-time and non-recurring costs. Its overall cost was £33,000, provided to Coventry University by the UK Railway Safety and Standards Board on a competitive basis.

The cost of running the pilot implementation can be described as follows:

Table 32: CS4 Implementation Costs

Implementation costs (Phase 1 - PILOT)	Cost
Sensors (10 units - 1 train)	£ 1,000.00
Technical staff (Coventry University)	£ 32,000.00
Technical staff (Railway Industry)	£ 8,000.00
Administrative /support staff	£ 8,500.00
Project Management Staff	£ 3,500.00
Travels	£ 3,400.00
Equipment and supplies	£ 12,000.00
Software licences/storage space	£ 3,400.00
Total non-recurring costs	£ 71,800.00

The periodic or recurring costs (e.g. operation costs) for one train running on one line (pilot conditions) were estimated as follows:

Table 33: CS4 Operation Costs

Periodic costs (Operation and maintenance) (yearly)	Min	Max	Comments
Hardware hosting	£ 2,400	£ 3,000	Hardware hosted and maintained at Coventry University
Software maintenance	£ 2,000	£ 2,500	Software produced by Coventry University
Data costs (capturing, transmitting, securing)	£ 10,000	£ 15,000	Virgin Trains collects the data and transmit it to Coventry University for secure storage and automatic analysis
Total recurring costs	£ 14,400	£ 20,500	

Total costs of an implementation of the pilot project: £106,700.

Benefits

The intangible benefits of a data-informed predictive maintenance strategy across the railway industry have been outlined in reports of all sorts. Some of these were briefly described in section 1.3. Quantifying those benefits has been a challenging task and required the use of

estimate values gathered from stakeholders and from documentation such as the [RSSB annual reviews](), primarily for the years 2014-2015 due to availability of the relevant figures.

An overview of the benefits is given in the table below. The overview is based on the following estimates:

- A Railway Capital Cost of 3 trillion GPB for the British Railway (approximate)
- A Railway Operational Cost of 9 trillion GPB for the British Railway (approximate)
- Cost related to Customer Satisfaction of £4m per year
- Cost related to Safety: £250m per year

Assumptions were made based on stakeholders' input, which are included in the table below.

To make our estimation as realistic as possible, a key assumption was made that the project would have a minuscule impact on the quality of only five specific KPIs as follows:

A 10^{-9} % (that is, 0.000000001%) on:
- Maintenance cost in the line being tested
- Operational cost benefits enabled by quicker move to more reliable powered trains
- Cost savings in quicker and more efficient integrated planning

A 10^{-4} % (that is, 0.0001%) on:
- Customer Satisfaction cost
- Safety costs

Table 34: CS4 Benefits

QUANTITATIVE ANALYSIS			TOTAL
Benefits per year (estimates)	Railway Capital Cost	Railway Operational Cost	
Our on-condition maintenance approach could reduce maintenance cost in the line being tested by 10^{-9} %	£ 3,000	£ 9,000	
Operational cost benefits enabled by quicker move to more reliable electrical powered trains reduces delays by 10^{-9} % of delay attribution per year	£ 3,000	£ 9,000	
Cost savings in quicker and more efficient integrated planning estimated as 10^{-9} % of the infrastructure capital budget per year	£ 3,000	£ 9,000	
TOTAL RECURRING Benefits	£ 9,000	£ 27,000	£ 36,000

OTHER Benefits per year	
Customer Satisfaction cost per year reduces by	£400
Safety cost per year reduces by (annual cost to railway: £250m per year) - expected benefit: 0.0001%	£2,500
TOTAL OTHER Benefits	£2,900

Total benefits received from the pilot project: £38,900 per year.

5.6.4.5 *The CBA modelling*

The implementation or the one-off costs included the following:

Table 35 CS4 Implementation costs

IMPLEMENTATION COSTS	
Sensors (10 units - 1 train)	€ 1,000.00
Technical staff (Coventry University)	€ 32,000.00
Technical staff (Railway Industry)	€ 8,000.00
Administrative /support staff	€ 8,500.00
Project Management Staff	€ 3,500.00
travels	€ 3,400.00
Equipment and supplies	€ 12,000.00
Software licences/storage space	€ 3,400.00
TOTAL NON-RECURRING COSTS (*1000)	**€ 71,800,000.00**

The operation and maintenance costs included the following:

Table 36 CS4 Operation and maintenance costs

OPERATION AND MAINTENANCE COSTS	
Software maintenance (per year, including storage)	€ 2,500
Hardware maintenance & operation	€ 2,500
TOTAL NON-RECURRING COSTS (*1000)	**€ 5,000,000.00**

On entering the costs in the model, the NPV was calculated for the recurring costs. The Treasury of the United Kingdom's recommended discount rate of 3.5% was used for this UK project. For years 0-4, the following net present costs were computed:

Table 37 CS4 Costs on multiple years

Costs on Multiple Years						
Year		Year 0	Year 1	Year 2	Year 3	Year 4
Software maintenance (per year, including storage)	Monetary Value	2.5m	2.5m	2.5m	2.5m	2.5m
	NPV		2.415m	2.334m	2.255m	2.179m
Hardware maintenance & operation	Monetary Value	2.5m	2.5m	2.5m	2.5m	2.5m
	NPV		2.415m	2.334m	2.255m	2.179m

The Total Net Present Value of Costs = £95.165m

The benefits were inputted in the model and the net present value of benefits were computed as below:

<p style="text-align:center;color:#1f6fc4;font-weight:bold;">Table 38 CS4 Benefits occuring on multiple years</p>

Benefits Occuring on Multiple Years						
Year		Year 0	Year 1	Year 2	Year 3	Year 4
Operational cost benefits enabled by quicker move to more reliable electrical powered trains reduces delays by 0.0001% of delay attribution per year	Monetary Value	133.42m	133.42m	133.42m	133.42m	133.42m
	NPV		128.908m	124.549m	120.337m	116.268m
Cost savings in quicker and more efficient integrated planning estimated as 0.0001% of the infrastructure capital budget per year	Monetary Value	133.42m	133.42m	133.42m	133.42m	133.42m
	NPV		128.908m	124.549m	120.337m	116.268m
Customer Satisfaction (annual cost £4m per year) - expected benefit: 0.0001%	Monetary Value	£4,000.00	£4,000.00	£4,000.00	£4,000.00	£4,000.00
	NPV		£3,864.73	£3,734.04	£3,607.77	£3,485.77
Safety (annual cost to railway: £250m per year) - expected benefit: 0.0001%	Monetary Value	£250,000.00	£250,000.00	£250,000.00	£250,000.00	£250,000.00
	NPV		£241,545.89	£233,377.68	£225,485.68	£217,860.56

The Total Net Present Value of Benefits = £1.248bn

<p style="color:#1f6fc4;font-weight:bold;">Net Present Value</p>

The net present value for case study 4 using:

$$NPV = \sum PV\,(B) - \sum PV\,(C)$$

NPV = £1,152.986m

The net present value with horizon value was:

$$NPV = PV(B) - PV(C) + PV(H)$$

NPV = £1,153.004m

Benefit Cost Ratio

The Benefit Cost Ratio:

$$BCR = \frac{\sum PV(B)}{\sum PV(C)}$$

BCR = 13.12

The BCR ratio>1 implies that the benefits of the project outweigh the costs and hence the project has to be considered.

A sensitivity analysis was carried out for different values of discount rates, this is presented in the table 31 below:

Table 39 CS4 Sensitivity analysis

		NPV
Discount Rate (-)	-10.0	£1,421.987m
	-9.0	£1,388.351m
	-8.0	£1,356.128m
	-7.0	£1,325.241m
	-6.0	£1,295.619m
	-5.0	£1,267.195m
	-4.0	£1,239.907m
	-3.0	£1,213.695m
	-2.0	£1,188.505m
	-1.0	£1,164.285m
	0.0	£1,140.986m
Discount Rate (+)	1.0	£1,118.563m
	2.0	£1,096.973m
	3.0	£1,076.175m
	4.0	£1,056.132m
	5.0	£1,036.808m
	6.0	£1,018.169m
	7.0	£1,000.184m
	8.0	£982.821m
	9.0	£966.054m
	10.0	£949.855m

The sensitivity analysis indicates that changes in the discount rate does not negatively impact the benefits over costs of the project.

A framework for the cost-benefits analysis of case study 4 has been developed. Different cost and benefit items have been identified, under the assumption that some less significant costs and benefits may have been unknowingly omitted due to the complex nature of the project, the qualitative nature of many of its benefits and the limited knowledge of these available within the NEWBITS team.

This analysis as also been influenced by the fact that the case study consisted of a pilot case of a potentially very large initiative, and that the main stakeholder (Network Rail) is in a position of owning all infrastructure involved, which also reduces the cost of comparison of costs and benefits with similar initiatives by other competitors in the same context. Due to the natural monopoly position of Network Rail and economies of scale obtained, the benefits outweigh the costs of infrastructure projects by economic theory.

However, even in these conditions a first exercise has been performed based on cost and benefits estimates made by the case study leader (Coventry University). The results suggest that implementing a decision-making system based on the use of infrastructure data collected from passenger trains is a feasible and potentially successful initiative.

A further elaboration of the social cost-benefit analysis should be performed to confirm these conclusions. This can possibly be done after the pilot period, as then more evidence on costs and benefits will be available.

However, the social cost benefits analysis gives no information on the business cases of other individual stakeholders, beyond Network Rail. Whilst as a system the Railway Industry would experience significant benefits, it is unclear how much would these extend to other stakeholders involved in the exercise.

5.7 Societal benefits

5.7.1 CS1 Social factors

In CS1, the customers' attitude to the carpooling services does not constitute any barrier to the market entry of new providers of this service. If any, it will only make the existing competition more severe, but the customers' attitude will not stop companies from entering this market.

In a more general landscape, car-pooling would positively affect social warfare by:

- o Abating level of emissions of polluting agents (mainly CO_2) thus partially reducing both the environmental problems and the health diseases which are significantly correlated with the emissions.
- o Abating the number of circulating vehicles, especially in peak-hours, to and from the city centres, restoring conditions for more effective public transports.
- o Reducing road congestion and average waiting time in traffic jams, thus saving a significant amount of time currently wasted.
- o Decreasing the aggregate risk of car accidents and enhancing safety in car circulation.
- o Curbing the exponentially increasing need for new parking places in the cities and, more generally, for bigger and larger road infrastructures, with savings in social costs.

Social benefits from a behavioural perspective could be the changes in cultural and social habits or in people's mentality. The force of habits and the psychological satisfaction from driving, the sensation of feeling free are social and irrational human behaviours working against a more extended car-pooling practises.

5.7.2 CS2 Social factors

Currently, users as well as policy makers are often unaware of the existence, the benefits and the development of Advanced Driver Assistance Systems and EEIS. After awareness, system acceptance becomes very important for systems to be successful. Generally, advisory systems are preferred over controlling ones, whereas supporting systems are preferred over enforcing ones. Also, the importance of the Human Machine Interface (HMI) has to be considered. Feedback from the system, the feeling of being in control of the vehicle and the possibility to overrule the system are key elements from the perspective of the driver. Finally, a system has to be affordable. This is not restricted to the price of the system, but also depends on the economic situation and the societal need of a system. In such a context, the willingness to invest in innovative solutions by local government represents an important factor.

5.7.3 CS3 Social factors

In the logistic sector there is increasing attention for shipment information, as is shown by the AberdeenGroup (2013) [44] [48] who find that supply chain visibility is the most important improvement point. This amplifies that the attitude of logistical operators towards track-and-trace of container transport has improved. Measures promoting the exchange of shipping information across different transport modes are therefore becoming more and more crucial for inland shipping to survive competition with road freight transport.

The main challenge for creating a track-and-trace service for sea containers is to combine the information of several sources. Contract arrangements often restrict sharing data for privacy reasons. There are ways to overcome these issues, but this requires cooperation between stakeholders to renew agreements on data sharing.

Another social factor besides the attitude towards real-time shipment information is increased attention for sustainability. The service will lead to an optimization of the transport decision where inland shipping is the preferred option. This option puts less pressure on the environment which results in social support.

5.7.4 CS4 Social factors

The project itself has a clearer social impact (i.e. increased safety) and the citizens are its main beneficiaries. An improved safety has a direct impact on society and its perception of the railway as a safe and efficient mode of transportation.

The railway is already one of the safest modes of transportation, with the fatality risk for a rail passenger in the EU in 2013 being 16 times lower than for a person travelling by car, and

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[48] Heaney B. (2013), Supply Chain Visibility A critical Strategy to Optimize Cost and Service, Aberdeen Group Available at
https://www.gs1.org/docs/visibility/Supply_Chain_Visibility_Aberdeen_Report.pdf Accessed on Nov. 2018

railway safety continuing to improve between 2010 and 2014[49]. Of course, any further increase in safety by such initiatives, as well as increases in punctuality and reliability, which are also among the outcomes, is expected to have increased social benefits and to result in a more favourable perception of the railways.

More specifically, the increased safety provided by the case study can lead to a positive social impact, reflected by improved customer satisfaction, improved levels of compliance, improved business performance, less cancellations and delays, an increased availability of service, increased customer satisfaction.

Similar projects and initiatives are expected to have a positive social impact in terms of level of services, customer satisfaction and positive perception of the railways.

5.8 Strategies for implementation

5.8.1 CS1: Guidelines for a strategy for the implementation of an ITS intelligent carpooling system for daily mobility

The findings of case study 1 suggest that it is important for an ITS intelligent carpooling system to consider at least the following requisites:

- A clear understanding of the context and the tangible problem (shortage of car parking spaces, limited alternatives to travelling by car, etc.). That is, the need for an improved service.
- A clear understanding of the Business Case by the organisation(s) developing/introducing the scheme. That is, the full costs of the current parking/transport service and the potential savings.
- Enough management support and commitment for car sharing. Managers should be able to get involved in promoting the scheme, as well as leading by example.
- Feasibility of a partnership between the organisations involved in introducing the carpooling scheme and with the local authority (a network-based approach).
- Enough preparation before the scheme is launched.
- Having a relative notion of the confidence of potential users of the scheme.
- Sufficient resources are or can be made available for the development, implementation and maintenance of the scheme.
- The feasibility of conducting an effective marketing campaign for the scheme. Finally, feasibility of providing incentives and supporting measures to encourage all potential users to adopt the system.

5.8.2 CS2: Guidelines for a strategy for the implementation of a C-ITS to manage drivers' behaviour crossing traffic lights intersections

Based on the experience of case study 2, it is recommended that a project to implement a C-ITS to manage drivers' behaviour crossing traffic lights intersections considers at least the following issues:

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[49] European Commission MOVE (2016), REPORT FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT AND THE COUNCIL Fifth report on monitoring development of the rail market. Available at https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=COM:2016:780:FIN Accessed on Nov. 2018

- Relative confidence of the need for the solution, e.g., significant current volume of cross traffic potentially leading to immediate efficiency improvements.
- A reasonable understanding of traffic patterns in the intersection where the traffic light is (or could be) located.
- A clear view of the potential benefits, e.g. optimisation of traffic for exhaust emissions, traffic throughput, minimisation of traffic, etc.
- System-wide view: Other, nearby traffic signals could be coordinated with each other to maximise the benefits of a particular intersection by sharing data, communicate needs, and dynamically adjust the timing offsets between the signals for optimum traffic flow.
- Ability to anticipate upcoming traffic situations by modelling historic data and manage traffic accordingly.
- Ability to run trials and collect relevant data to find optimal traffic patterns to refine the system using a modelling scenario before it is put into practice.
- Ability to expand/further develop the system by using different types of sensors to collect, for example, video and other types of data potentially useful for the refinement/improvement of the technology.
- It is important that –in case of a major issue, the system could be reverted to its original status of using 'traditional' signal timings.
- Confidence that the system is safe and secure from the physical and digital perspectives.

5.8.3 CS3: Guidelines for a strategy for the implementation of new ICT methods to increase efficiency in logistic chain of ports

The findings of case study 3 highlighted that, as in many ICT-enabled logistic efficiency strategies, the implementation of new ICT methods to increase efficiency in logistic chain of ports should consider at least the following principles:

- Connectivity as a key to a new ICT method for increased efficiency. A key understanding of the different stakeholders is required, as well as of their ability to use the new ICT methods for consistent connectivity, enhanced visibility and streamlined processes.
- The new solution must be configurable. By understanding stakeholder needs and requirements the new ICT method will not be a forced fit but a solution that can be configured fully to their various needs.
- Accurate data must be available for use throughout the system. Accurate data (e.g. a centralised overview of container planning; continuously updated ETA; Actual Time of Arrival (ATA); container status, e.g. customs information, commercial release) help making informed decisions and planning for future success.
- The new ICT methods should not become an end but a mechanism for enabling the ports to incorporate innovations such as cloud technology, track and trace technology, voice technology etc. in the logistic processes.

5.8.4 CS4: Guidelines for a strategy for predictive maintenance in railway

Based on the findings of case study 4, it is recommended that a predictive maintenance strategy in railway consists of at least the following steps:

- Definition of the goals, objectives and measures of the initiative.
- Identification of the different stakeholders and the level of support expected from each of the organisations they represent.
- Determine the readiness level for the infrastructure to be monitored, including the feasibility of collecting the relevant data.
- Definition of the change management strategy that will enable the stakeholders to move from condition monitoring to predictive maintenance
- Planning the implementation of the new approach to maintenance. This is expected to include:
  - Specific infrastructure to be monitored
  - Data to be collected
  - Technology to be used for data collection
  - Approach to data analysis
- Implementation of the data acquisition and analysis to support decision making
- Stakeholder training.

5.9 Sustainability

5.9.1 CS1: Sustainability of investments in an ITS intelligent carpooling system for daily mobility

The implementation of an ITS intelligent carpooling system for daily mobility VAOPoint (case study 1) and the analysis of its potential costs and benefits shows that this type of ITS allows commuters to offset the costs of driving on their regular commute routes. In doing so, it brings a significant number of benefits (from cost savings to time and reduction of carbon footprint), which offset the costs of its implementation and confirm the sustainability of investments in the service.

In order to ensure its adoption and sustainability, planning and implementation of systems of this kind require a detailed analysis of the relationships between the different stakeholders.

5.9.2 CS2: Sustainability of investments in C-ITS to manage drivers' behaviour crossing traffic lights intersections

Case study 2 has highlighted the benefits of investing in a C-ITS to manage drivers' behaviour when crossing traffic lights intersections. Despite the lack of robust evidence in the form of historic data, it is understood that the solution is financially sustainable. Evidence gathered by similar initiatives in other contexts demonstrates the significant social and environmental impact of this solution and its potential success at city-level transport networks. It has been learned that when drivers are provided with information about other drivers approaching the same intersection, different behavioural indicators are affected in a way that a positive effect is perceived on the safety and efficiency of the interaction process at the intersection.

It is important to highlight that in order to ensure a sustainable deployment of this solution, it appears critical to overcome governance issues relating to the upgrading/maintenance of (C)-ITS infrastructure, to guarantee systems interoperability and to concentrate on reducing the cost of required road-side and on-board unit device.

5.9.3 CS3: Sustainability of investments in new ICT methods to increase efficiency in logistic chain of ports

The track-and-trace service for container transport from the sea port by inland waterway and truck (for the last mile of the container to the warehouse) defined by case study 3.

The cost benefit analysis carried out in this work package for the track-and-trace system for hinterland transport shows that even at a relatively low number of containers (around 20,000 per year) the benefits for the users exceed the costs of the system. This number of containers roughly corresponds to transport carried out for about 25 medium-sized shippers and is equal to about 2% of the handled import containers by IWT in hinterland transport of the Port of Rotterdam. A profitable operation of this service seems therefore feasible for this market.

Aggregation and access to information such as a centralised overview of the container planning, continuously updated ETA, Actual Time of Arrival (ATA) and container status has a direct, positive impact on logistics processes and the volume of containers transferred. As the cost-benefit analysis has shown, this is a sustainable solution in the short, medium and long terms.

It is important to highlight, however, that the volume and quality of data exchanged with the aim of being transformed into valuable information is a factor affecting the business case success. Other factors are the increase of clients using the specific port and the savings that they benefit from its use.

To realise the critical volume for a sustainable market operation of the service it is required that the various benefits of the service are clearly demonstrated to potential clients (by disseminating the pilot results). Furthermore, the pilot should show that a robust data governance system is part of the service in order to get support from all stakeholders in sharing the required data. Finally, it is believed that a close cooperation between the ICT company deploying the service and a supporting logistic partner is key to successfully deploy the service.

5.9.4 CS4: Sustainability of investments in predictive maintenance in railway:

The lessons learned from the implementation of case study 4 and the analysis of its costs and monetary and non-monetary benefits conducted in this work package shows that the application scope of predictive maintenance in the railway sector is wide-ranging. The benefits are wide-reaching and have positive repercussions on the safety, reliability, condition and life-cycle of the infrastructure, as well as in cost optimisation and reliability indexes.

The cost-benefit analysis suggests the fast recovery of costs and the sustainability of the benefits related to predictive maintenance. However, it is important to mention that predictive maintenance solutions must be implemented when there is a clear business case in which improvements in availability, reliability, maintainability and safety – with regard to infrastructure and rolling stock, can be accomplished.

Our study shows the importance of aligning the implementation of predictive maintenance solutions with the business model of a company or the railway industry in general, as in the

case of the British railway. To do so, collaboration between different stakeholders within the industry becomes an imperative.

6 Business cases templates

During the conduction of this deliverable a desk research has been performed, to understand and verify the importance of business cases as a notion to transform the four case studies into business cases and afterwards derive and propose a generic business case template for ITS / C-ITS solutions. From the performed research one of the key understandings has been that a business case is a notion targeting practitioners rather than the academic community. Business cases appear to be coherent and rather compact documents describing usually in a structured and bullet format the key elements of a potential business case.

The development and deployment of an ITS / C-ITS solution can be considered as a project with unique characteristics and requirements. According to Herman, B. & Siegelaub, J. M. (2009) [46][50] a business case is a reference point before, during, and after a project. Business cases are considered important to identify valuable resources that should be utilized by organisations during the development of an ITS / C-ITS solution. Business cases provided a rational and quantified justification of the expenditure of resources during the implementation of a project as the deployment of an ITS/ C-ITS solution. One of the outcomes of a business case is the definition of the value that the project will deliver. As already analysed in previous sections of this deliverable costs and benefits are key reference points, but other elements contribute significantly to presenting a solid and coherent Business Case.

The integration of business cases in the decision processes by governmental agencies and organisations appear to have an important role especially in Great Britain. In the 2018 publication "Guide to developing the project business case", important information, have been identified, on the key components of business cases in the context of decision -making process of public authorities (Great Britain, HM Treasury Office, 2018) [47][51]. According to the author of the publication, a well prepared Project Business Case: enables the organisation and its key stakeholders to understand, influence and shape the project's scope and direction early on in the planning process; assists decision makers to understand the key issues, the available evidence base and to avoid committing resources to schemes that should not proceed; demonstrates to senior management, stakeholders, customers and decision makers the continuing viability of the project; and provides the basis for management, monitoring and evaluation during and after implementation. In the framework of NEWBITS project and as it is clarified in previous paragraphs the deployment of ITS / C-ITS solutions are considered as projects. In the above-mentioned publication, a Project Business Case is recommended as best practice and is proposed to be prepared following

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[50] Herman, B. & Siegelaub, J. M. (2009). Is this really worth the effort? The need for a business case. Paper presented at PMI® Global Congress 2009 - North America, Orlando, FL. Newtown Square, PA: Project Management Institute.

[51] Great Britain, HM Treasury Office in U.K. (2018). Guide to developing the project business case: Better Business Cases: for better outcomes Available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/749086/Project_Business_Case_2018.pdf (Accessed: November 2018)

the approval of senior management to the organisational strategy, mandate and brief for the project. The Project Business Case is considered as a working document which is proposed to be developed and revisited over the duration of the scheme. The proposed Project Business Case applies to all types of projects and requires trained people who have the capabilities and competencies to undertake the tasks involved.

In order to design the proposed business case guidelines, the following five case elements presented in The Transport Business Cases (Great Britain, Department of Transport, 2013) [48][52] have been taken into consideration:

- should be supported by a robust case for change that fits with wider public policy objectives – the 'strategic case';
- should demonstrate value for money – the 'economic case';
- should be commercially viable – the 'commercial case';
- should be financially affordable – the 'financial case'; and
- should be achievable – the 'management case'.

In the 2006, Guidelines for Developing a Business Case & Business Case Template by Oregon Department of Human Services[53], an effective business case is defined as a multi-purpose document that generates the support, participation and leadership commitment required to transform an idea into reality. A business case identifies an idea, problem, or opportunity. It provides context and content around the problem and equally illustrates the desired objectives and outcomes. The problem and desired outcomes are normally defined and described in terms of the business [49].

In NEWBITS project it is proposed to adopt the following definition of a Business Case [50][54], by Metrolinx (an agency of the Government of Ontario) which defines it as a generic term for a collection of evidence which, when assembled in a logical and coherent way, explains the contribution of a proposed investment to organizational objectives and supports a decision-making process to sift options, select a preferred option and optimize the preferred option. Business Cases should define a problem or opportunity and make the case (including strategic fit, benefits, and costs).

For structuring NEWBITS four business cases, it is proposed to use the following business case template as it is presented in Figure 19 Proposed business case template by Metrolinx. The template includes eight sections that describe clearly each case study. Most of the required content has been already collected in previous project phases and WPs as WP2, WP3 and WP4, through the holistic approach that has been applied during the

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[52] Great Britain, Department of Transport in U.K. (2013). The Transport Business Cases Available at
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/85930/dft-transport-business-case.pdf (Accessed: November 2018)
[53] Oregon U.S., Department of Human Services (2006). Guidelines for Developing a Business Case & Business Case Template. Available at: https://apps.state.or.us/Forms/Served/de0096c.doc
[54] Metrolinx (2018): Business Case Guidance Draft (March 2018), [Online], Available: http://www.metrolinx.com/en/regionalplanning/projectevaluation/benefitscases/2018_08_03%20Metrolinx%20Guidance%202.pdf , 5th December 2018

implementation of the NEWBITS project. It has been up to each CSL to transpose all the available information into the following template.

Introduction (Chapter 1)

Provides an overview of the Business Case

Problem Statement: the case for change (Chapter 2)

Investment Options (Chapter 3)

Strategic Case (Chapter 4)

Economic Case (Chapter 5)

Financial Case (Chapter 6)

Deliverability and Operations Case (Chapter 7)

Business Case Summary (Chapter 8)
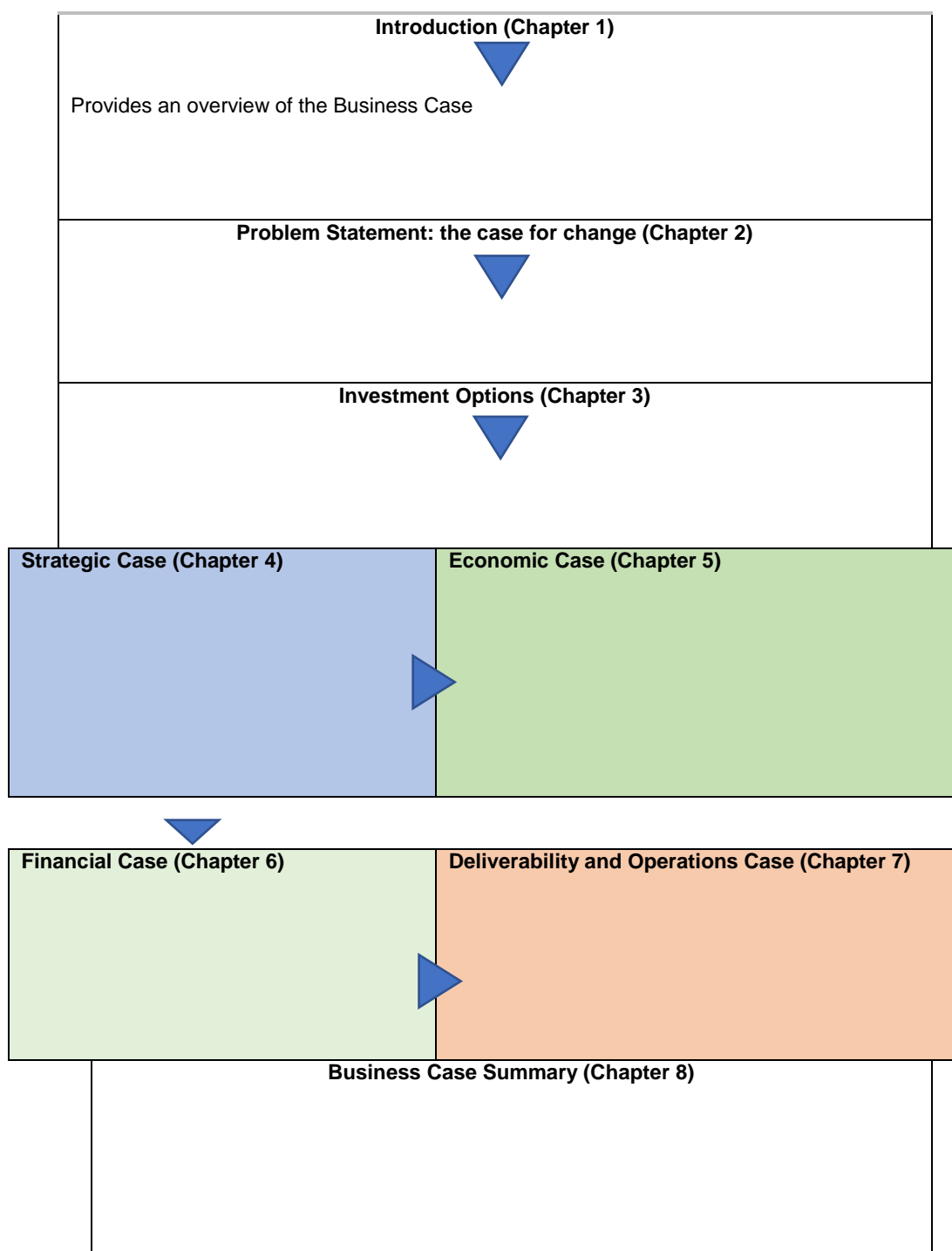
Figure 19 Proposed business case template by Metrolinx

The first **introductory chapter (C1**) provides an overview of the business case. **The problem statement (C2)** sets out the problem and a corresponding set of vision, goals, and objectives to address the problem. The third chapter **Investment Options (C3)** sets out a set of options to be tested against the vision, goals, and objectives. The **Strategic case (C4)** describes how does the investment achieve strategic goals and objectives of each case. In the framework of NEWBITS, it describes how the investment can address the problem or opportunity along with potential risks to investment performance. Establishes 'why' an investment should be pursued from a strategic lens. The **Economic Case (C5)** and the

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Financial Case (C6) are performed in section 5.5 pg.47 of this deliverable and key results of each case will be included. Information about the potential markets of each business case are extracted from WP3. The **Deliverability and Operations Case (C7)** has been analysed in T4.2 through the performed value network analysis (VNA). Each CSL finally should provide a summary of the core findings from each chapter along with recommendations for future investment development Business Case Summary (C8).

6.1 Business case 1: ITS intelligent carpooling system for daily mobility VAOPoint

Introduction

The low occupancy of automobiles in metropolitan areas has important implications in terms of mobility in that it directly implies a greater number of vehicles, greater congestion, more infrastructure needs, higher energy consumption, higher CO_2 emissions, etc.

The tools based on the use of the internet allow systems to be designed to facilitate the sharing of information between users about origins and destinations and to promote win / win agreements that reduce the number of vehicles used in traveling and achieve a more efficient mobility. It is about the carpooling systems.

Problem Statement: the case for change

UAB campus get filled up with over 13,000 vehicles of a very low occupation index: 1.2 people per vehicle - the same average as that of the metropolitan region of Barcelona. On a normal day there is a peak of 8,000 concurrent cars while there are only 7,000 parking spaces. While the UAB does not have sanctioning capacity, badly parked vehicles generate serious mobility problems such as blocking roads, invasion of unauthorized spaces, hindering mobility of pedestrians and service vehicles, etc.

- For the UAB it means having infrastructures that require constant investment and maintenance, as well as having a space that could be used for other, more productive uses
- For system users, the main problem is the time, cost and quality of the trip to and from the university
- With regard to society, in general, there is unnecessary pollution and an increase in congestion of the road network.

Investment Options

In a broad context where different measures are combined in order to reduce the number of private vehicles (cars) that access the campus of the university daily, one of them is to develop a carpooling system that allows users to share vehicles in exchange for receiving certain benefits, in particular, to be able to access privileged parking areas within the campus.

The VaoPoint project (CS1) is based on developing a web-based system and mobile devices that allow users to connect with each other and agree on shared journeys that, via geolocation and tracking through their smartphones, can guarantee that the vehicle has been really shared. And, when the vehicle arrives at the campus, provide a parking space in a reserved area.

The most relevant part of the system is the software that supports it, but other actions must also be carried out, such as the adaptation of spaces, from free parking to accessible parking by means of identification, which will involve carrying out works, installing vehicle identification devices (readers of license plates) and automated barrier opening. It will also be necessary to carry out awareness and dissemination campaigns to encourage the use of the system.

Strategic Case	Economic Case
• Thanks to the use of the Vaopoint system, the project aims to reduce the vehicles that arrive on campus every day in 2000, in three years. This would allow it to be below the threshold of available car parks and would greatly reduce the number of badly parked vehicles on	• Reducing the number of vehicles in circulation provides a direct impact in terms of social benefits. • First of all, more evident and quantifiable, is the reduction of CO_2 emissions derived from the reduction in the total number of journeys. By itself it already provides an economic justification of the investment made.

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- campus and therefore solve the problems that this entails.
- It will also provide a large set of real high-value data on user mobility that can be used to design new strategic options designed to further reduce the use of private vehicles to access the campus.
- The parking guarantee will mean a better mobility experience and therefore reduces the possible reluctance of future users to opt for a non-urban campus university
- Promotion of interaction between users of different faculties or areas. Aligned to the corporate objective of promoting multidisciplinary innovation initiatives on campus

- Additionally, the reduction of vehicles has positive effects on the need for road infrastructures and their maintenance, the reduction of congestion, accidents and productive hours lost in traffic jams. All of them are intangible of high value but difficult to quantify.

Financial Case

- The Total Net Present Value of Costs of the project is just over €322K and is part of an institution, the UAB, with a budget (2017) of €317M, which gives us an idea of the magnitude it represents.
- A part of the financing, that of the application pilot, was made via European funds under the H2020 FrontierCities project. The rest of the funding is direct investment from the university.
- The return on investment is achieved very quickly (beginning of the third year) taking into account only the quantification of the CO_2 emissions savings derived from the reduction of travel, even with very conservative assumptions, so the financial viability of the project is very clear.

Deliverability and Operations Case

- There are no significant risks arising from the technical complexity or operational difficulties of implementing the system.
- However, implementation difficulties may arise due to changes in the political will resulting from a change in the governance of the university, and since the impact is very high, we consider that the probability of occurrence is very low.
- Another risk of high impact would be the derivative of a possible low use of the system by potential users. In this case, it would affect the attainment of the anticipated reduction objectives and, therefore, the viability could be compromised.
- However, the pilot and the indicated tests suggest that the probability of occurrence, although significant, is relatively low. Even so, if the expected results did not occur, additional measures could be taken, within the current framework of governance, more aggressive such as the reduction of free parking spaces.

Business Case Summary (G2 Chapter 8)

There is a need to reduce the number of vehicles that arrive daily at the campus of the autonomous university of Barcelona given that the peak of arrivals is 8,000 vehicles and there are only 7,000 parking spaces.

Reducing the number of vehicles means significant improvements in mobility and in the reduction of emissions.

The use of an intelligent carpooling system also implies additional benefits at an acceptable and easily recoverable cost.

6.2 Business case 2: C-ITS to manage the drivers' behaviour crossing traffic lights intersections

Introduction

C-ITS systems allow vehicles to communicate with each other, road users and the road infrastructure, while advising drivers on how to act within specific situations to improve their mobility options.

The European project Compass4D implemented various C-ITS services aimed at increasing drivers' safety and comfort by reducing the number and severity of road accidents, as well as by optimising the vehicle speed at intersections and by avoiding queues and traffic jams. The Compass4D services were piloted during one year in seven cities: Bordeaux, Copenhagen, Helmond, Newcastle, Thessaloniki, Verona and Vigo.

In Verona, a C-ITS was deployed and tested to demonstrate reductions in CO2 emissions and fuel consumption for equipped vehicles. Following on from the successful results of the Compass4D project, the business case for Verona has been further developed and refined in NEWBITS within the framework of Case Study 2.

Problem Statement: the case for change

The so-called Traffic Light Assistance (TLA) service was implemented throughout the whole Verona urban transport network by integrating information coming from all urban traffic lights into the city-level traffic management centre. The service was made freely available via a smartphone app giving the following information to users travelling on certain urban corridors: time-to-green (TTG) to the next signalised intersection and speed advice for the green phase (Green Light Optimal Speed Advice, GLOSA).

The realisation of this technological service is enabled by a continuous communication between vehicles and traffic lights (i.e. Infrastructure to Vehicle, I2V, communication network) and the information was provided to various types of users (i.e. private road drivers, bus drivers or commercial fleet drivers).

Verona pilot operation was carried out over a period of 12 months, divided into 3 months 'baseline' operation (to collect data without C-ITS services), and 9 months 'functional' operation (to collect data with C-ITS services in use), during which 40 vehicles participated in the demonstration trials driving through approximately 150 road intersections.

Investment Options

The C-ITS applications deployed and piloted in Verona accord with the city's priorities. These included adaptations and extensions on basic applications and platform functionality, based on I2V communication technology (providing TTG and GLOSA information to users). The vast majority of Verona city centre was considered for the pilot, in particular the main corridors and arteries where C-ITS devices were installed; these included 25 cooperative ETSI G5 compliant RSUs installed along the piloting routes as well as OBUs for 40 vehicles (10 buses and 30 municipal vehicles). A total of 50 vehicle users were selected by the city of Verona to run the tests (with smartphones and tablets) using the 3G/LTE communication network.

Strategic Case	Economic Case
• Various KPI's were estimated from the data collected on field from RSUs and OBUs, such as distance, speed and time required to cross an intersection, emissions and fuel consumption, as well as the number of stops experienced by a vehicle crossing an	• The financial cost of implementing a C-ITS service, according to the experience achieved with the Verona demonstrator, would be recovered within a long period of time, considering the relatively high implementation costs as compared to monetary benefits. IT should be noted that improvements to travel times could not

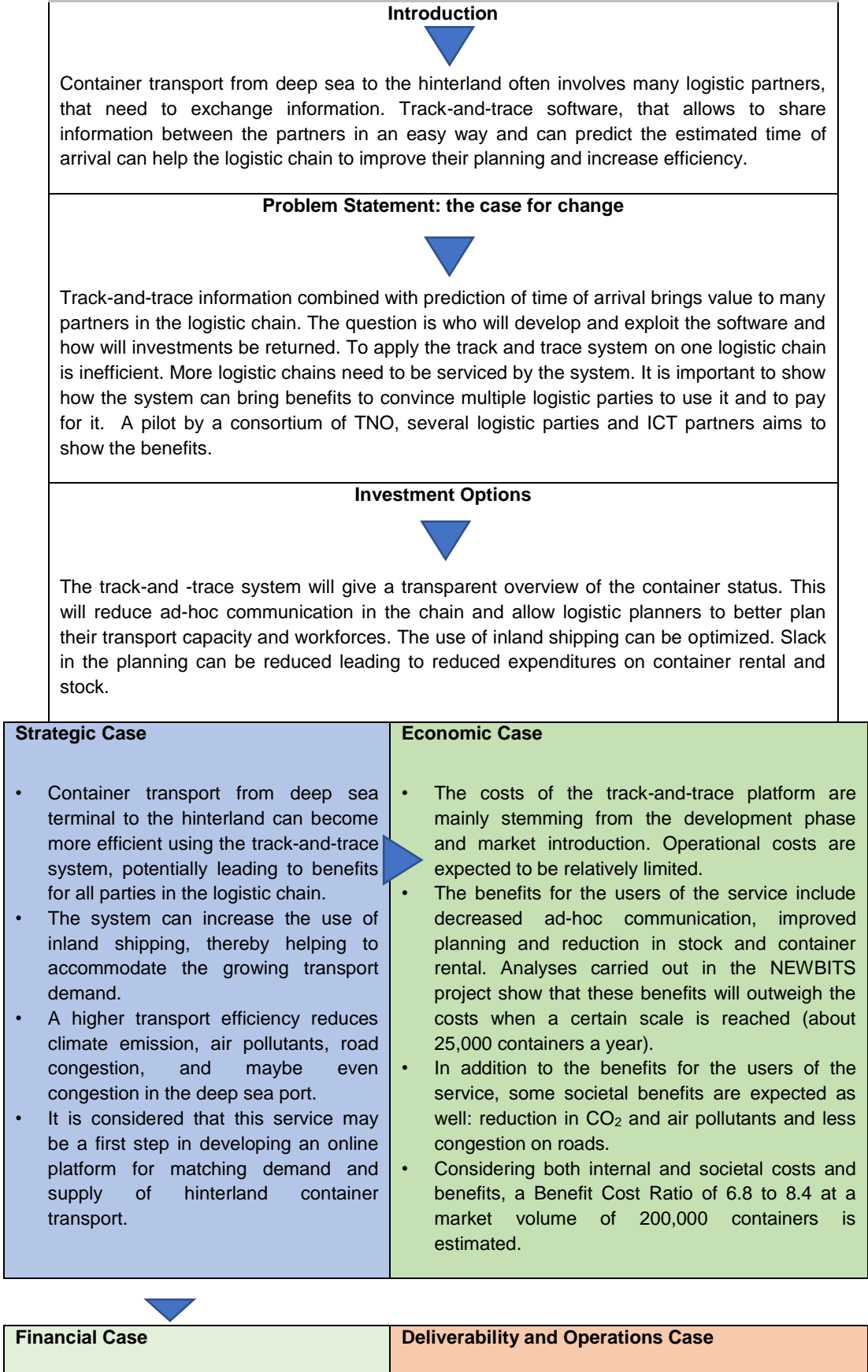|	
intersection. • In most Compass4D pilot sites, an appreciable reduction in stationary time and number of stops has been observed by the drivers, resulting in energy efficiency improvements, travel time reduction (not possible for Verona due to lack of data) and increase of driving comfort. • It is considered that the sustainable deployment of C-ITS services will prepare the technology ground for the upcoming autonomous driving solutions.	be estimated due to the absence of this data. • Therefore, given the successful results achieved in other Compass4D pilots where GLOSA and TTG services were implemented, it is considered that the low financial sustainability level attained strongly depends from the lack of robust evidence available. • In light of the above, it is considered that the financial performance of the system will improve as more robust data (about environmental impacts and travel time changes) is inputted into the assessment, following which the cost of the pilot project will most likely be recovered within a shorter period time.

Financial Case	**Deliverability and Operations Case**
• Although the analysis for CS2 could not demonstrated a financial case, the commitment of policy makers involved in the Compass4D project was reflected by their decision to continue operating C-ITS services within their cities regardless of European funding after the Compass4D project finished. This acknowledges the social and environmental benefits that can be achieved for large urban transport networks.	The deliverability of I2V applications for traffic efficiency and safety, will depend on: • defining roles and responsibilities for operating C-ITS systems infrastructure (covering both on-board and road side units), for further upgrade and maintenance, for equipping additional vehicles and fleets in compliance with the local schemes • ensuring the interoperability between different vendor's systems • reducing infrastructure and on-board unit costs (installation could be performed alongside other maintenance or installation works) • fulfilling the need from fleet operators to integrate service functionalities in the display already existing on-board their vehicle or on nomadic devices used for professional purposes, whereas drivers would prefer the information directly projected in their car dashboard to reduce driver distraction.

Business Case Summary

- There is a current need to look out for new innovative solutions to solve outdated traffic congestion issues in and around European cities to ensure liveable urban environments
- C-ITS has the potential to deliver appreciable energy efficiency improvements, travel time reduction and increase of driving comfort
- C-ITS would also bring additional benefits as it will prepare the transport industry for the adoption and implementation of future technology-based products and services, such as autonomous driving systems.
- Although the evidence available from the Verona pilot was limited to justify the financial sustainability of implementing a C-ITS, evidence collected from elsewhere demonstrates significant social and environmental benefits can be achieved for entire city-level transport networks.
- To ensure sustainable deployment, it appears critical to overcome governance issues relating to the upgrading/maintenance of C-ITS infrastructure, to guarantee systems interoperability and to put efforts in reducing road-side and on-board unit

device costs.

6.3 Business case 3: New ICT method to increase efficiency in logistic chain of ports

Introduction

Container transport from deep sea to the hinterland often involves many logistic partners, that need to exchange information. Track-and-trace software, that allows to share information between the partners in an easy way and can predict the estimated time of arrival can help the logistic chain to improve their planning and increase efficiency.

Problem Statement: the case for change

Track-and-trace information combined with prediction of time of arrival brings value to many partners in the logistic chain. The question is who will develop and exploit the software and how will investments be returned. To apply the track and trace system on one logistic chain is inefficient. More logistic chains need to be serviced by the system. It is important to show how the system can bring benefits to convince multiple logistic parties to use it and to pay for it. A pilot by a consortium of TNO, several logistic parties and ICT partners aims to show the benefits.

Investment Options

The track-and -trace system will give a transparent overview of the container status. This will reduce ad-hoc communication in the chain and allow logistic planners to better plan their transport capacity and workforces. The use of inland shipping can be optimized. Slack in the planning can be reduced leading to reduced expenditures on container rental and stock.

Strategic Case	Economic Case
• Container transport from deep sea terminal to the hinterland can become more efficient using the track-and-trace system, potentially leading to benefits for all parties in the logistic chain. • The system can increase the use of inland shipping, thereby helping to accommodate the growing transport demand. • A higher transport efficiency reduces climate emission, air pollutants, road congestion, and maybe even congestion in the deep sea port. • It is considered that this service may be a first step in developing an online platform for matching demand and supply of hinterland container transport.	• The costs of the track-and-trace platform are mainly stemming from the development phase and market introduction. Operational costs are expected to be relatively limited. • The benefits for the users of the service include decreased ad-hoc communication, improved planning and reduction in stock and container rental. Analyses carried out in the NEWBITS project show that these benefits will outweigh the costs when a certain scale is reached (about 25,000 containers a year). • In addition to the benefits for the users of the service, some societal benefits are expected as well: reduction in CO_2 and air pollutants and less congestion on roads. • Considering both internal and societal costs and benefits, a Benefit Cost Ratio of 6.8 to 8.4 at a market volume of 200,000 containers is estimated.

Financial Case	Deliverability and Operations Case

- The economic analysis showed that given the benefits, users are likely willing to pay for using the service.
- It is considered that the service will be commercialised by an ICT company that will get revenues from customers in container logistics paying a fee to use the service.
- The fee structure still needs to be developed and should be aligned with the expected benefits for the various parties in the logistic chain.

- It is believed to be crucial that the ICT company operating the service is supported by a large logistic partner with an extensive network in container logistics. In this way sufficient volume in demand for the service can be more easily reached and risks are minimalised. Cooperation between these two partners needs to be further investigated.
- According to the conjoint analysis, the service should include: notification of delay and last mile transport in the service.
- As this service requires cooperation between a large number of stakeholders (exchanging company data), trust between the various partners is key. Developing the services within a pilot environment is believed to contribute to open cooperation between the relevant stakeholders and hence to the successful development of this service.
- The pilot of the service is expected to be important to show the benefits of the services to potential customers.

Business Case Summary (G2 Chapter 8)

- A track-and-trace service, that allows to share information between the partners in an easy way and can predict the estimated time of arrival can contribute to more efficient hinterland transport.
- This service will result in lower costs for users of the service and may result in a modal shift of hinterland transport from road to inland navigation, resulting in various societal benefits (e.g. less CO_2 and air polluting emissions).
- There is evidence that the costs of the service significantly outweigh the benefits, not only at the societal level but also at the level of individual stakeholders. It is therefore believed that there will be a willingness to pay of potential users of this service.
- The fee structure for the service needs to be developed in line with the expected benefits for the different users.
- To ensure successful operation of the service, it seems to be critical that the ICT company operating the services is supported by a large logistic partner with an extensive network in container logistics.

6.4 Business case 4: KEEP SAFE - A Knowledge-based approach to understanding railway safety

Introduction

One of the most promising aspects of the rail industry's digital transformation is predictive maintenance – using data collected on equipment during operation to identify maintenance issues in real time. This means repairs can be properly planned, with the benefits that trains don't need to be unexpectedly taken out of service for emergency or unnecessary routine maintenance.

Technologies enabling predictive maintenance, reducing operating costs and extending a fleet's lifetime, have the potential to deliver huge financial and non-financial rewards.

However, there are challenges associated to designing and implementing a predictive maintenance programme: collecting the data required, transmitting and storing it securely, and analysing it to get the right insights.

Problem Statement: the case for change

Achieving the qualitative and quantitative benefits of predictive maintenance in railway requires proper planning and management. There is an important cost-benefit case which must be made ahead of any major investment into predictive maintenance.

Case Study 4 consisted of a Pilot Study carried on by Coventry University with Funding from Network Rail, collecting infrastructure (electric system) data from a single (passenger) train running in a single line (London-North West) in the UK.

The pilot designed and tested a mechanism for collecting infrastructure data using passenger trains, transmitting it to Coventry University for secure storage and analysis, and providing infrastructure managers in the railway industry with a visual outline of the evolution of the infrastructure to inform decision making in the form of predictive maintenance.

Investment Options

The options for investment included:

- Conducting the theoretical study required

- Gaining experts' input on the nature of data required, the frequency of its collection, infrastructure where data would be collected, required sensors, etc.

- Selecting a train and taking it off service for the fitting of sensors
- Adapting the train to the requirements of the data collection
- Testing the data collection and communication mechanisms in place.

- Start the process of data collection and running it until a considerable amount of data was available

- Acquiring the hardware and developing the software required for data analysis.

Strategic Case	Economic Case

• A predictive maintenance strategy is likely to have a significant positive impact on qualitative KPIs for th railway such as safety, customer satisfaction, quality of the service • It would also bring additional benefits as it will prepare the railway industry for the adoption and implementation of future technology-based products and services	• The financial cost of implementing a predictive maintenance strategy would be recovered within a short period of time • While the cost of the pilot project is likely to be recovered within a short time, the benefits of a larger scale initiative would far outweigh its costs.

Financial Case	Deliverability and Operations Case
• The Pilot Case has demonstrated the financial case for the design and implementation of a predictive maintenance strategy which can be extended to the British railway infrastructure.	• The Pilot Case has demonstrated the feasibility of the design and implementation of a predictive maintenance strategy which can be extended to the British railway infrastructure.

Business Case Summary (G2 Chapter 8)

- There is a need to develop more effective ways to manage the railway infrastructure
- Predictive maintenance has the potential to deliver huge financial and non-financial rewards: reducing operating costs, extending a railway fleet's lifetime, reducing delays and disruptions, improving safety and customer satisfaction.
- Predictive maintenance would also bring additional benefits as it will prepare the railway industry for the adoption and implementation of future technology-based products and services.
- The financial cost of implementing a predictive maintenance strategy would be recovered within a short period of time.

7 C- ITS business case guidelines

7.1 Derived from Business Case 1

Success factors

- The main factor of success that is also critical is the **political will of the university's governance team** to carry out the project and commit to the planned investments. The underlying risks are really low because it is a recognized need and a widely known problem is the overcrowding of parking spaces; and, on the other hand, the investment amount is very little significant to take advantage if it is eliminated
- The **degree of adoption of the system by users** is also very important. It is necessary to reach a significant number of users, so an attractive system must be offered, which **adds value and satisfies real needs**. It is also important to make an **effective communication** capable of properly delivering the message so that users are aware of the alternative.
- **Security and trust** are also relevant factors. The identification of users and the tracking system provide confidence to users about whom they will share the vehicle with. The co-user stops being a stranger and becomes someone identified with the university's guarantee of identification. On the part of the management, the tracking system provides sufficient guarantee to determine that it is a real car sharing and therefore a reward can be offered as a reserved parking.
- The security and privacy standards must be ensured as regards the data generated. The information must maintain the necessary degree of confidentiality as users are identified and their routes are followed up so that the generated data must be treated adequately.

Proposed KPI's for measuring successful outcomes

- Degree of adoption (and derived)
  a. Number of users registered
  b. Number of active users per time unit (day, month,…)
  c. % of cars in reserved parking places versus total number of cars parked
  d. Saturation of reserved parked space (Spaces used /total spaces)
  e. CO2 savings achieved (current and accumulated)
- User satisfaction
  a. Users' assessment of the system. Periodic and systematic data collection.

7.2 Derived from Business Case 2

Success factors

A number of potential driving factors for successful implementation of C-ITS are related to these categories:

- **Interoperability of data formats and transmission protocols** would allow stakeholders' (i.e. service providers) and their proprietary systems to interact in a timely, costly and efficient manner.
- **Privacy & Security standards need to be ensured** since C-ITS implementation requires the tracking of users during their trips, therefore consent from users' needs to

be gained beforehand. However, it is considered that nowadays this does not represent a reason of concern for users who gain concrete benefits in return. Similarly, cyber security may represent a critical aspect only when the C-ITS is going to be transferred in a road environment dominated by a multitude of transport players.

- **Skilled workforce** is strongly required to implement and operate C-ITS successfully; the lack of skilled resources could in fact prevent an efficient deployment and an associated monetization of the service with road operators, which most likely do not have adequate technical expertise to disseminate the information and maintain the service on their own.
- **Political support from Central Governments** is considered critical to make C-ITS a successful business case transferable to differing geographic and economic contexts, to regulate the market and give clear directions to local authorities who should in turn promote and implement such C-ITS services as part of their sustainable mobility plans.
- **Awareness raising and dissemination initiatives** must be strongly promoted in order to proactively engage users and deliver an added value to citizens' mobility.

Proposed KPI's for measuring successful outcomes

A hierarchy of metrics may be deployed to monitor the success of the TLA service, these being:

- *Mobility-related metrics*:
  - % change in peak period journey time (by vehicle type) along routes where TLA service is implemented;
  - % change in peak period traffic flow (by vehicle type) along routes where TLA service is implemented;
- *Productivity-related metrics*
  - % change in Vehicle-hours of travel (VHT). For instance, a decrease in VHT generally indicates improved system performance with vehicles experiencing fewer delays along TLA-implemented routes.
  - % change in intersection throughput due to improved driver behaviour.
  - % change in lost productivity as % change in capacity lost due to flow breakdown
- *Safety-related metrics*
  - % change in the number of reported accidents (by accident severity, road segment and time period) along routes where TLA service is implemented;
- *Environment-related metrics*
  - % change in annual CO_2 emissions on routes where TLA service is implemented

7.3 Derived from Business Case 3

Success factors

Several driving factors for successful implementation of the service are:

- Clear data governance. This involved authorisation to the various stakeholders to see relevant data and protection of the data to be revealed to third parties.
- Demonstrated benefits: to incentivize potential clients of the service to join, the benefits of the service should be clearly demonstrated and quantified.

- Sufficient volume of end users: higher volumes will result in larger revenues, while costs are relatively constant (due to large share of fixed costs). Furthermore, some additional (cross-chain) benefits (i.e. increased utilisation of barge capacity) may occur when a certain market volume is reached.
- Involvement of logistic partner in the exploitation of the service: network and knowledge of logistic partner is required to successfully enter the market for container transport.

Proposed KPI's for measuring successful outcomes

Several measures can be used to monitor the effectiveness of the service (benefit KPIs) and the deployment of the service (deployment KPIs).

Benefit KPIs

3. % change in lead-time of containers between port and warehouse/end user when service is implemented.
4. Difference in lead-time reliability of transport between nodes in the transport chain (difference in % container arriving in pre-set time window)
5. % change in hours used per incoming or outgoing operational variable (e.g. container, order) when service is implemented.
6. % change in market share of IWT in total hinterland transport when service is implemented.
7. Change in attractiveness of IWT for hinterland transport when service is implemented (by using a survey).

Deployment KPIs

1. Volume of data requests (# transactions)
2. The number of stops (i.e. data point) made by a customer using the service
3. Number of unique users of the service
4. Revenues of the services
5. The number of imported containers that go through the service

7.4 Derived from Business Case 4

The following lessons have been learned from the design of new initiatives for the implementation and exploitation of a predictive maintenance strategy in railway in the context of the British Railway industry in case study 4.

Key performance indicators related to predictive maintenance in railway:

The main KPIs for a predictive maintenance strategy, as per our case study, are related to the success of the practical implementations of the principles developed by this project. Benefits in the context of the current implementation by Network Rail were perceived as follows:

Increased safety, leading to:

Positive social impact

- Improved customer satisfaction

- Improved levels of compliance

- Improved business performance

Reduction of unplanned maintenance and repairs, leading to:

- Less cancellations and delays

- An increased availability of service

- Increase customer satisfaction

- Improved levels of compliance

Improved business performance and readiness for adoption and implementation of future technology-based solutions.

Critical success factors for its implementation:

- Understanding of functions –primarily safety, reliability, and comfort, expected to be achieved in the short and long terms for different parts of the railway network.

- In line with the above, full implementation of a purpose-oriented maintenance system with access to information on infrastructure models, planned and completed maintenance work, the condition of the infrastructure, functional faults, incidents and accidents, etc..

- A clear mechanism is designed for assessment and analysis of the condition of the infrastructure and its degradation, informing the decision-making processes.

- A mechanism is clearly defined for measuring the cost-effectiveness of maintenance operations so that the value of the innovation is fully understood.

- Guidelines and procedures are in place for the feedback of knowledge and experience from engineers and other stakeholders.

Business case guidelines

Based on the KPIs and CSFs, a set of overall principles have been understood by case study 4 as necessary at strategic level for the implementation of a predictive maintenance strategy in railway. These include:

Overall Principle 1. The need for a definition of a strategically appropriate target regional and structural railway data sharing partnership allowing the collection, secure storage and analysis of the data and the sharing of the findings of the analysis across all relevant stakeholders.

Our case shows the importance of defining well in advance what the industry expects from the implementation of predictive maintenance in every specific case before they embark in the implementation. This implies, as Digital/McKinsey [55] suggest, an understanding of:

- Segment and competitive context. This comprises the competitive pressure and, thus, the need for action in the specific context (e.g. urban/regional or cargo rail operators).

- Fleet characteristics. Understanding the extent to which the fleet is dominated by legacy assets or a large heterogeneity, and its implications for the rail operator in their efforts to innovate itself or involve rolling stock OEMs in the process.
- Number of assets. Larger, more powerful rail operators with a multitude of assets will have a great incentive to conduct their maintenance in-house, while smaller rail operators might find it beneficial to outsource the maintenance – to either rolling stock OEMs or independent workshops. This has been particularly visible in our case study, where Network Rail owns the overall railway infrastructure and was the main driver for the implementation of the concept.
- Number of different operating contexts. A heterogeneous set of operating contexts puts rail operators in the pole position for condition monitoring and predictive maintenance. This is because the operating context of a train determines the limits of functionality of its components. It makes a big difference whether a train is operated in an urban area with winding roads or, for example, in the mountains.
- Current market share in rail maintenance. Rail operators that are already heavily involved in rail maintenance will have significant reason to continue playing a part in the maintenance game and not hand it over to other players. For them, in-house maintenance might be more cost efficient than outsourcing.

Overall Principle 2. The need for a physical space to merge engineering, railway and analytics know-how. In our case Coventry University became that space where experts from different areas of the British railway industry joint forces with safety and data analysis experts to come to a mutually agreed view of the problem and its solution.

Our case study showed revealed the need for experts from different areas to collaborate in the design and implementation of the solution. One dominating experience during our pilot was that the desired results do not emerge solely from pure data analytics or pure safety data, as this may lead to:

- Poor data quality. Existing data and data history are not rich enough to predict the failure of specific subcomponents of more complex systems.
- Unreliable correlations. Prediction models reveal seeming correlations between sensor data and failure codes that ultimately prove to be wrong. Interpretation of the results and adaptation of the models is needed – which can only be made successful in close cooperation with engineering and analytics experts.
- Insufficient lead time. The findings of the prediction models often cannot be incorporated into the maintenance processes because the time between failure alert and component failure is often insufficient.

Overall Principle 3. The need for an industry-wide commitment to digitisation of all relevant components and dissemination of the benefits extracted from the data generated by such digitisation.

Sensor technology and analytical capabilities alone are not enough to realise the efficiency potential of condition-based maintenance systems. The entire maintenance process needs to be upgraded with digital capabilities – component by component and/or sub-fleet by subfleet, to ensure positive ROI.

Summary:

In short, a well-planned mechanism for predictive maintenance must ensure that, in practice:

1. Identify the value-add of predictive maintenance in the specific context;

2. The right system or subsystem is chosen for prediction;

3. The necessary data can be collected from the system/subsystem;

4. Rail expertise is well connected with data analytics during the data analysis process;

5. A mechanism is established whereby the results of the data analysis are translated into maintenance action minimising disruption of other services and required planned maintenance strategies.

8   Conclusions and Recommendations

The European Parliament on February 2018 published a report on a European strategy on Cooperative Intelligent Transport Systems (2017/2067(INI)) [56]55. In this report the EP, among other issues, highlights the potential of digital technologies and related business models in road transport and recognises the Strategy as an important milestone towards the development of C-ITS and, ultimately, fully connected and automated mobility; notes that cooperative, connected and automated vehicles can boost the competitiveness of European industry, make transport seamless and safer, reduce congestion, energy consumption and emissions, and improve interconnectivity between different modes of transport; points out, with that in mind, that infrastructure requirements must be established to ensure that the systems concerned can function safely and effectively;

During the conduction of Task 5.1 and Deliverable 5.1 in NEWBITS Project a multi perspective research and validation methodology has been applied so key recommendations for the enhancement of the deployment of (C)-ITS applications and solutions, can be proposed.

Based upon the analysis it is recommended that awareness raising, and dissemination initiatives should be enhanced. Raising awareness will guarantee a sufficient volume of end users that most of the applications require to be fully operational and their users get their most of their benefits. C-ITS applications appear to be heavily depended on skilled workforce. Actions and initiatives to develop skilled workforce specialised in topics as big data, data mining, and artificial intelligence are proposed.

The second set of recommendations are related to data. It is proposed that all stakeholders related to C-ITS (EC, National agencies and technical associations) enhance their efforts to build, adopt and enforce the utilisation of open interoperability data formats and transmission

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protocols. It is recommended that clear data governance is required. Data management of C-ITS and ITS application is considered as a prerequisite to assure the privacy & security standards

(C)-ITS applications require the political support from governments. The society to benefit from C-ITS the support is recommended to be in the form of Regulations and Compliance mechanisms.

Finally, as the analysis has shown most of the (C)-ITS applications are developed by multi-stakeholders and innovative networked business ecosystems. The collaboration between stakeholders is recommended to be further supported, through initiatives that take into consideration all potential interested parties. The adoption of the notion of Communities of Interest and the support of web-based networking platforms as the NNP[56], developed in the NEWBITS project can actively support this recommended collaboration.

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Appendices

Appendix 1 CS3: New ICT method to increase efficiency in logistic chain of ports

In the table below the environmental benefits are specified. The external cost reduction due to emission reduction of reduced trucking (CostT$_{ex}$) has been calculated by the following formula:

$$CostT_{ex} = Ttkm \times \left(EF_{truck} - EF_{barge}\right) \times ECF \times \frac{1}{1000.000}$$

With:

Ttkm = tonne-kilometers reduced trucking: calculated assuming an average distance of 100km for barging or ad-hoc trucking and 15.75 tonnes load per container. As stated earlier, it is assumed that 3-4% of the containers is trucked in the reference alternative and 50% of this is avoided in the policy alternative.
EF$_{truck}$ = Average emission factor (CO_2, $PM_{2.5}$, PM_{10} or NO_x) in gram/tkm for truck (values specified in table below)
EF$_{barge}$ = Average emission factor (CO_2, $PM_{2.5}$, PM_{10} or NO_x) in gram/tkm for barge (as specified in table below)
ECF = external cost factor of the reduced emissions (€/ tonne) (values specified in table below)

The external cost reduction due to increased efficiency of barging (CostB$_{ex}$) has been calculated by the following formula:

$$CostB_{ex} = Btkm \times EF_{barge} \times red\% \times ECF \times \frac{1}{1000.000}$$

With:
Btkm = tonne-kilometers by barge: calculated assuming an average distance of 100km for barging and 15.75 tonnes load per container. As stated in the table above it is assumed that 3-4% of the containers is trucked in the reference alternative and 50% of this is avoided in the policy alternative.
Red% = relative emission reduction due to improved barge efficiency (km/tkm)
EF$_{barge}$ = Average emission factor (CO_2, $PM_{2.5}$, PM_{10} or NO_x) in gram/tkm for barge (values specified in table below)
ECF = external cost factor of the reduced emissions (€/ tonne) (values specified in table below)

Environmental benefits	Min	Max	Comments
CO_2 reduction reduced trucking	€ 21,007	€ 28,010	CE Delft assumption according formula above with: EF$_{truck}$ = 102 g/tkm , EF$_{barge}$= 20 g/tkm and ECF = € 57 €/ tonne CO_2
NOx Reduction reduced trucking	€ 16,396	€ 21,861	CE Delft assumption according formula above with: EF$_{truck}$ = 0.36 g/tkm , EF$_{barge}$=0.26 g/tkm and

			ECF = € 35,000 €/ tonne NOx
PM2.5 reduction reduced trucking	€ (3,048)	€ (4,064)	CE Delft assumption according formula above with: EF_{truck} = 0.004 g/tkm , EF_{barge}= 0.009 g/tkm and ECF = € 129,000 €/ tonne $PM_{2.5}$
PM10 reduction reduced trucking	€ 2,438	€ 3,251	CE Delft assumption according formula above with: EF_{truck} = 0.008 g/tkm , EF_{barge}= 0 g/tkm and ECF = € 65,000 €/ tonne PM_{10}
Total environmental benefits reduced trucking	**€ 36,794**	**€ 49,058**	
CO2 redcution of increased efficiency barging	€ 4,309	€ 8,618	CE Delft assumption according formula above with: EF_{barge}= 20 g/tkm and ECF = € 57 €/ tonne CO_2. The emission reduction due to improve efficiency (Red%) is 1- 2%
Nox Reduction of increased efficiency barging	€ 28,419	€ 56,839	Idem with EF_{barge}= 0.26 g/tkm and ECF = € 35,000 €/ tonne
PM reduction of increased efficiency barging	€ 3,657	€ 7,314	Idem with EF_{barge}= 0.009 g/tkm and ECF = € 129,000 €/ tonne
Total environmental benefits of increased efficiency barging	**€ 36,386**	**€ 72,771**	

Table 40 CS3 Environmental benefits

Source of ECF values: Handboek milieuprijzen 2017, CE Delft 2017;

Source emission factors: Stream Freight transport 2016, CE Delft 2016