COBRA Cooperative Benefits for Road Authorities

ERA-NET ROAD

Mobility:

Getting the most out of Intelligent Infrastructure

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Deliverable 4.1
Example Results of Cost Benefit Analysis

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1 Introduction

1.1 Overview

Cooperative systems communicate and share information dynamically between vehicles or between vehicles and the infrastructure. In so doing, cooperative systems can give advice or take actions with the objective of improving safety, sustainability, efficiency and comfort to a greater extent than stand-alone systems, thus contributing to road operators' objectives. However the nature of the benefits and the scale of costs to road operators vary between services, and only a limited amount of work has been undertaken to quantify them. The business case for road authorities depends not only on these benefits and costs, but also on their business model for delivering services.

The COBRA project aims to help road authorities to position themselves to realise the potential offered by developments in cooperative systems. It does so by providing insights into the costs and benefits of investments, both from a societal perspective and a business case perspective. These insights are provided on the basis of a decision support tool which enables the costs and (monetised) benefits of cooperative services to be compared in various contexts.

This document is intended to demonstrate the scope and capabilities of the tool developed in the project, the relative influence of different types of factor on the case for investment, and the benefits which may be achieved by road authorities. This is done by presenting a series of examples of the results of analysis of costs and benefits and the business case for national road authorities to invest in cooperative systems in different situations.

In a separate document (COBRA D4.2) [4], the user guide describes how to use the tool and provides further details on the assumptions and information used and how these are processed within the tool to produce outputs, such as those presented in the examples in this report.

1.2 Scope and limitations

This section introduces the services which can be assessed in the tool, the countries and timescale included, and the way in which comparisons can be made with current services delivered using existing infrastructure. It also outlines how users can make selections from the options available to represent different views of how deployment will take place, who will bear the costs of in-vehicle equipment, and the role of road authorities in the business model for delivering services. The main limitations arising from the way in which the scope of the tool has been defined are also introduced.

The tool is seen as a first version, using the best information currently available. It could, in future, be expanded and enhanced to take account of future developments and the availability of additional information.

1.2.1 Services

The tool enables road authorities to consider investment in cooperative systems to deliver services in three 'bundles' of functions based on communications between vehicles and infrastructure (see COBRA deliverables [2] and [3] for more information about the bundles):

1. Local Dynamic Event Warnings: Hazardous location notification, road works warning, traffic jam ahead warning and post-crash warning (eCall)
2. In-vehicle Speed and Signage: In-vehicle signage, dynamic speed limits and Intelligent Speed Adaptation (ISA)
3. Travel Information and Dynamic Route Guidance: Traffic information and recommended itinerary, multi-modal travel information and truck parking information and guidance.

1.2.2 Communications and technologies

For the first and second of these bundles, the options within the tool enable users to choose between two communications platforms for delivery: cellular network communications (e.g. mobile phone) or wireless beacons at the roadside. The third bundle is unlikely to be deployed using wireless beacons so cellular is the only communications platform offered in the tool for this bundle. In practice there may be situations in which both forms of communication would be used to support some cooperative systems, but this option is not available in the current version of the tool.

In the cellular communications options, the effect of deployment via aftermarket in-vehicle equipment or smartphones can also be assessed: users may define the proportion of vehicles equipped with aftermarket devices and smartphones. These options can be used in the tool to represent a situation in which vehicles can accept functional upgrades, overcoming the problem that services based on cooperative systems evolve over much shorter timescales than the replacement cycle of vehicles themselves.

Although differences in costs between the cellular and wireless beacons have been estimated within the tool, there was only limited evidence available on how impacts differ between systems delivered using these communications platforms, so this version of the tool assumes that the impacts of a given service are the same, whether it uses cellular or wireless communications. The exception is the in-vehicle speed and signage bundle in which the estimated cost of in-vehicle equipment varies with the communications platform: vehicles receiving ISA via wireless beacons are assumed to have a system fitted in the vehicle which provides ‘voluntary’ ISA through a throttle with haptic feedback (which the driver can over-ride), which is more expensive than ‘advisory’ or ‘informative’ ISA delivered via cellular communications through a smartphone or other nomadic device which does not require any connection with the vehicle. It seems reasonable to assume that users with a haptic throttle will be more likely to comply with speed limits than those who are simply informed of the speed limit via their smartphone, and therefore the impacts will differ. For the purpose of demonstrating the tool an assumption was made that 50% of drivers comply with ‘advisory’ ISA, while 100% of equipped drivers comply with ‘voluntary’ ISA due to the haptic throttle[1].

1.2.3 Countries

The geographical scope of the tool is limited to two countries as examples: the UK and The Netherlands. An area of the tool has been set aside for users to insert data on an additional country. This could also be used to enter data for a specific region or route where a road authority is considering the options for further investment.

An important implication of this focus on the UK and The Netherlands is that these are countries where the national road authorities have already invested heavily in existing roadside technologies and dynamic traffic management. This means that it is more difficult for these road authorities to achieve significant further benefits through cooperative systems than it would be in countries where existing roadside technologies and ITS services have been deployed at a lower level.

1.2.4 Timescale

The tool covers investments and potential benefits up to the year 2030; users can choose different rates and timescales for deployment within this time frame, but the current version of the tool does not enable a longer time horizon to be considered. This ability to select different timescales and rates of deployment within this time frame means that users can assess the effect of deployment following an EC mandate or a market-led roll-out of services. For example potential effect of an EC mandate can be represented by selecting 100% deployment by a given date.

1.2.5 In-vehicle costs

The tool also includes options for the user to select different levels of in-vehicle costs (full costs, one-third, half or no costs), which can be used to represent different views of who bears the costs of in-vehicle equipment and different deployment scenarios. For example the potential effect of introducing a common European in-vehicle platform for cooperative systems (such as the proposed European Wide Service Platform) can be represented by choosing to reduce the costs of in-vehicle equipment to one-third, reflecting the reduction in cost through economies of scale.

1.2.6 Deployment level

Data on the penetration rate of in-vehicle units was used from the SAFESPOT project, which comprised two sets of “Low”, “Medium” and “High” curves. The estimates for OEM-fitted units (wireless beacons platform) are a curved increase, starting from zero in 2015. The estimates for Aftermarket

[1] There is evidence in the iMobility Effects Database that impacts on accidents are higher in the case of haptic throttle than advisory ISA, but no evidence was found on differences in compliance. Source: iMobility Effects Database : http://www.esafety-effects-database.org/applications_07.html

units (cellular platform) are a linear increase, starting from zero in 2012. These deployment curves are the same for each of the three bundles. It is possible for the user to include better estimates in the tool where these are available.

For the wireless beacons platform, data on the deployment level of roadside beacons is a user input. For the cellular platform it is assumed that there is 100% network coverage.

1.2.7 Business model

Within the tool there are various options available for the user to select which reflect different business models for delivering services. These represent different roles for the road authority and the private sector in covering the costs of the services and the infrastructure to deliver them. The Business Models are described in detail in COBRA D2 [2].

1.2.8 Existing infrastructure

Users can adjust the current level of existing infrastructure, as well as forecast future deployment of these systems. Although some adjustments to the existing infrastructure are possible, it has been necessary to make some assumptions and simplifications, which are not open to adjustment in the current version of the tool These points are discussed briefly below and in more detail in COBRA D2 [2] and Section 6.

1.2.8.1 Overlap of functions between Cooperative System bundles and Existing Technologies

The cooperative services are assumed to be the same as equivalent services delivered by means of existing technology. The user of the tool must therefore specify the percentage of the network that is equipped with three types of existing infrastructure. This is illustrated in Figure 1.

Bundle 1 Local Dynamic Event Warnings	↔	**"Queue Protection"**
Bundle 2 In-vehicle Speed and Signage	↔	**"Managed Motorways"**
Bundle 3 Travel Information & Dynamic Route Guidance	↔	**"Roadside travel and routing information"**

Figure 1 Overlap between bundles of cooperative systems and services delivered using existing technology

The existing technologies considered are:

- Managed motorways: An integrated set of traffic management systems to improve traffic flow and road capacity; in the UK they primarily involve variable speed limits and hard shoulder running.
- Queue protection on motorways is an automatic traffic management system used to detect sudden traffic disruptions and warn upstream traffic heading for the congested area.
- Roadside travel and routing information provides travel and routing information via Variable Message Signs (VMS) (known in some countries as Dynamic Roadside Information Panels – DRIPs - and Graphical Roadside Information Panels - GRIPs).

An alternative way to consider this assumption is "the percentage of the network for which the cooperative systems have no impact". Although this is not ideal, it is consistent with the aim of the tool to avoid over-optimistic assessments. In practice there may be some additional benefits on sections of the network with existing infrastructure.

1.2.8.2 Variable Message Signs and infrastructure cost savings

Variable Message Signs (VMS) are used by road authorities to deliver a variety of information to road users.

VMS can perform several different functions, including:

- Routing information (diversions during road closures or long delays)
- Danger warning messages (weather, incident, congestion, road status)
- Speed control (variable mandatory speed limits, variable advisory speed limits)
- Lane control (closures due to road works, other temporary closures)
- Other information (planned events, unplanned events, general information).

There are many different types of VMS, which vary for different countries, but may include:

- Very simple VMS, such as “50” or “X” (“Matrix Signals”)
- Basic VMS, consisting of a few words
- More advanced VMS, consisting of several words, possibly with graphics
- Other types

Each of the three types of existing infrastructure (shown in Figure 1) use VMS in some way to deliver the information to the driver. However, the type and nature of VMS will vary across the network and between different countries; for example Queue Protection may be delivered through Matrix Signals on some sections and through more advanced VMS on other sections.

There is an option to "Include infrastructure cost savings" for scenarios where VMS are phased out and superseded by cooperative systems. In the current version of the tool, it is possible to specify only one type of VMS.

When considering infrastructure cost savings, it is important to tailor tool inputs to match the particular implementation of the type of VMS. As well as the cost savings, it is important to consider the negative impacts of removing existing VMS. This has been attempted in the current version of the tool, although this part of the tool should be treated with caution, because the impacts of VMS were outside the scope of the Impact Assessment. It is also necessary to consider the current and future functions of the VMS; for example, for road works lane closures, some countries are considering completely phasing out metal signs and instead using VMS.

1.2.8.3 Existing sensors

An assumption in the tool is that the bundles use only existing sensors and no additional sensing equipment will be deployed. In practice this simplification may not be the case, and so the tool has a blank column for additional sensor costs, which could be included for a particular implementation. Likewise, for simplicity, cost savings related to sensors are not included in the tool; this is discussed further in Section 6.

1.3 This report

The document consists of six chapters following this introduction.

Chapter 2 provides some background on cost benefit analysis, business models and decision-support in the COBRA tool. Chapter 3 contains example results and analysis of the cost benefit and business case for specific scenarios involving the bundles. It also includes a description of the key influencing parameters. Chapter 4 summarises the expected impacts of each bundle and identifies the most promising business cases. Chapter 5 presents conclusions and Chapter 6 recommendations for further work. Finally, Chapter 7 provides a glossary of terms.

2 Background on cost benefit analysis, business models and decision-support in the COBRA tool

Societal cost benefit analysis (CBA) is based on the principle of welfare economics which assesses whether or not society as a whole is expected to be better off as a result of introducing a measure, so that the estimated total benefits are greater than the estimated total costs incurred. The resource savings made (capital equipment, labour, time, fuel etc.) are assumed to be deployed elsewhere in the economy at least as productively as before the measure was introduced. CBA is a tool that allows those who gain from an intervention to compensate the losers if that is considered desirable.

The tool follows the methodology presented in COBRA report D2 and summarised in Figure 2, and uses the synthesis of published evidence on the impacts of services which was presented in COBRA report D3. The method used in the tool is based on recommended techniques for benefit cost analysis developed in European projects. The user guide which accompanies the tool (D4.2), describes the cooperative systems and scenarios which are available for assessment, the parameters which can be set by users, and the technical aspects of using the tool.

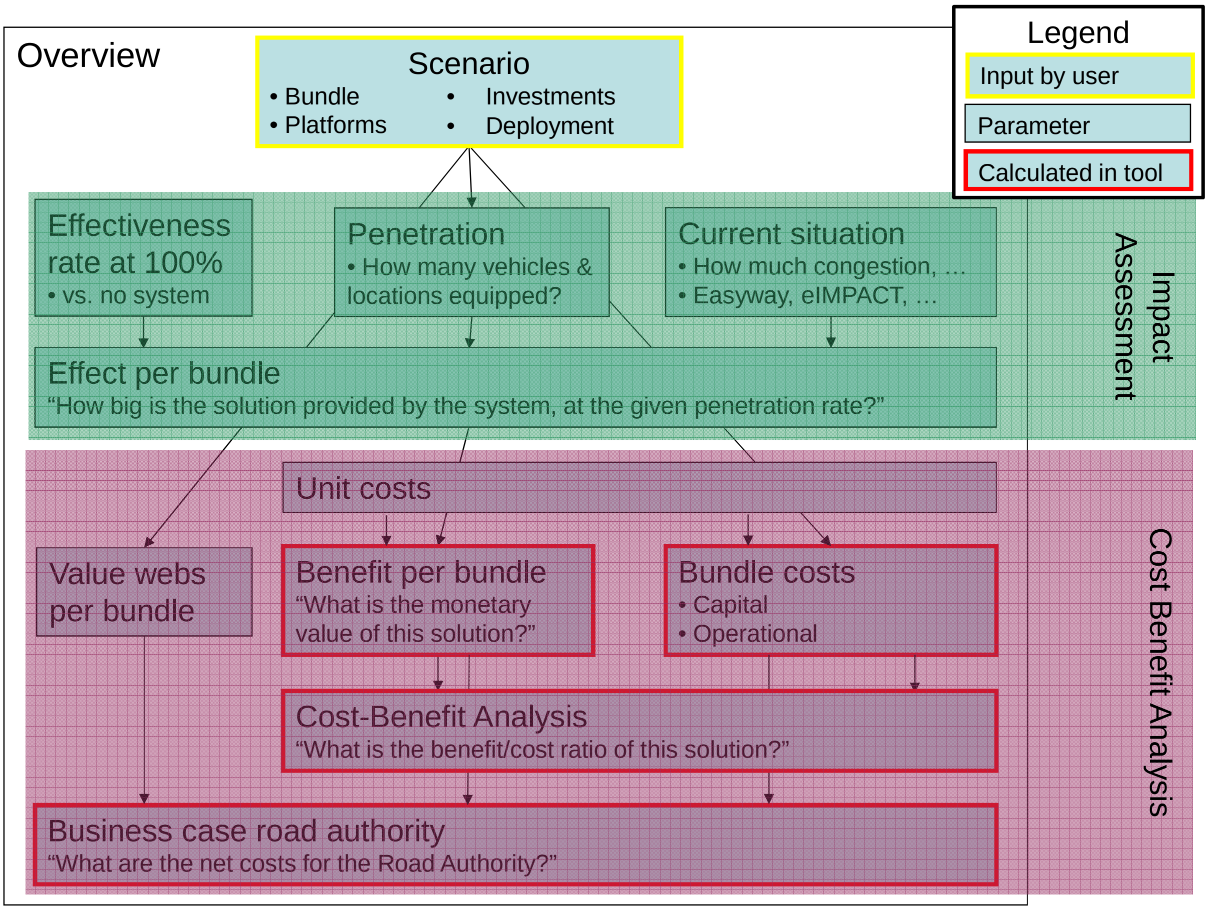


Figure 2 Methodology overview

The tool itemises the main benefits in monetary terms for each bundle of services. Monetised benefits can be identified as arising from two sources:

- Societal benefits, where the cooperative services provide a monetisable benefit to society as a whole, for example the cost saving of preventing a fatal accident.
- Direct monetary benefits, where the implementation of (a bundle of) cooperative services leads to a direct saving to the road authority, for example by reducing infrastructure costs.

The benefits included in the tool are:

- Reduced fatalities and injuries
- Reduced accidents, leading to less incident-induced congestion, and hence more reliable journey times
- Reduced travel times
- Reduced fuel consumption
- Reduced emissions (CO_2, NO_x, PM) from smoother traffic flow
- Reduced infrastructure requirements (both CAPEX and OPEX) once a certain market penetration has been reached – typical examples here include the reduced requirement for non-essential signage like VMS. There are however social and possibly legal consequences which will need to be considered by decision-makers, such as how to serve the remaining

non-equipped users, which could offset some of the benefits. Legal issues are addressed in Deliverable 5.

The tool works on the principle of making conservative estimates to reduce the likelihood of over-optimistic assessments, for example by including only the benefits where quantified estimates can be made and using estimates of likely costs that are at the higher end of possible cost estimates. Thus, for example, non-quantifiable benefits could make the investment more attractive to decision-makers. Similarly since the cost of electronic equipment is likely to fall over time the estimates included in the tool may exceed that that will be incurred in practice. The valuation of benefits is based on the estimated impacts using expert judgement and data from studies of the impacts of non-cooperative versions of these services. The tool uses the best information currently available. It could, in future, be enhanced to take account of additional information. The approach taken has been influenced by the availability and quality of the data. The tool enables a certain degree of flexibility in terms of which costs to be included; for example, depending on policies on the scope of the business case, some decision makers may only wish to include costs that are directly borne by the road authority and exclude (either wholly or in part) those that would be borne by owners such as for in-vehicle equipment. This flexibility is relevant since even relatively small costs (or benefits) that are incurred by a large number of vehicle owners can have a substantial influence on the results.

The term ‘unintended impacts’ has been used to denote impacts which may be seen as negative (such as increasing journey times). For the purpose of calculating a benefit: cost ratio (BCR), such impacts are often treated as a negative benefit to be subtracted from other (positive) benefits. However this can result in a negative benefit: cost ratio (when there are no actual benefits) or a BCR less than 1:1, which was felt to be confusing; to avoid this, unintended impacts have been treated as additional costs for the purpose of calculating the benefit: cost ratio in the tool. This tends to bring the BCR closer to 1:1. However, using this alternative method has no effect on the overall conclusions about investment decisions. Similarly, negative costs, i.e. cost savings, are treated as benefits.

Note that some key types of societal benefit are not included. These include indirect benefits such as wider economic benefits, for example growth and employment, and distributional effects such as social inclusion. Such benefits are difficult to evaluate and it may be disputed whether these are in fact due exclusively to the package itself and not to other factors. Thus, the approach proposed will tend to underestimate the possible benefits from the package rather than overestimate them. The introduction of ITS systems will generate a wide range of impacts, many of which are not easily monetised, for example due to the lack of a market-based pricing mechanism, but which need to be identified and, if possible, measured according to an acceptable scale. Another point to bear in mind in relation to distributional impacts is that they will vary according to location, activity, social group etc. These differences need to be appreciated so that cost benefit analysis becomes just one tool in the decision-making process.

In many examples there will be no financial benefits to the road authority since there would be no revenue stream or operational cost reductions generated for them as a result of the investment. While this means that the local cost-benefit case does not justify the investment, it does not mean that the investment should not proceed. Theoretically, if the benefit: cost ratio exceeds 1.0 there may be a more global case for the cooperative service and it could, therefore, be a candidate for funding. In practice however, some road authorities will not be prepared to invest in systems with a benefit: cost ratio which as low as this, and may only consider funding those with a higher benefit: cost ratio (for example 1.6 or 2.0).

In the following section, eight examples (each comprising two scenarios) are presented to show the COBRA tool in use. They illustrate for different bundles of services and different assumptions about the cost of in-vehicle equipment, the effect of varying some of factors which are likely to have an important influence on investment decisions. Road authorities should not however use these examples alone as a basis for investment decisions; at a minimum, the underlying parameters and assumptions underlying them should be reviewed carefully and updated where appropriate.

3 Results of selected cost benefit analysis and business case analysis using the tool

3.1 Key factors influencing the cost benefit analysis and business case

This section helps users to consider the most and least sensitive areas of the tool. The default values for the various parameters and input data are reproduced and there is an analysis of their relative influence on the results. This analysis provides an indication of where it is most important to obtain accurate information in order to obtain a realistic assessment from the tool.

3.1.1 *In-vehicle factors*

Any factors associated with in-vehicle costs are likely to have a large influence on the results. This is mainly due to the very large numbers of vehicles involved. Factors may include: one-off capital costs (equipment and installation); annual operational costs (subscriptions and cellular communication costs); lifetimes of in-vehicle equipment; forecasted number of vehicles; deployment levels; the balance between “Smartphone” (no equipment costs) and “Aftermarket” (some equipment costs) in the cellular scenario.

3.1.2 *Societal problem costs*

The societal problem costs fall into four categories: road safety (fatalities, injuries, damage and other associated costs); travel time; fuel consumption (i.e. money spent petrol and diesel, excluding tax); and emissions (CO_2, NO_X, particulate matter). These were quantified for the two example countries, the UK and the Netherlands, using the best available data[2]. The graphs in Figure 3 and Figure 4 below shows the societal problem cost for the UK and the Netherlands in the years 2012 and 2030 (note that the scale of the ‘y’ axis is different in each case).

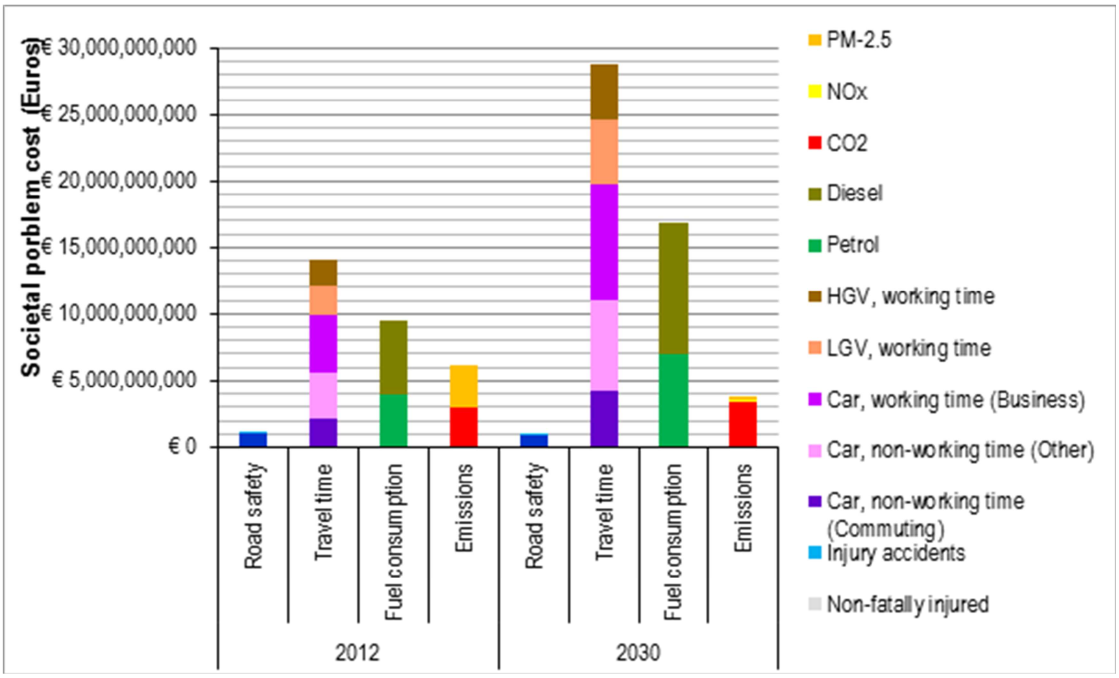


Figure 3 Distribution of societal problem costs in the UK: 2012 and 2030

[2] See Appendix A in D4.2. for input data, forecasts and sources for the UK.

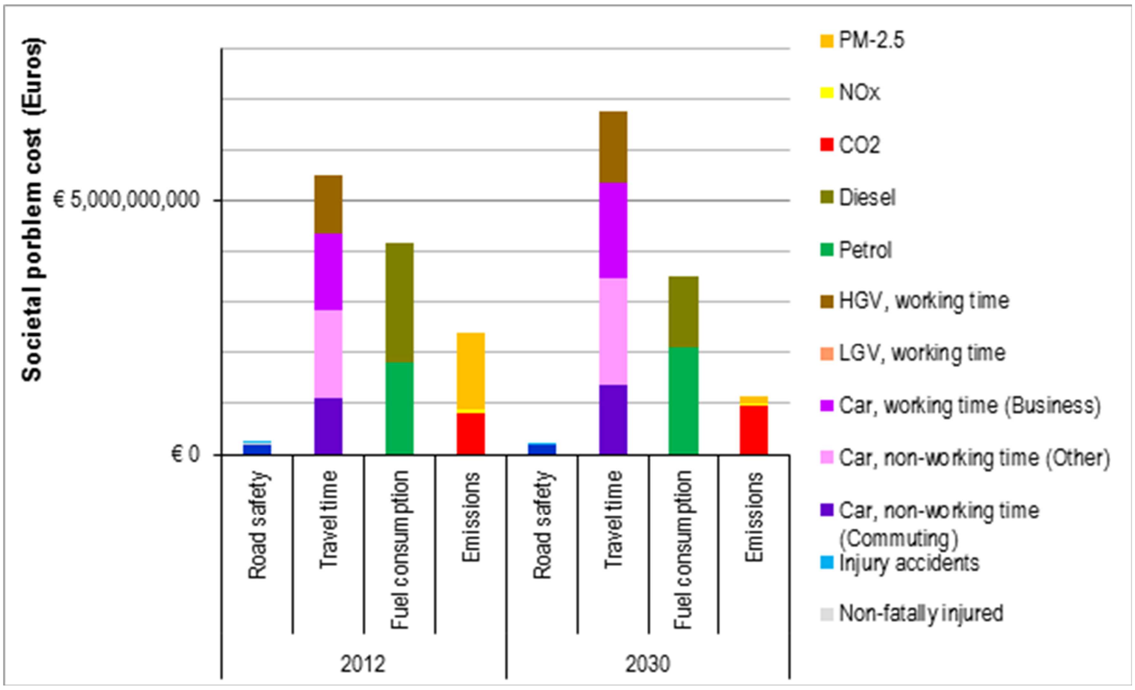


Figure 4 Distribution of societal problem costs in The Netherlands: 2012 and 2030

By carrying out a range of different analyses to test the model, it was found for the two example countries that any factors relating to travel time have a large influence on the results, relative to the other societal costs. This is because although the unit cost is relatively low, it is multiplied by a very large number of hours spent travelling. Factors associated with travel time include: total vehicle hours; unit cost of travel time (occupancy, GDP forecasts, balance between working and non-working time); impacts of each bundle on travel time (from D3).

The road safety societal problem cost was found to be relatively small, because although the unit cost is high, it is multiplied by a relatively small number of occurrences. However, this is not to say that "road safety is not important". Some road authorities have adopted the approach that "No loss of life is acceptable", such as the Swedish "Vision Zero" concept[3]. Furthermore, it should be noted that the scope of the project was to consider the Easyway network, which is predominantly motorway, and has relatively lower numbers of fatalities and injuries compared to rural and urban roads. Additionally, the two example countries have relatively safer roads compared to other European countries.

3.1.3 Hotspots and existing infrastructure

Another part of the model that is likely to have a large influence on the results is the assumption that the bundles only have an impact on the sections of network that are not equipped with existing infrastructure. This is discussed in Section 1.2.8.1. Coupled with this, is the "Hotspots" assumption that the sections of road are equipped first where the greatest benefits can be reaped. There are two hotspots curves. The one for accidents is "59:50" (59% of the accidents occur on the worst 50% of the network). The curve for travel time, fuel consumption and emissions is approximately "65:50" (65% of travel time occurs on 50% of the network). (Note that this is a simplification and it is likely that the curves for fuel consumption and emissions would not be the same as the travel time curve.) In the illustrative example in Figure 5 below, 40% of the network is equipped with existing infrastructure, and so there are impacts from the cooperative systems on only 60% of the network; this equates to 45% of the possible travel time benefits, as shown by the green arrow.

[3] http://www.visionzeroinitiative.com/en/Concept/

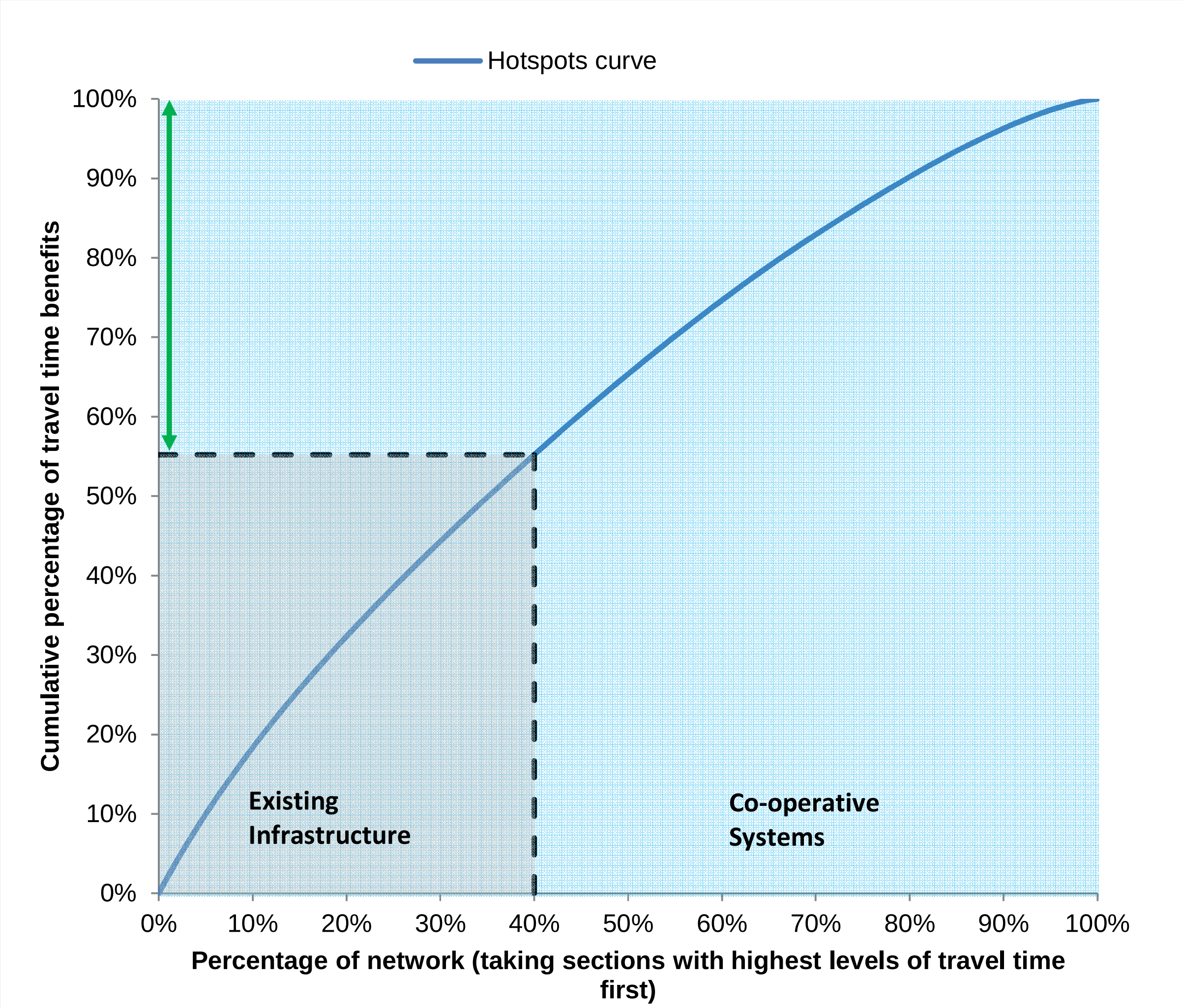


Figure 5 Impacts of cooperative systems are assumed to be realised only on sections of the network where services are not delivered using existing infrastructure

The two example countries have a large amount of existing infrastructure and so these parameters have a large effect on the results. This parameter can be set to zero for other countries where there is no existing infrastructure performing the same functions as the cooperative systems.

3.1.4 Summary of relative sensitivity

Table 1 shows the values used for estimating costs, benefits and other parameters which have been used in the example analysis presented in this report. There is also a "relative sensitivity", which is an imprecise measure, but aims to summarise the degree to which the results are sensitive to variations in the values of parameters, input data and assumptions.

Table 1 Sensitivity of results to parameters and input data

Type	Parameter / Data	Default value	Relative sensitivity	Discussion of sensitivity
In-vehicle costs	Annual subscription costs	€20	Very high	Multiplied by total number of vehicles and annual.
	Annual communication costs (only Cellular scenario)	€10	Very high	Multiplied by total number of vehicles and annual.
	One-off in-vehicle equipment costs	€100 to €250	Very high	Multiplied by total number of vehicles.

Type	Parameter / Data	Default value	Relative sensitivity	Discussion of sensitivity
	Forecast of number of vehicles	country-specific	Very high	Large number.
	For Cellular scenario, the balance (adding up to 100%) between Aftermarket and Smartphone	20%/80%	Very high	Multiplied by total number of vehicles and annual. Smartphone equipment costs are assumed to be zero, and Aftermarket equipment costs are non-zero.
Societal problem cost	Time spent travelling	€14.1bn to €28.7bn (annual UK value)	Very high	Unit costs, unit cost forecasts, societal problem size, societal problem forecasts all affect the societal problem cost.
	Fuel consumption	€9.6bn to €16.9bn (annual UK value)	Medium	
	Emissions	€6.1bn to €3.7bn (annual UK value)	Low	
	Road Safety	€1.3bn to €1.1bn (annual UK value)	Low	
Impacts	Impacts	Values from the Impact Assessment in D3	High	In particular the impacts on time spent travelling and fuel consumption have much greater impact on the results due to the societal problem cost (see above).
Deployed units	Number of VMS per km (one side of motorway)	1	Low	Only relevant when considering VMS cost savings.
	Number of wireless beacons per km (one side of motorway)	3.333	Low	Only relevant when considering Wireless Beacons scenario.
	Road length	country-specific	Low	Only relevant when considering Wireless Beacons scenario and VMS cost savings.
	Number of back offices	1	Low	Multiplied by the back office costs
Deployment of existing roadside infrastructure	Roadside travel and routing information	country-specific	Very high	Assumed 100% overlap with Bundle 3 (Travel Information and Dynamic Route Guidance)
	Queue protection	country-specific	Very high	Assumed 100% overlap with Bundle 1 (Local Dynamic Event Warnings)
	Managed Motorways	country-specific	Very high	Assumed 100% overlap with Bundle 2 (In-vehicle Speed and Signage)
Hotspots	Travel time, fuel consumption and emissions	65:50	Very high	Assumption that if e.g. 50% of the hotspots are equipped then you reap 65% of the benefits - for travel time, fuel consumption and emissions. This is particularly relevant when combined with the 100% overlap with services based on existing roadside infrastructure
	Accidents	59:50	Low	Assumption that if e.g. 50% of the hotspots are equipped then you reap 59% of the benefits - for accidents. This has a lower sensitivity due to the lower societal problem size of accidents.

Type	Parameter / Data	Default value	Relative sensitivity	Discussion of sensitivity
Discount rate	Discount rate	country-specific	Medium	Typically there are more costs up-front and the benefits take longer to come through. Therefore a higher discount rate reduces the BCR.
Component costs	Infrastructure - Existing VMS (per sign)	CAPEX - €409k Annual OPEX - €1k	Low	Only relevant when considering VMS cost savings.
	Infrastructure - communication platform (wireless beacons) (per sign)	CAPEX - €16k Annual OPEX - €0.5k	High for NRA business case but Low for societal CBA	Only relevant when considering Wireless Beacons scenario.
	Infrastructure - back office	CAPEX - €200k Annual OPEX - €20k	Medium	Cost included for all scenarios.
	Infrastructure - app development (1-off)	CAPEX - €200k Annual OPEX - €20k	Medium	Cost included for all scenarios.
	Lifetimes	5 to 30 years	High	There are lifetimes for each of the cost components, which affect the number of units that need to be replaced each year. Sensitivity depends on which type of cost component.

3.2 Outline of analysis

The analyses which have been carried out in this report have been designed to cover a range of different situations, illustrate different issues and to indicate where the main costs and benefits arise and how these change over time. They also demonstrate the sensitivity of the results to certain key parameters.

The most sensitive aspects of the model are any parameters that affect in-vehicle costs. For simplicity, the model was first run for each of the three bundles with all in-vehicle costs set to zero; for these runs the bundles were considered at Medium and High penetration rates (with penetration in the vehicle fleet at 75% and 100% by 2035) – see examples 1 - 3 listed below. The model was then run to show the impact of including in-vehicle annual communication and subscription costs and also one-off in-vehicle equipment costs (examples 4 and 5 below). The model was then run to show the effect of choosing the Cellular or Wireless Beacons platforms and also the effect to the NRA of choosing different business models (examples 6 and 7 below). Finally there was a comparison between the UK and the Netherlands (example 8 below). All of the analyses present the results for deployment over the entire assessment period covered by the model: 2012 – 2030.

The examples which have been analysed are listed below and summarised in Table 2:

1. Local Dynamic Events Warnings in the UK, no in-vehicle equipment cost included, effect of penetration (Section 3.3.1)
2. In-vehicle Speed and Signage in the UK, no in-vehicle equipment cost included, effect of penetration (Section 3.3.2)
3. Travel Information and Dynamic Route Guidance in the UK, no in-vehicle equipment cost included, effect of penetration (Section 3.3.3)
4. Travel Information and Dynamic Route Guidance in the UK, in-vehicle operating costs only included, effect of subscription costs (Section 3.3.4)
5. Local Dynamic Events Warnings in the UK, effect of in-vehicle equipment cost (Section 3.3.5)
6. In-vehicle Speed and Signage in the UK, one third of in-vehicle equipment cost included, effect of communications platform (Section 3.3.6)

7. In-vehicle Speed and Signage in the UK, one-third of in-vehicle equipment cost included (i.e. approximate cost to supplier), effect of business model for road authority (Section 3.3.7)
8. Local Dynamic Events Warnings, one-third of in-vehicle equipment cost included, comparison between the UK and the Netherlands (Section 3.3.8).

Table 2 Examples of situations analysed

Bundle	Effect of:				
	Penetration rate	Communications platform	Business model	Difference UK and NL	Cost to users
Local Dynamic Event warnings	1: Section 3.3.1			8: Section 3.3.8	5: Section 3.3.5
In-vehicle Speed and Signage	2: Section 3.3.2	6: Section 3.3.6	7: Section 3.3.7		
Travel Information and Dynamic Route Guidance	3: Section 3.3.3				4: Section 3.3.4

3.3 Results of cost benefit analysis and business case analysis for each bundle

3.3.1 Example 1: Local Dynamic Event Warnings – effect of penetration

Reason for comparison

To verify that the monetary value of the impacts changes as expected with different levels of penetration rate for in-vehicle units.

To see if any scenario is beneficial in social cost-benefit terms.

Description of scenarios

The scenarios considered are for the Local Dynamic Event Warnings bundle delivered by cellular network communications in the UK.

The only parameter varied between the two scenarios is the penetration rate. This changes between "medium" in Scenario 1 (reaching 75% equipped vehicles in 2035) and "high" in Scenario 2 (reaching 100% equipped vehicles in 2035).

Key input parameters

The country is the UK. This parameter determines the size of the "problem" and the number of vehicles.

The communications platform is cellular network.

No in-vehicle capital costs are included; it is assumed that drivers equip their vehicles with smartphones external to the scenario being considered. Back-office costs are included.

No operating costs for the vehicle unit are included; it is assumed that data communication costs are already included in the owner's service bundle; back-office communication costs are part of on-going operations. Both of these cost assumptions are reasonably realistic.

The penetration rate increases linearly over time, reaching its maximum in 2035. A 100% penetration is not realistic but useful in illustrating the maximum effect. Even a 75% equipment rate is possibly optimistic.

Main benefits

The main benefits are in fuel consumption and safety, as expected, arising from increased driver awareness. There are also, smaller, benefits to emissions. The monetary value of benefits in fuel consumption is higher than that of safety benefits because in monetary terms the societal cost of fuel consumption is far greater than safety (as Figure 3 showed).

Under both Scenarios 1 and 2, there are unintended impacts registered (see graph 1 in Figure 6 below). These arise from different studies that found different effects of components of this bundle of services. However, these are smaller than the effects on safety and fuel consumption in these scenarios.

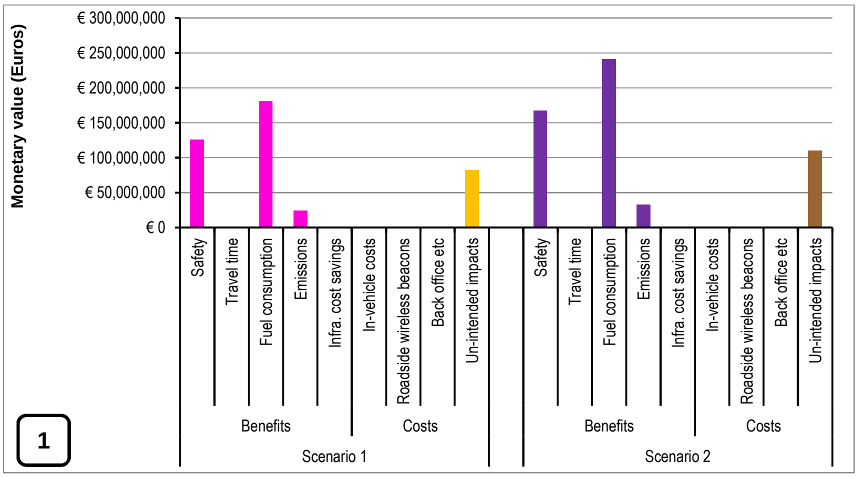


Figure 6 Local Dynamic Event Warnings - distribution of benefits and costs comparing 75% (Scenario 1) and 100% penetration (Scenario 2)

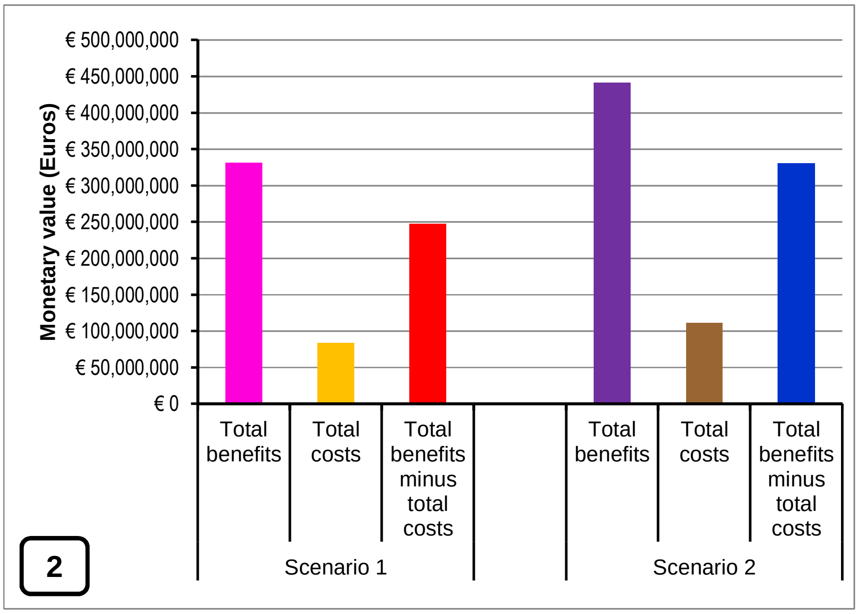


Figure 7 Local Dynamic Event Warnings – total benefits and costs comparing 75% (Scenario 1) and 100% penetration (Scenario 2)

Main costs

The direct (CAPEX/OPEX) costs in this scenario relate to the back-office, and these are small compared with the benefits, so these lines are closer to the x-axis in both graphs 3 and 4 in Figure 8. It is assumed that no additional sensors are provided by the road authority so the cost of sensors is assumed to be zero. All in-vehicle costs (capital equipment costs and annual communications and subscription costs) are also assumed to be zero.

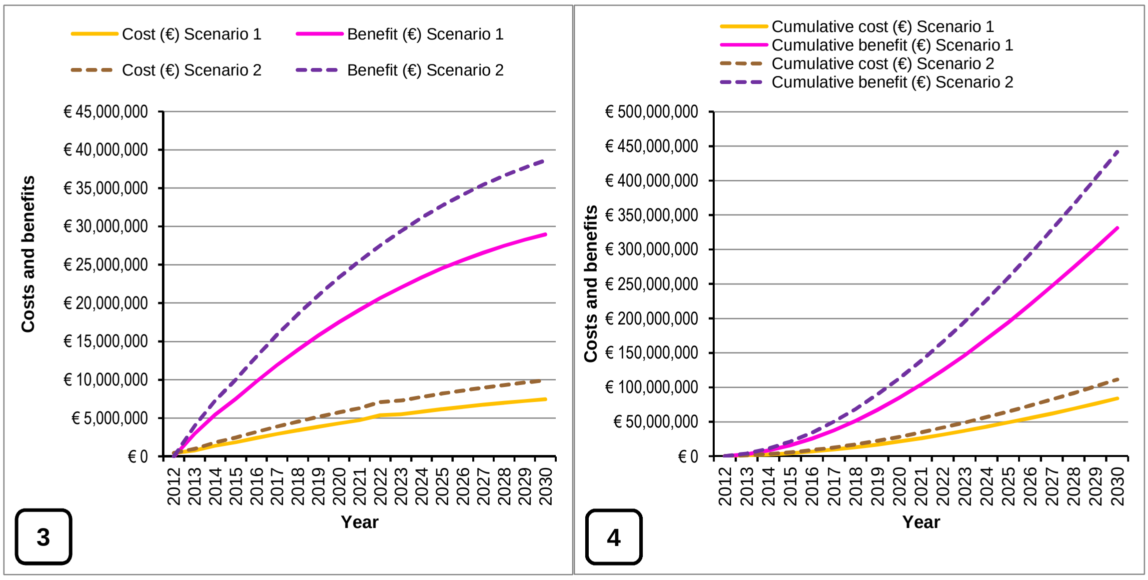


Figure 8 Local Dynamic Event Warnings – costs and benefits over time (in specific years and cumulatively to a given year) comparing 75% (Scenario 1) and 100% penetration (Scenario 2)

Changes over time

The costs show a small increase around 2022 which can be explained by the assumption that the back-office system and App would need to be completely renewed after 10 years. The benefits in both scenarios increase over time as more vehicles are equipped and the increase is larger for the higher penetration rate, as expected.

The increase in benefits becomes less steep over time. This is because the safety benefit reduces as vehicles and roads become generally safer over time (hence the contribution of this bundle acts on a smaller problem size). Furthermore, as all benefits are discounted, all benefits reduce into the future. The combined effect is a reduction in the steepness of the curve in graph 3 in Figure 8. Cumulatively, the benefits continue to grow over time (graph 4 in Figure 8) as penetration rate increases.

Benefit cost ratio

As the benefits are substantial and the costs are relatively very low, the benefit cost ratio is positive and increases over time to around 2020 as future benefits are added in (graph 5, Figure 9). The small "glitch" in the BCR graphs around 2022 is explained by the assumption that the back-office system and App would be renewed after 10 years. In practice this would be undertaken over time, so this feature of the graphs is not significant.

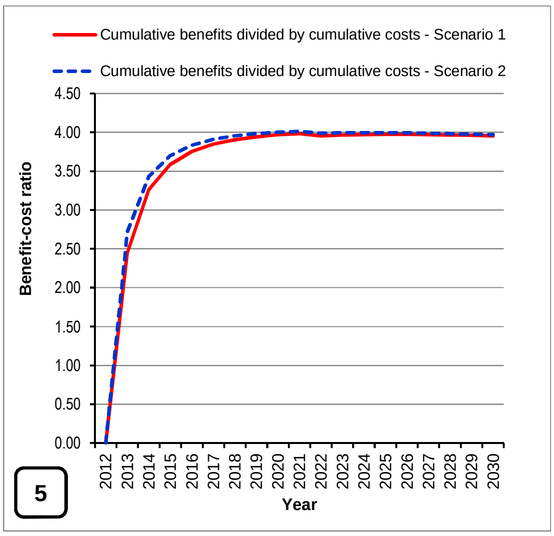


Figure 9 Local Dynamic Event Warnings – benefit cost ratio comparing 75% (Scenario 1) and 100% penetration (Scenario 2)

Conclusion

These scenarios generate positive social benefits, particularly in terms of fuel consumption and safety. Therefore in social cost-benefit terms, investment in this bundle could be very worthwhile.

For a National Road Authority, dynamic information provision is becoming a core part of road operations. There are choices about whether such services are delivered in-vehicle or on road signs and whether by the road operator or other service providers.

Clearly the results are sensitive to the penetration level assumed, even between the 75% and 100% levels tested here: the difference in benefits between these two scenarios increases over time.

3.3.2 Example 2: In-vehicle Speed and Signage – effect of penetration

Reason for comparison

To verify that the monetary value of the effects changes as expected with penetration.

To see if any scenario is beneficial in social cost-benefit terms.

Description of scenarios

The scenarios considered were for the In-vehicle Speed and Signage bundle delivered by cellular network communications in the UK. The form of ISA is "information only" and only partial (50%) compliance is assumed.

The only parameter varied between the two scenarios was the penetration rate. This changed between "medium" in Scenario 1 (reaching 75% equipped vehicles in 2035) and "high" in Scenario 2 (reaching 100% equipped vehicles in 2035).

Key input parameters

The country is the UK. This parameter determines the size of the "problem" and the number of vehicles.

The communications platform is cellular networks. This also means that the form of ISA is information-only.

No in-vehicle capital costs or operational costs are included; it is assumed that drivers equip their vehicles with smartphones external to the scenario being considered and that data communication costs are already included in the owner's service bundle.

Back-office capital and operational costs are included.

The penetration rate increases linearly over time, reaching its maximum in 2035. A 100% penetration is not realistic but useful in illustrating the maximum effect. Even a 75% equipment rate by 2035 is possibly optimistic.

Main benefits

There are benefits to safety, partly from increased general driver awareness and, particularly, from greater speed limit observance. The speed reduction also generates benefits in terms of fuel consumption and emissions and these factors are substantial on high-speed roads; in monetary terms the main benefits are in reduced fuel consumption (see Figure 10).

A key dis-benefit in both scenarios arises from the unintended impacts, notably the additional time spent travelling (drivers exceeding the speed limit reduce their speed, outweighing the overall value of safety improvements through accident reductions). This is because in monetary terms, the number of drivers reducing their speed weighted by the value of their time, produces a far greater monetary value than the relatively small number of accidents avoided, albeit weighted by the much higher monetary value of accidents.

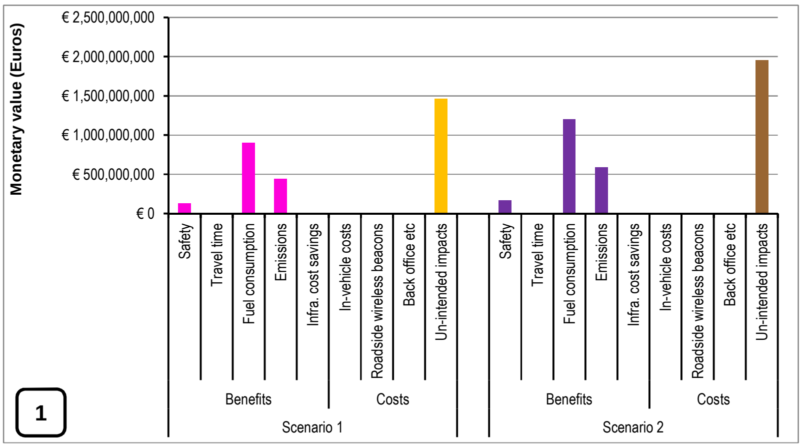


Figure 10 In-vehicle Speed and Signage - distribution of benefits and costs comparing 75% (Scenario 1) and 100% penetration (Scenario 2)

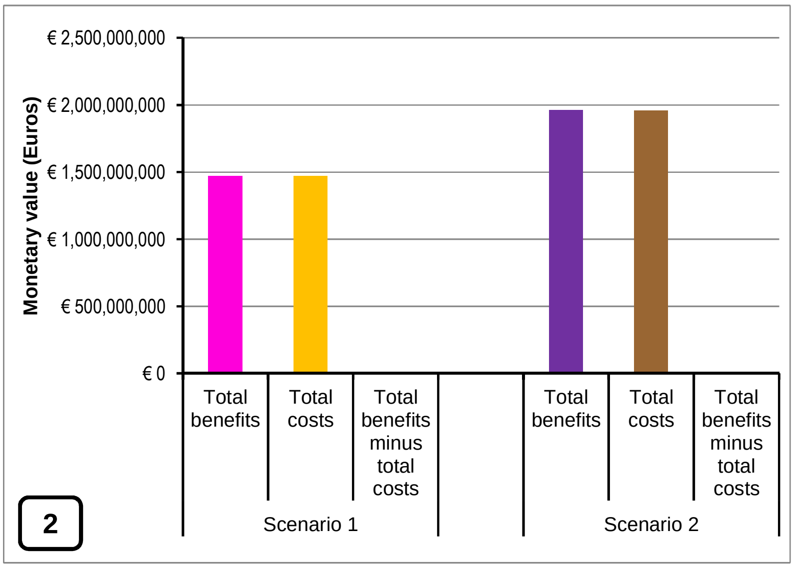


Figure 11 In-vehicle Speed and Signage - total benefits and costs comparing 75% (Scenario 1) and 100% penetration (Scenario 2)

Main costs

There are no direct (CAPEX/OPEX) costs in this example but there is a cost in terms of increased travel time (as a result of better observance of speed limits). These costs are substantial are approximately equivalent to the monetised benefits.

Changes over time

Both the benefits and the costs (increased travel time) increase with time as more vehicles are equipped. The increase is steeper for the higher penetration rate.

The increase in benefits becomes less steep over time (graph 3 in Figure 12) as roads generally become safer in the future and vehicles become more efficient. However, the cost of increased travel time continues to grow at a higher rate, because there are more and longer journeys, and forecasts for the value of time are linked to increases in GDP.

Cumulatively, the benefits continue to grow over time (graph 4 in Figure 12) as penetration rate increases.

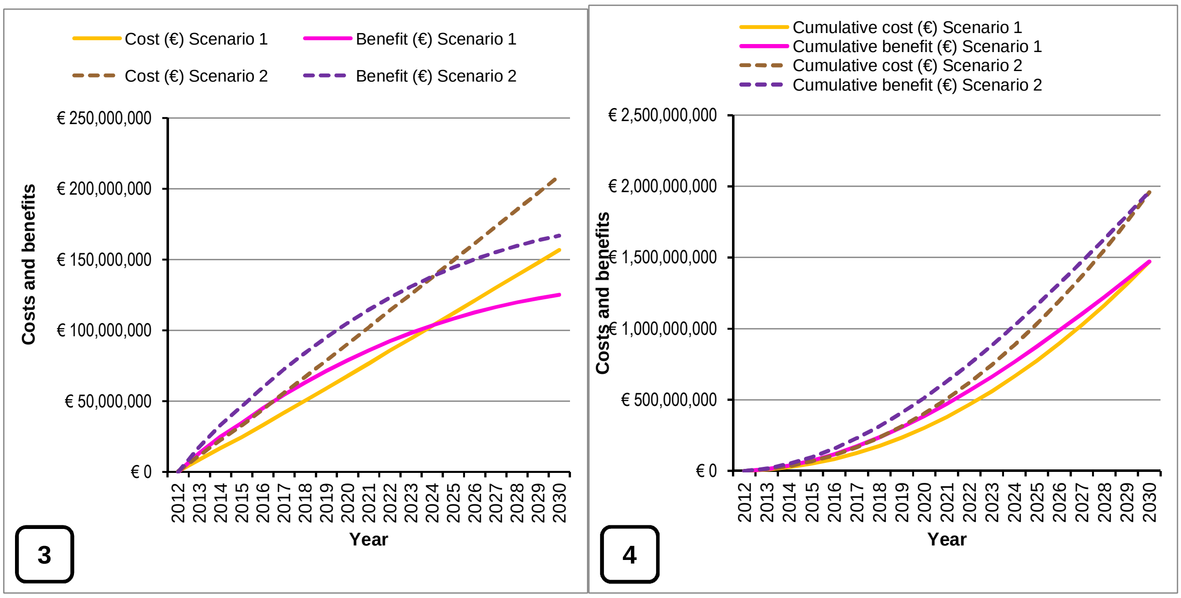


Figure 12 In-vehicle Speed and Signage - costs and benefits over time (in specific years and cumulatively to a given year) comparing 75% (Scenario 1) and 100% penetration (Scenario 2)

Benefit cost ratio

The benefits and costs are relatively similar, so the scenario achieves a maximum BCR of about 1.4 in 2013 (graph 5, Figure 13). It reduces over time as the cost of travel time grows faster than the value of the benefits (safety, fuel consumption and emissions).

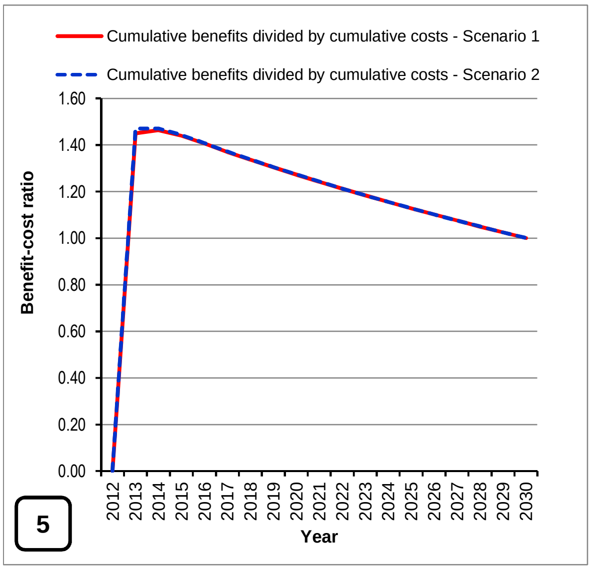


Figure 13 In-vehicle Speed and Signage – benefit cost ratio comparing 75% (Scenario 1) and 100% penetration (Scenario 2)

Conclusion

These scenarios generate social benefits in terms of road safety with reduced fuel consumption and emissions. However, in social benefit-cost terms the dis-benefit of increased travel time is relatively high compared with the benefits so the highest value of the BCR is 1.4 in 2013, declining to 1 by 2030. Therefore in social cost-benefit terms, investment in this bundle of services is considered to be marginally worthwhile.

For a National Road Authority, safety considerations may, of course, be more important than the results of the cost-benefit analysis. Also, since the ISA provides information, it is for individual drivers to decide which speed to adopt but an NRA would want to promote adherence to national speed limits.

This example demonstrates the sensitivity of the impacts to different penetration rates: both the benefits and costs are higher in Scenarios 2 than in Scenario 1, but because the differences are similar the overall BCR is the same in these two scenarios.

3.3.3 Example 3: Travel Information and Dynamic Route Guidance – effect of penetration

Reason for comparison

To verify that the monetary value of the effects changes as expected with penetration.

To see if any scenario is beneficial in social cost-benefit terms.

Description of scenarios

The scenarios considered were for the travel information and dynamic route guidance bundle delivered by cellular network communications in the UK.

The only parameter varied between the two scenarios was the penetration rate. This changed between “medium” (reaching 75% equipped vehicles in 2035) – Scenario 1 and “high” (reaching 100% equipped vehicles in 2035) – Scenario 2.

Key input parameters

The country is the UK. This parameter determines the size of the “problem” and the number of vehicles.

The communications platform is cellular network.

No in-vehicle capital costs or operational costs are included; it is assumed that drivers equip their vehicles with smartphones external to the scenario being considered and that data communication costs are already included in the owner’s service bundle.

Back-office capital and operational costs are included.

Although these cost assumptions are reasonably realistic, since dynamic route guidance is currently a paid-for service, it is probably not realistic that there are zero operating costs (but see next scenario, below).

The penetration rate increases linearly over time, reaching its maximum in 2035. A 100% penetration is not realistic but useful in illustrating the maximum effect. Even a 75% equipment rate is possibly optimistic by 2035.

Main benefits

There are relatively small benefits to safety, mostly from increased driver awareness. The most significant benefit is delivered through saving in travel time (as a result of being aware of problems and re-routing). This, consequently, generates benefits in terms of fuel consumption and emissions.

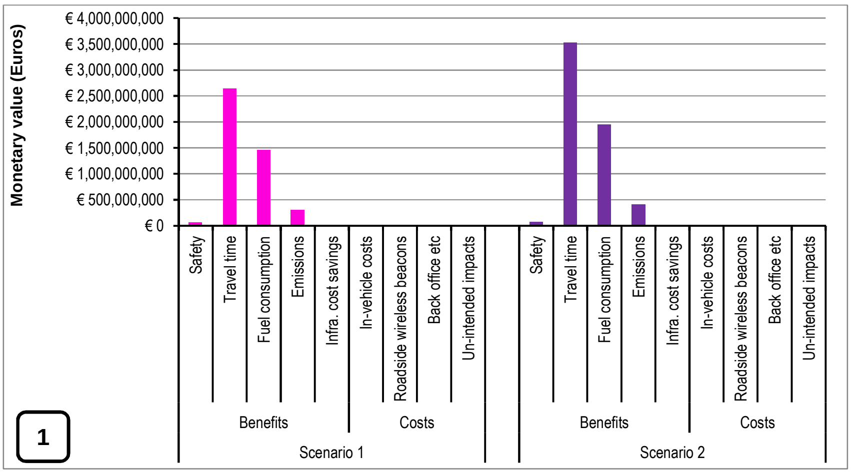


Figure 14 Travel Information and Dynamic Route Guidance – distribution of benefits and costs comparing 75% (Scenario 1) and 100% penetration (Scenario 2)

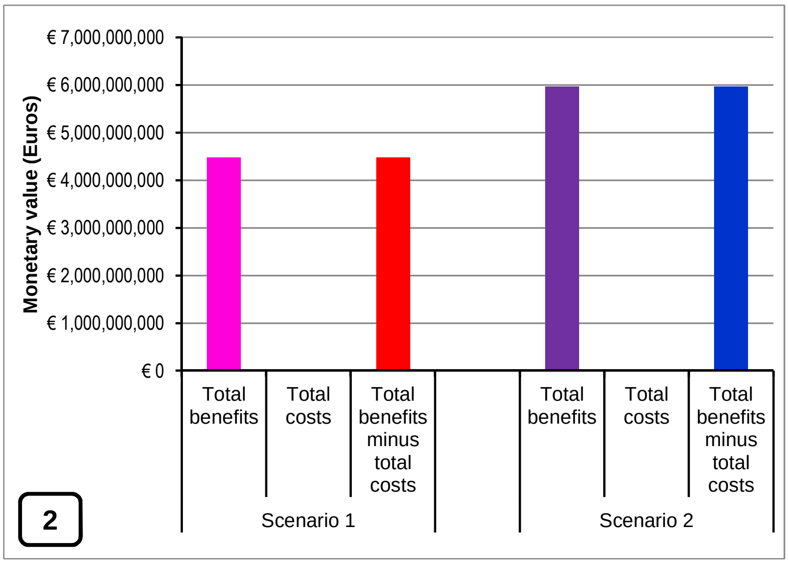


Figure 15 Travel Information and Dynamic Route Guidance – total benefits and costs comparing 75% (Scenario 1) and 100% penetration (Scenario 2)

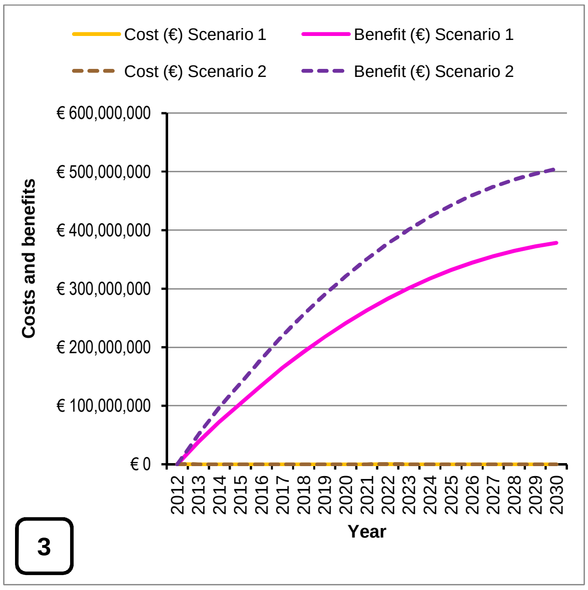
Main costs

The direct (CAPEX/OPEX) costs in this scenario relate to the back-office, and these are small compared with the benefits, so these lines are relatively close to the x-axis in both graphs 3 and 4 (Figure 14 and Figure 15).

Changes over time

The costs remain close to the x-axis (as explained above) since no in-vehicle costs are included in the analysis. The benefits in both scenarios increase over time as more vehicles are equipped and the increase is larger for the higher penetration rate, as expected.

The increase in benefits becomes slightly less steep over time. Safety benefits reduce; the cost of travel time increases and, as all benefits are discounted, all benefits reduce into the future. The combined effect is a very slight reduction in the steepness of the curve in graph 3 in Figure 16. Cumulatively, the benefits continue to grow over time (graph 4 in Figure 16) as penetration rate increases.



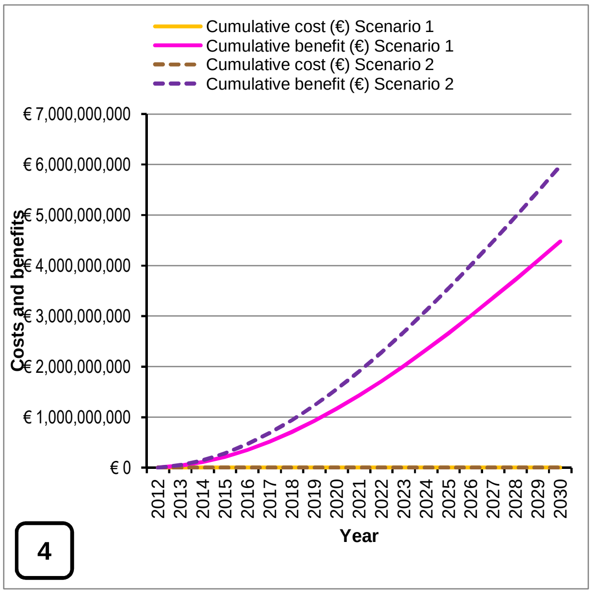


Figure 16 Travel Information and Dynamic Route Guidance – benefits and costs over time (in specific years and cumulatively to a given year) comparing 75% (Scenario 1) and 100% penetration (Scenario 2)

Benefit cost ratio

As the benefits are substantial and the costs are relatively very low, the benefit cost ratio is positive and increases over time as future benefits are included (graph 5, Figure 17).

The small "glitch" in the BCR graphs can be explained by the assumption that the back-office system and App would need to be completely renewed after 10 years. In practice this would be undertaken over time, so this feature of the graphs is not significant.

The BCR is actually unfeasibly large (around 2000 - 2500 after 10 years) which calls the underlying data and scenario assumptions into question. Nevertheless, the clear message is that if the operating costs are sufficiently modest, this scenario offers a very good social cost-benefit from an early stage of deployment.

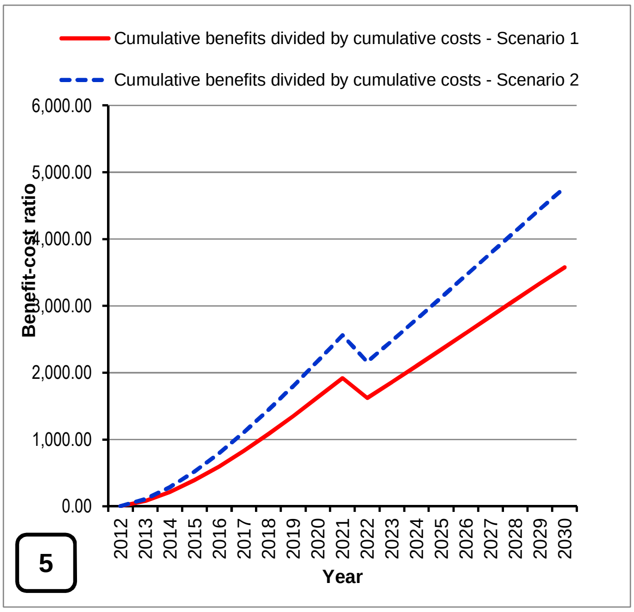


Figure 17 Travel Information and Dynamic Route Guidance – benefit cost ratio comparing 75% (Scenario 1) and 100% penetration (Scenario 2)

Conclusion

These scenarios generate significant positive social benefits, particularly in terms of travel time savings. Therefore in social cost-benefit terms, investment in this bundle could be very worthwhile.

For a National Road Authority, travel information and route guidance services are becoming a core part of road operations. There are choices about whether such services are delivered in-vehicle or on road signs and whether by the road operator or other service providers. For in-vehicle provision, we know that personal route guidance is popular and that some drivers might be prepared to pay for an in-vehicle service.

The sensitivity of the benefits to different penetration rates is demonstrated in this example, with a higher BCR in Scenario 2 than Scenario 1.

3.3.4 Example 4: Travel Information and Dynamic Route Guidance – effect of subscription costs

Reason for comparison

In the previous example, the bundle of services was assumed to be free (no CAPEX or OPEX costs to the user). However, a more realistic situation is that the user has to pay a subscription to receive the information and dynamic routing service.

Description of scenarios

The scenarios considered were for the travel information and dynamic route guidance bundle delivered by cellular network communications in the UK.

The only parameter varied between the two scenarios was the operating cost to the user. This changed between zero in Scenario 1 and €30 per year in Scenario 2 (comprising €20 subscription and €10 communications).

Key input parameters

The country is the UK. This parameter determines the size of the "problem" and the number of vehicles.

The communications platform is cellular network.

Back-office costs are included in both scenarios.

The penetration rate is set to "medium" for this comparison. It is assumed to increase linearly over time, reaching its maximum of 75% in 2035.

The dominant significant parameter is the annual operating cost.

Main benefits

The most significant benefit is delivered through savings in travel time (as a result of being aware of problems and re-routing). This, consequently, generates additional benefits in terms of fuel consumption and emissions. There are, in monetary terms, relatively small benefits to safety, mostly from increased driver awareness.

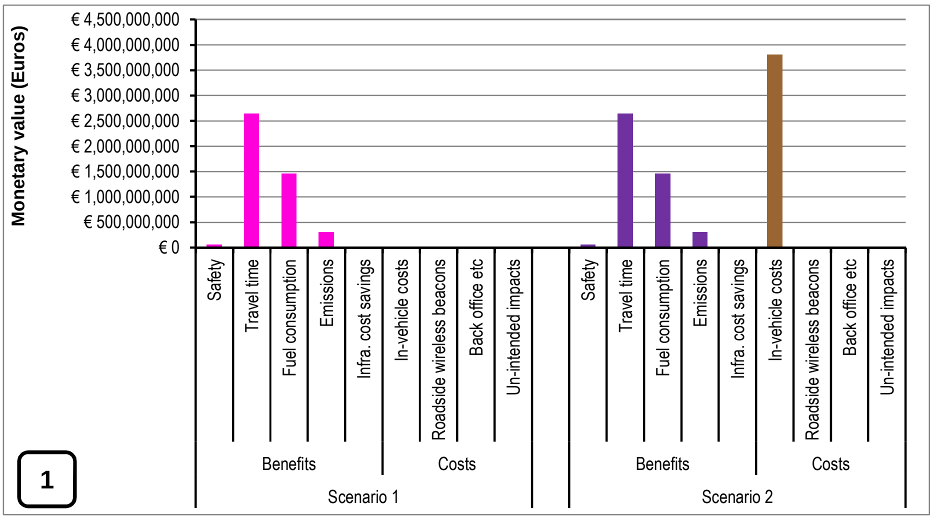


Figure 18 Travel Information and Dynamic Route Guidance – distribution of benefits and costs comparing €0 (Scenario 1) and €30 subscription costs (Scenario 2)

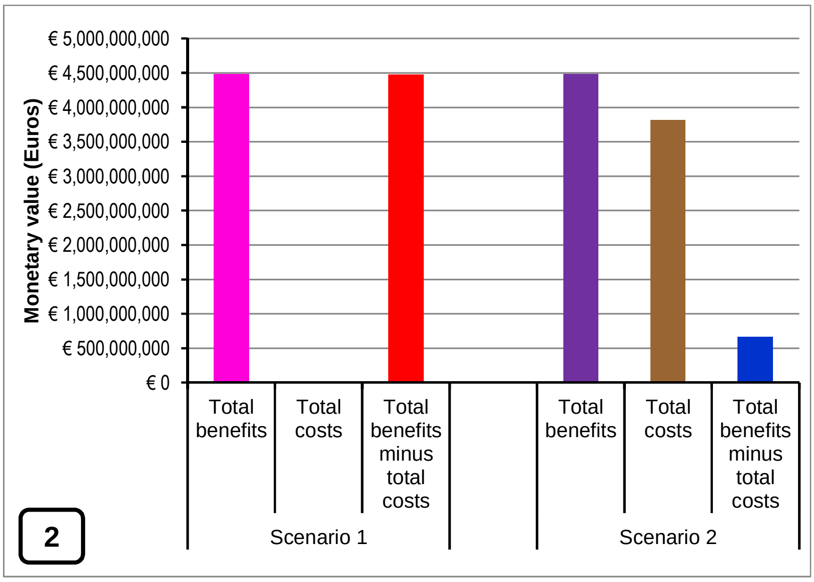


Figure 19 Travel Information and Dynamic Route Guidance – total benefits and costs comparing €0 (Scenario 1) and €30 subscription costs (Scenario 2)

Main costs

Both scenarios include back-office costs. However, on the scale of graph 3 in Figure 20 these are essentially negligible. The dominant cost is that of the subscription and communication cost in Scenario 2 as €30 is paid annually by each user.

Changes over time

The dominant (operating) cost is in Scenario 2. This increases over time as penetration rate increases but the steepness of the curve tails off due to discounting. The cumulative costs in graph 4 in Figure 20 obviously increase also with time.

The benefits from both scenarios are, obviously, the same as only the cost was changed between the scenarios. The benefits also increase over time as penetration rate increases and the curve is nearly linear (as the increasing cost of congestion is balanced by the discount rate).

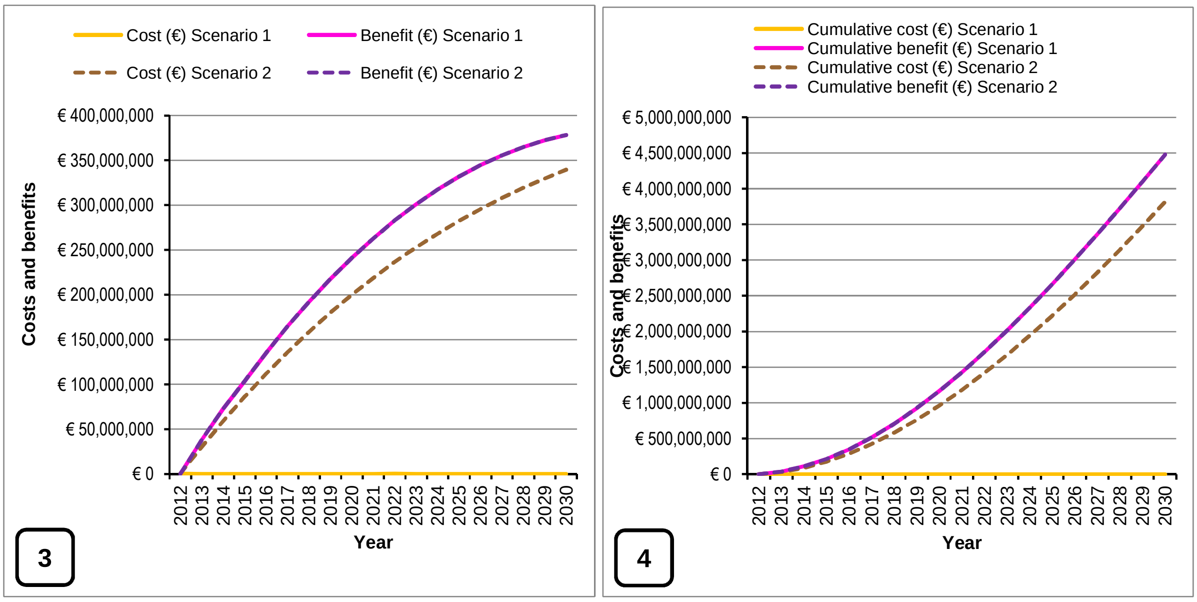


Figure 20 Travel Information and Dynamic Route Guidance – benefits and costs over time (in specific years and cumulatively to a given year) comparing €0 (Scenario 1) and €30 subscription costs (Scenario 2)

Benefit cost ratio

For Scenario 1, the benefits are substantial and the costs are relatively very low, so the benefit cost ratio is positive and increases over time as future benefits are included.

The small “glitch” in the BCR graphs can be explained by the assumption that the back-office system and App would need to be completely renewed after 10 years. In practice this would be undertaken over time, so this feature of the graphs is not significant.

The BCR for Scenario 2 looks essentially zero on graph 5 in Figure 21. It is actually around 1.2. Its value is very sensitive to the annual operating costs. This arises due to the assumption that cooperative systems provide benefits only on sections of the network which are already equipped with infrastructure to deliver these services (as shown in Figure 5).

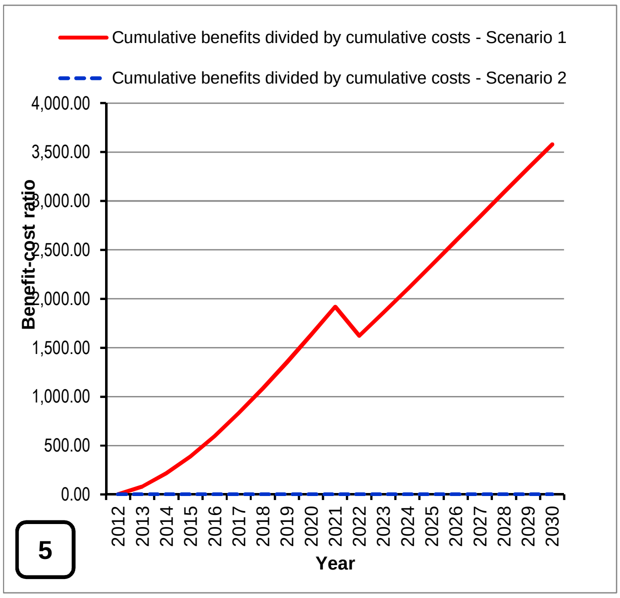


Figure 21 Travel Information and Dynamic Route Guidance – benefit cost ratio comparing €0 (Scenario 1) and €30 subscription costs (Scenario 2)

Conclusion

In social cost benefit terms, the travel information and dynamic route guidance bundle only just produces a positive return if the annual operating costs are €30.

For a National Road Authority, information and route guidance services are becoming a core part of road operations. However, there are choices about whether such services are delivered in-vehicle or on road signs and whether by the road operator or other service providers. We know that some drivers are prepared to pay for commercial routing services. Thus the choice of business model is crucial in determining how attractive this example is for National Road Authorities However, in social cost-benefit terms, it seems that there is only a positive return if the annual operating costs are less than €30.

3.3.5 Example 5: Local Dynamic Event warnings – effect of in-vehicle capital cost

Reason for comparison

To investigate the impact of allocating the costs of in-vehicle equipment to vehicle owners upon the overall benefit-cost ratio (BCR) (rather than excluding them from the analysis) as well as upon the timeline for the distribution of costs and benefits.

To investigate the impact of allocating these costs upon the payback year.

Description of scenarios

The scenarios considered were for the local dynamic event warnings using the business model in which a free road authority application is available using cellular technology (Business Model 1 in the tool).

A medium level of penetration is assumed for both the aftermarket/ smartphones and OEM markets.

The only parameter varied between the two scenarios was the cost of the in-vehicle equipment. For Scenario 1, 1/3 of the cost of the in-vehicle equipment in the aftermarket is assumed to be covered directly by the vehicle owner/ purchaser (this is considered to be equivalent to the cost to the manufacturer). For Scenario 2 none of the costs of the in-vehicle equipment are assumed to be financed by the vehicle owner/ purchaser.

Infrastructure savings are not included.

Key input parameters

The country is the UK. This parameter determines the size of the effect and the number of vehicles involved. A medium level of penetration for in-vehicle units is assumed.

The communications platform is cellular network.

For the in-vehicle units, it is assumed that 80% are ‘Smartphone’ (no equipment costs) and 20% are ‘Aftermarket’ devices (some equipment costs). So in Scenario 1, one third of the equipment cost of 20% of the devices is taken into account.

No operating costs are included; it is assumed that data communication costs are already included in the owner’s service bundle.

Back-office communication costs are included in the analysis.

Main benefits

The main benefits of this scenario are fuel consumption and safety improvements although emissions are also reduced (see graph 1, Figure 22).

Under both Scenarios 1 and 2, there are small unintended impacts registered. These arise from different studies that found different effects of components of this bundle of services. However, these are relatively small.

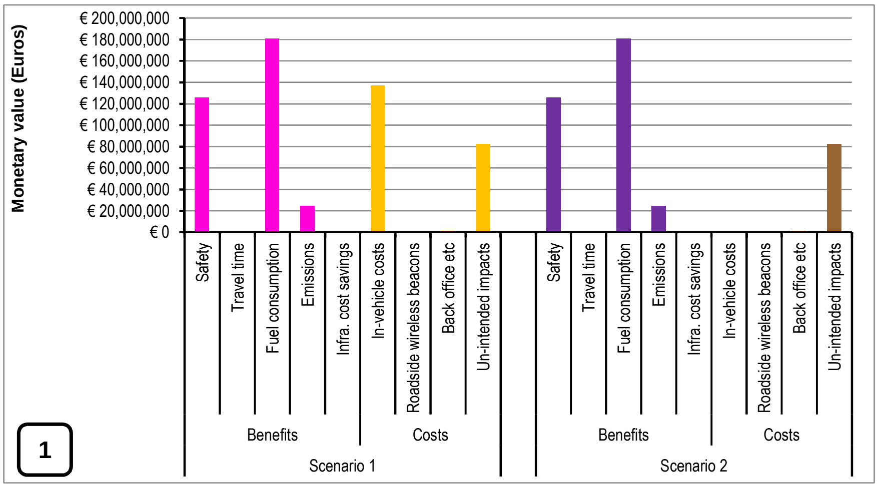


Figure 22 Local Dynamic Event Warnings – distribution of benefits and costs comparing 1/3 (Scenario 1) and zero in-vehicle capital costs (Scenario 2)

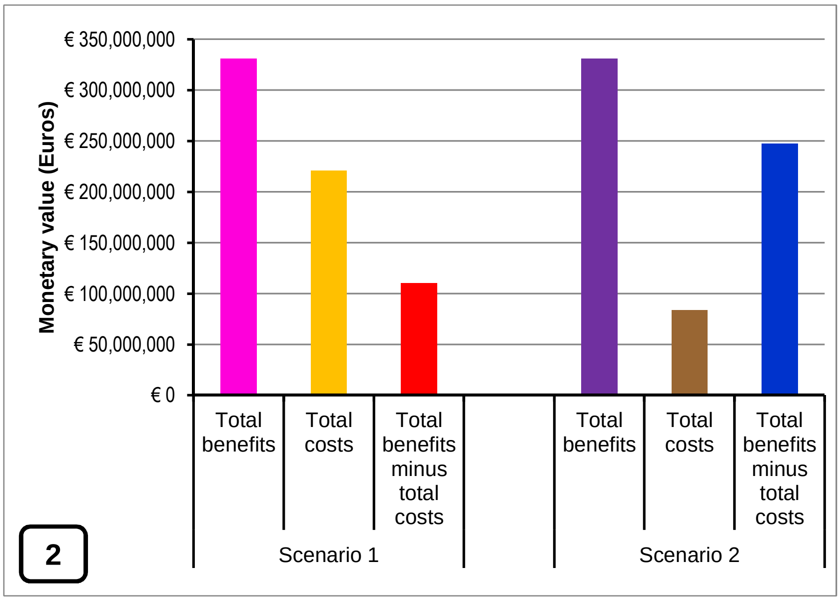


Figure 23 Local Dynamic Event Warnings – total benefits and costs comparing 1/3 (Scenario 1) and zero in-vehicle capital costs (Scenario 2)

Main costs

Under Scenario 1 costs are overwhelmingly dominated by the costs of in–vehicle units. At a modest €100 cost for an after-market unit with over 30million vehicles on the highways this cost will inevitably be large, even if vehicle owners/ purchasers only pay 1/3 of the cost (see graph 1, Figure 22).

Changes over time

Under Scenario 1 the cost graph (graph 3 in Figure 24) shows two steps. These are due to the costs of aftermarket in-vehicle units purchased from 2012 onwards which are replaced ten years later when their lifetime is assumed to have expired. Also, after ten years the capital investment in the back office facilities is replaced. In practice these costs will occur over time and so this step is not really a significant feature of the scenario.

Since Scenario 2 excludes in-vehicle costs its cost profile is much lower (under €8 million in 2030 compared to over €16 million). The slight increase and reduction in the years 2022-2023 is due to the replacement of existing equipment.

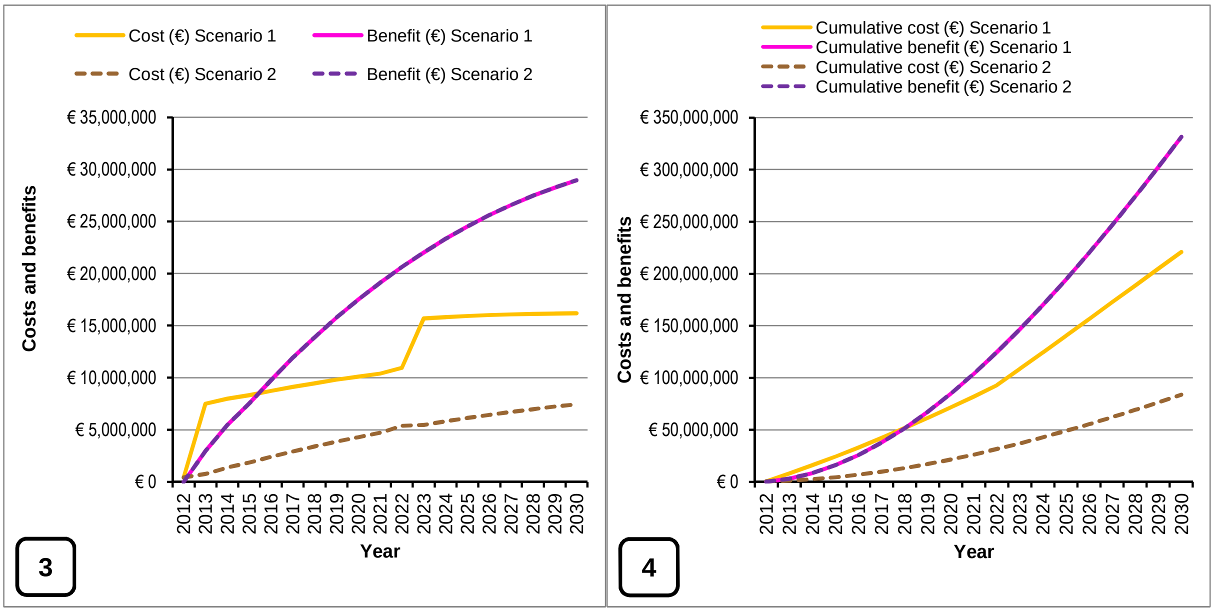


Figure 24 Local Dynamic Event Warnings –benefits and costs over time (in specific years and cumulatively to a given year) comparing 1/3 (Scenario 1) and zero in-vehicle capital costs (Scenario 2)

Benefit cost ratio

Graph 2 (Figure 23) demonstrates that Scenario 2 has very high net benefits when compared to Scenario 1 (€250 million compared to around €110 million). As a result the BCR for Scenario 2 is higher as well; almost 4:1 by 2022, compared to reaching 1.5:1 in 2030 under Scenario 1 (see graph 5, Figure 25).

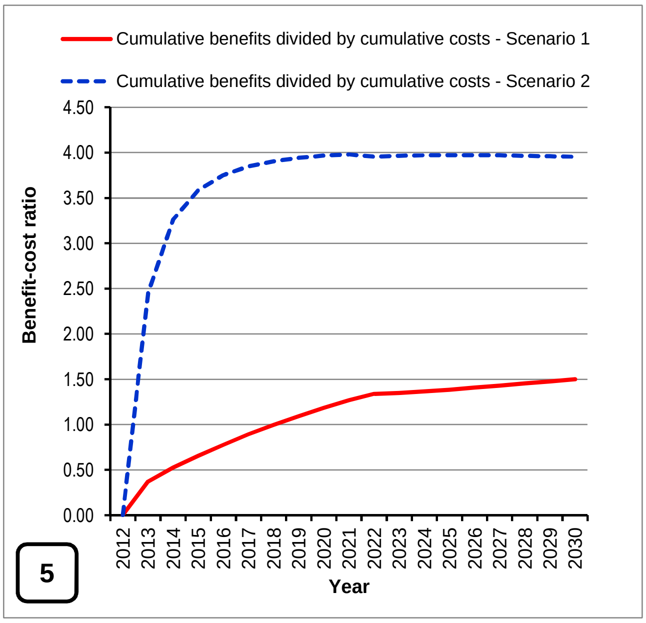


Figure 25 Local Dynamic Event Warnings –benefit cost ratio comparing 1/3 (Scenario 1) and zero in-vehicle capital costs (Scenario 2)

Payback year

Whereas the payback year for Scenario 2 is very quick – benefits exceed costs in the first year (2013) – the payback year for Scenario 1 does not occur until 2019 due to the much higher costs involved.

Business case

Looking at only the costs to the NRA and potential savings for the NRA, it can be seen that the cost of back-office facilities falls to the NRA but that there are no cost savings in this scenario. Therefore, the the cost profile always exceeds the benefits to the NRA.

Conclusion

On the basis of the social cost-benefit outputs for this bundle (local dynamic event warnings using a free road authority application with cellular technology) and these scenarios, the results are very dependent on the in-vehicle capital cost (the in-vehicle operating costs are zero in these scenarios). From an overall social perspective, the BCR for Scenario 2 is relatively high (up to 4:1) whereas that for Scenario 1 is only 1.5:1 by 2030. Clearly the main caveat is that the costs of in-vehicle units are excluded from the analysis under Scenario 2. However, this situation may arise if vehicle manufacturers bundle such costs into the overall cost of a new vehicle or if pre-purchased hardware (such as a smartphone) is re-used, so that the end user does not see any additional cost.

From the perspective of a NRA, there are costs associated with the back office but there are no direct cost savings.

3.3.6 Example 6: Comparison of cellular and beacon communications

Reason for comparison

To compare the costs and benefits using cellular technology and roadside wireless beacons taking the example bundle of in-vehicle speed and signage.

Description of scenarios

The scenarios considered were for the in-vehicle speed and signage bundle delivered by cellular networks and wireless technology. Two scenarios are compared:

- Scenario 1 is based on Business Model 1 – free app with cellular technology; and
- Scenario 2 uses Business Model 5 – public road-side wireless beacons on 2% of the network.

Key input parameters

The country is the UK. This parameter determines the size of the issue and the number of vehicles involved. A medium level of penetration for in-vehicle units is assumed (which is slower and lower for wireless beacons than cellular communications – as illustrated in Section 2 of the User Guide [4] and on the instructions worksheet in the tool). It is also assumed that the driver pays 1/3 of the cost of the in-vehicle unit.

Back office costs are included in both scenarios and it is assumed that back-office communication costs are part of on-going operations.

The key difference between scenarios is the communications platform: cellular networks or roadside wireless beacons. This means that the form of ISA is 'Advisory' (i.e. informative or information-only) for cellular and 'Voluntary' (i.e. haptic feedback on the throttle which the driver can over-ride) for wireless beacons. No operating costs fall to the users in these scenarios so it is assumed that data communication costs are already included in the owner's cellular service bundle and there are no communication charges for beacon communications.

Main benefits

The main benefits in both scenarios are from reductions in fuel consumption and emissions. There are also safety benefits partly from increased general driver awareness of incidents and, particularly, from greater speed limit observance resulting from ISA. The speed reduction generates benefits in terms of fuel consumption and emissions and these factors are substantial on high-speed roads. The benefits in Scenario 1 are much greater because Scenario 2 involves OEM fitment (and this is at a slower and a lower rate than Scenario 1) and also beacon deployment so that the benefit of ISA occurs only at the beacons.

A dis-benefit in both scenarios arises from the unintended impacts, which is the additional time spent travelling as result of compliance with speed limits etc. As discussed in Section 3.3.2, these unintended impacts outweigh any other benefits, even before other costs are considered. Note that the value of the unintended impacts is greater in the case of the cellular scenario than the wireless beacons; again this is due to the slower and lower rate of beacon deployment compared with the cellular scenario.

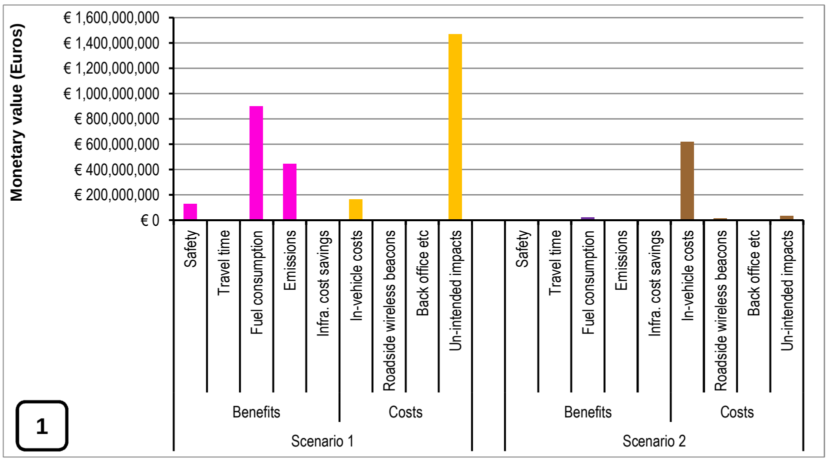


Figure 26 In-vehicle Speed and Signage – distribution of benefits and costs comparing cellular (Scenario 1) and beacon communications (Scenario 2)

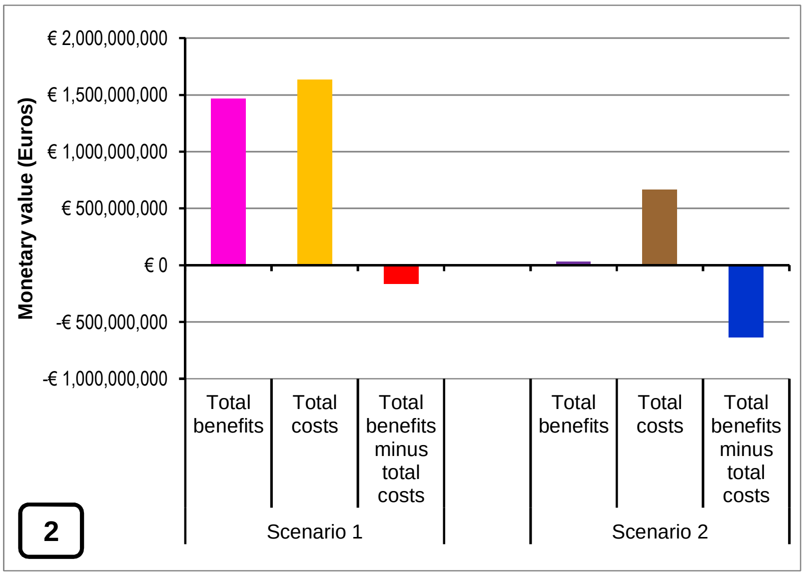


Figure 27 In-vehicle Speed and Signage – total benefits and costs comparing cellular (Scenario 1) and beacon communications (Scenario 2)

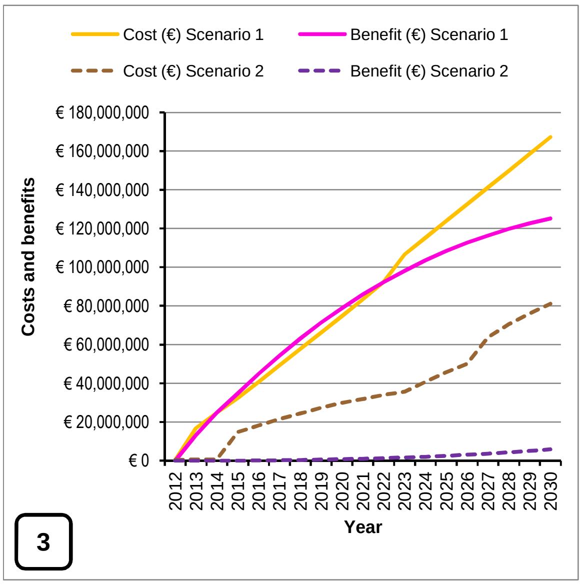
Main costs

Costs in both scenarios are overwhelmingly dominated by a mixture of the costs of the unintended impact of increased travel time and the in–vehicle units. The cost of the in-vehicle units is higher in the wireless beacons scenario than in the cellular networks scenario, because there is a higher in-vehicle cost due to the integration with the accelerator pedal. At a modest cost for an after-market unit with the number of vehicles to be equipped, this cost element will inevitably be large due to the number of vehicles, even if vehicle owners/ purchasers only pay 1/3 of the cost (see graph 1 in Figure 26).

Changes over time

The cost curve for Scenario 1 has two small step changes due to the costs of back office facilities; the initial set up costs in 2012 and replacement costs in 2022, which increase the costs of aftermarket vehicle unit equipment. Under Scenario 2 the OEM vehicle unit costs start in 2015 (there being no aftermarket costs) while the costs of wireless beacons (the communications platform) start in 2013 and rise thereafter.

Scenario 1 benefits increase over time as more vehicles become equipped. The benefits also increase in Scenario 2 but begin later (as it takes more time to install beacons) and are less pronounced.



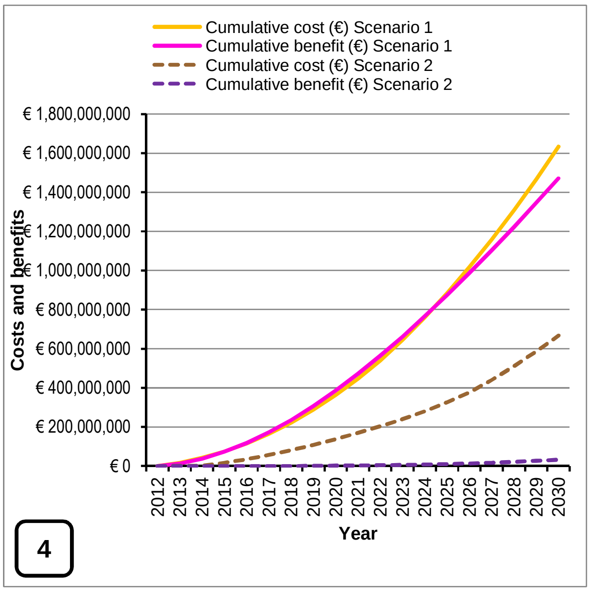


Figure 28 In-vehicle Speed and Signage – benefits and costs over time (in specific years and cumulatively to a given year) comparing cellular (Scenario 1) and beacon communications (Scenario 2)

Benefit cost ratio

The BCR for both scenarios is low. For Scenario 1 the BCR just exceeds 1:1 between 2016 and 2024 while for Scenario 2 the BCR is approximately zero until 2019 and but then it gradually rises, although it does not exceed 1:1 before 2030.

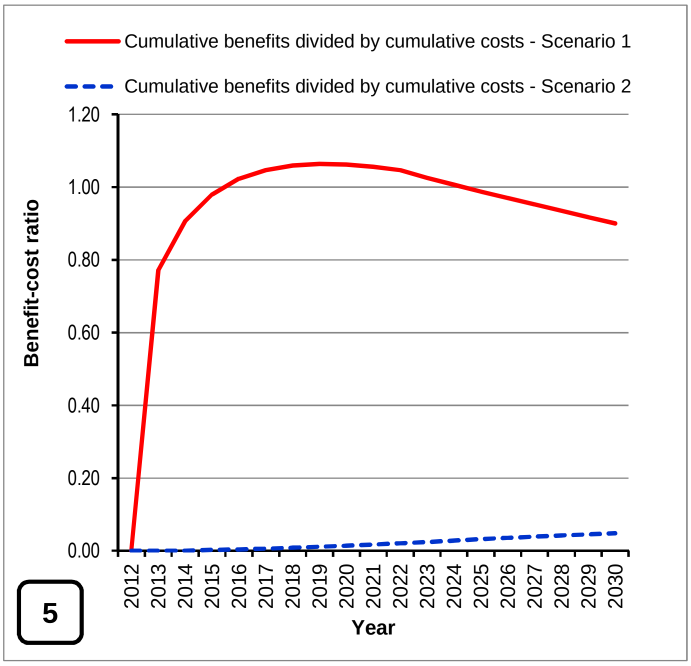


Figure 29 In-vehicle Speed and Signage – benefit costs ratio comparing cellular (Scenario 1) and beacon communications (Scenario 2)

Payback year

Under Scenario 1 the social benefits exceed the costs by 2016 but under Scenario 2 the investment does not generate sufficient social benefits to cover the social costs before 2030.

Business case

For both scenarios the back office costs are the same and fall to the NRA. There are no savings to the NRA in either scenario.

Due to the high cost of the roadside wireless beacons in Scenario 2 (beacons and Business Model 5) the business case for this scenario is even worse than Scenario 1 (cellular and Business Model 1).

Conclusion

Both communication platforms generate social benefits in terms of road safety with reduced fuel consumption and emissions. However, in social benefit-cost terms the dis-benefit of increased travel time more than outweighs the benefits so the BCR only exceeds 1:1 by a small margin for a few years in the cellular communications scenario. Therefore in social cost-benefit terms, investment in this bundle of services is not considered worthwhile.

For a National Road Authority, safety considerations may, of course, be more important than the results of the cost-benefit analysis. Also, since the ISA provides information, it is for individual drivers to decide which speed to adopt but a NRA would want to promote adherence to national speed limits.

Since under both scenarios the costs are substantial and exceed the monetised benefits the BCR is not sufficient under the wireless beacons scenario and is only marginally above 1:1 in the cellular scenario; however, for a NRA wishing to implement this service, the cellular platform provides a substantially more cost-effective route.

3.3.7 Example 7: Comparison of business model for road authority

Reason for comparison

To consider the business case for the NRA for investing in In-vehicle Speed and Signage using wireless beacons and in particular the effect of the NRA or a private provider being responsible for the in-vehicle “app” software.

Description of scenarios

Two business models are compared:

- Business Model 5 involving public road-side wireless beacons (Scenario 1); and
- Business Model 6 involving a public-private service with road-side wireless beacons provided by the NRA but with apps provided by the private sector (Scenario 2).

Key input parameters

The country is the UK. This parameter determines the size of the issue and the number of vehicles involved.

The communications platform is roadside wireless beacons. This means that the form of ISA is ‘Voluntary (i.e. haptic feedback on the throttle which the driver can over-ride). A medium level of penetration for in-vehicle units is assumed in both scenarios and, as in the scenario above, the deployment of roadside beacons is 2.5% in both scenarios.

Main benefits and costs

These are all as described in the scenario above for the Business Model 5 business case. The section below highlights the business case aspects, and therefore shows graphs 6, 7, 8 and 9 which have not been presented in the previous example results.

Business case

If the private sector provides the in-vehicle app rather than the NRA providing it, the costs to the NRA reduce slightly (both initial cost and maintenance, listed under “Back office etc” in Figure 30). However, as noted above, due to the high cost of the roadside wireless beacons in both scenarios there is no business case for NRA investment.

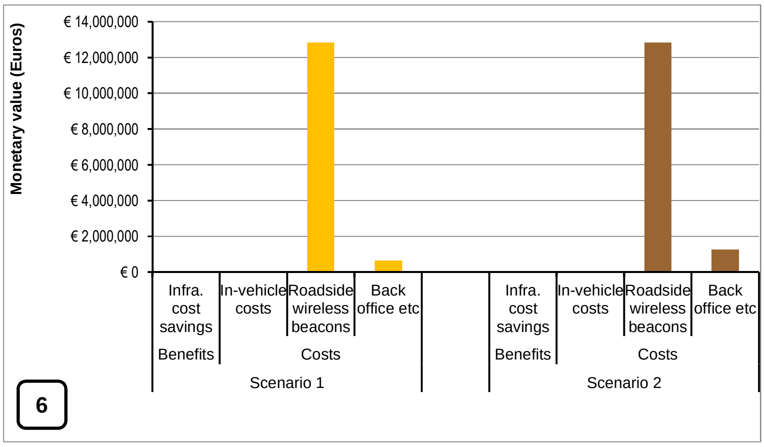


Figure 30 In-vehicle Speed and Signage – distribution of benefits and costs for road authority comparing public roadside beacons (Scenario 1) and service with public beacons and private service (Scenario 2)

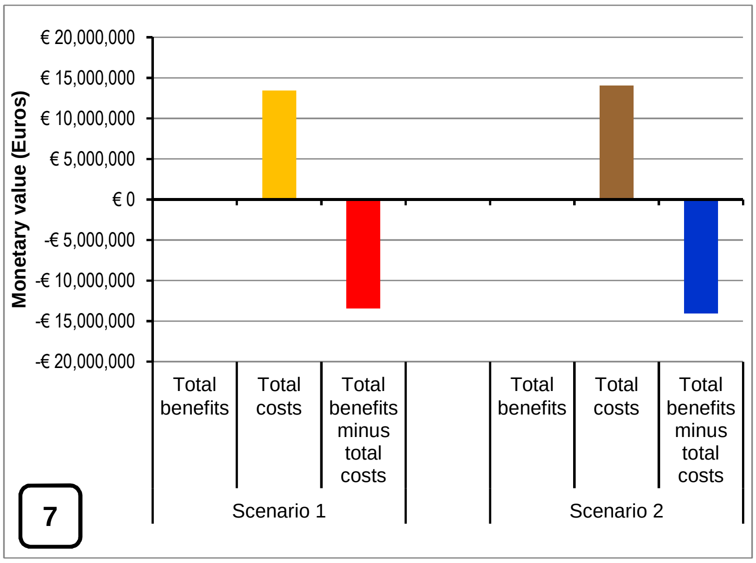
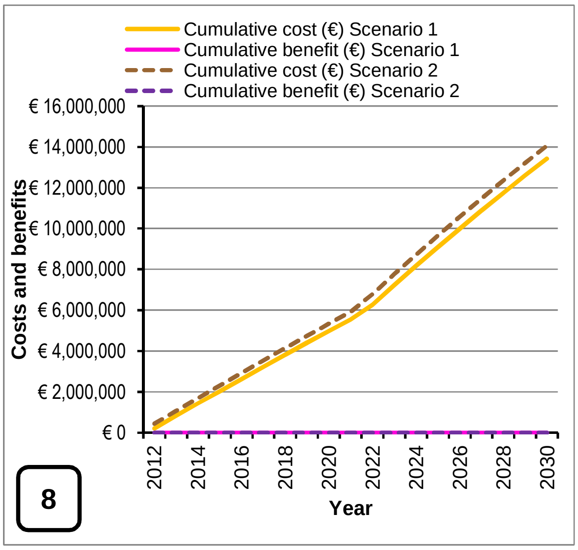


Figure 31 In-vehicle Speed and Signage – total benefits and costs for road authority comparing public roadside beacons and service with public beacons and private service



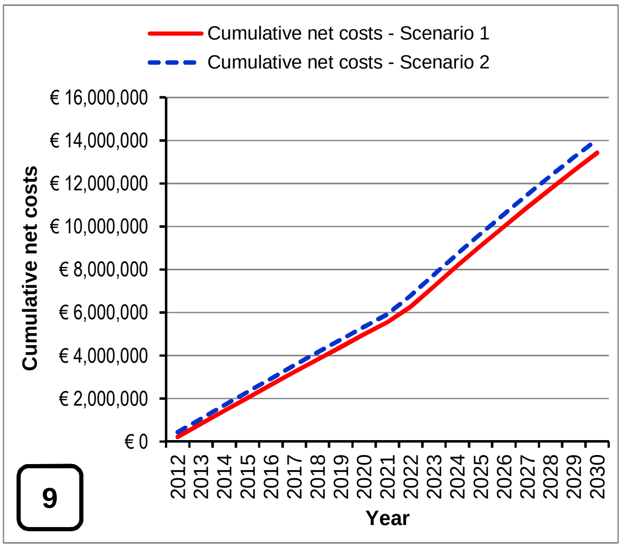


Figure 32 In-vehicle Speed and Signage – benefits and costs for road authority over time (in specific years and cumulatively to a given year) comparing public roadside beacons (Scenario 1) and service with public beacons and private service (Scenario 2)

Conclusion

Since under both scenarios the costs are substantial and the monetised benefits negligible the BCR is not sufficient under either scenario for this investment in beacons to be recommended to the NRA.

3.3.8 Example 8: Comparison between the UK and the Netherlands

Reason for comparison

To explore differences between data for the two example countries.

Description of scenarios

The scenarios considered are for the Local Dynamic Event Warnings bundle delivered by cellular network communications in the UK (Scenario 1) and The Netherlands (Scenario 2).

Key input parameters

The key parameter difference between the two scenarios is the country. This parameter determines the size of the "problem" and the number of vehicles.

The communications platform is cellular networks.

A medium penetration of 75% by 2035 is taken in these scenarios with 1/3 of the nominal in-vehicle hardware price being funded by the drivers. Back-office costs are included.

No operating costs for the vehicle unit are included; it is assumed that data communication costs are already included in the owner's service bundle; back-office communication costs are part of on-going operations. Both of these cost assumptions are reasonably realistic.

Main benefits

As in the first example described above, the main benefits in both countries are in fuel consumption. In the UK safety is also significant, arising from increased driver awareness. The relative societal problem costs are different between the two countries (see Figure 3 and Figure 4), which explains why the UK results are of a larger scale than those for the Netherlands.

In the UK and the Netherlands there are some unintended impacts registered from increases in CO_2. These arise from different studies in the Impact Assessment that found different effects of components of this bundle of services.

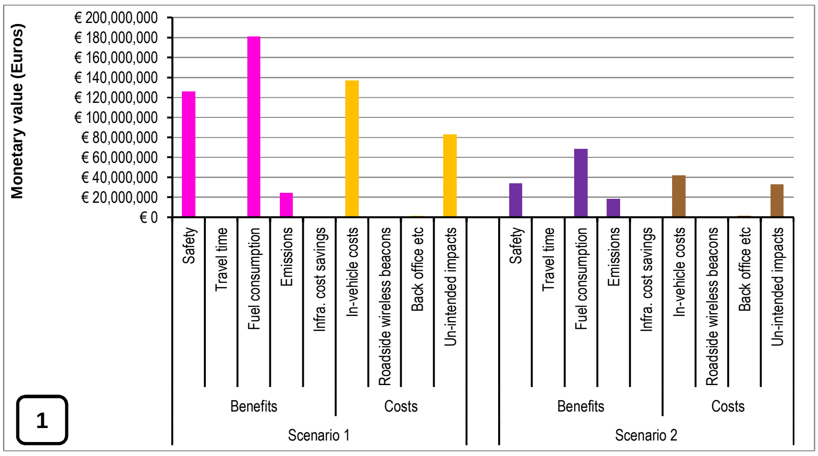


Figure 33 Local Dynamic Event Warnings – distribution of benefits and costs comparing the UK (Scenario 1) and The Netherlands (Scenario 2)

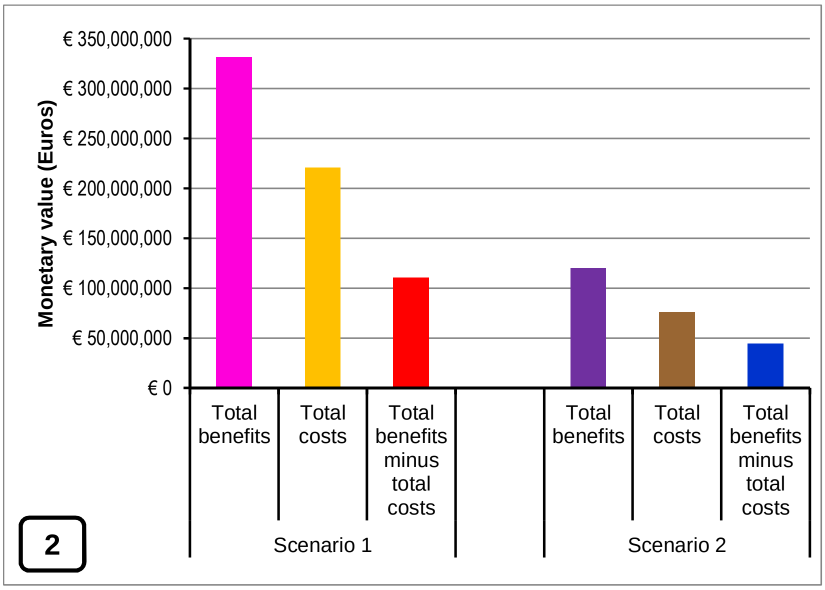


Figure 34 Local Dynamic Event Warnings – total benefits and costs comparing the UK (Scenario 1) and The Netherlands (Scenario 2)

Main costs

The main costs relate to the in-vehicle units (paid by drivers). There are also back office costs (paid by the NRA).

Changes over time

The costs in both countries increase over time as more vehicles are equipped. Under both scenarios the cost graph (graph 3 in Figure 35) shows two steps. These are due to the costs of the provision of back-office facilities and for the replacement of the aftermarket in-vehicle units, both of which have a 10-year lifetime.

The benefits in both scenarios increase over time as more vehicles are equipped. The increase in benefits becomes less steep over time. This is because the safety benefit reduces as vehicles and roads become generally safer over time (hence the contribution of this bundle acts on a smaller problem size). Furthermore, as all benefits are discounted, all benefits reduce into the future. The combined effect is a reduction in the steepness of the curve in graph 3 in Figure 35. Cumulatively, the benefits continue to grow over time (graph 4 in Figure 35) as penetration rate increases.

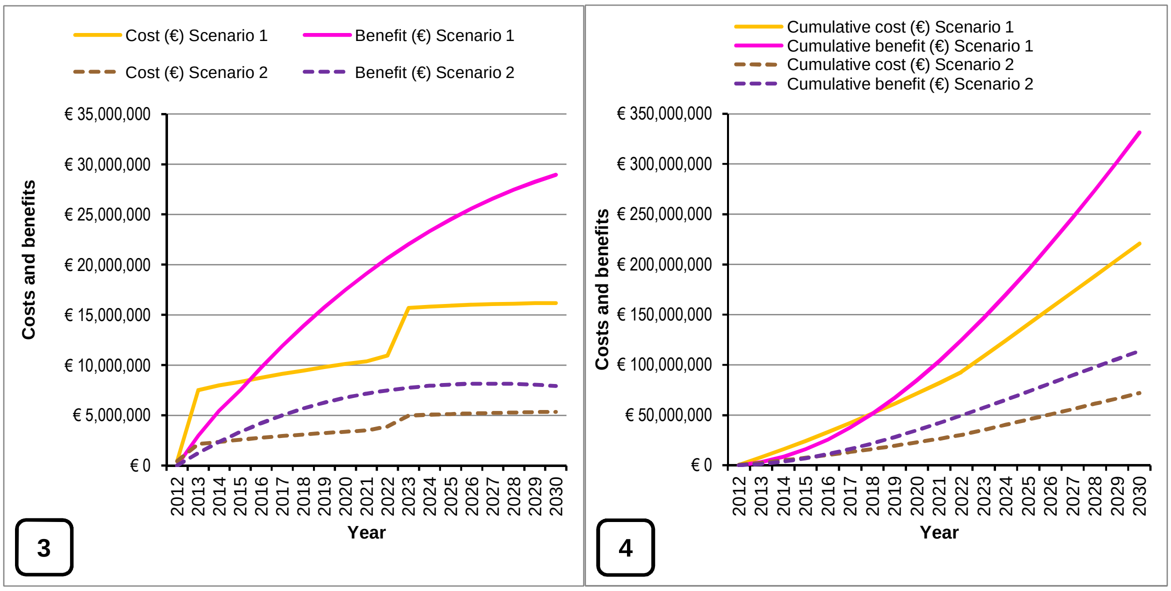


Figure 35 Local Dynamic Event Warnings – benefits and costs over time (in specific years and cumulatively to a given year) comparing the UK (Scenario 1) and The Netherlands (Scenario 2)

Benefit cost ratio

As the benefits and costs are broadly similar, the benefit cost ratio, although starting small, increases over time as future benefits are added in. The small “glitch” in the BCR graphs around 2022 can be explained by the 10-year lifetime of the back-office system, App and in-vehicle units. In practice these renewals would be undertaken over time, so this feature of the graphs is not significant. After about 2021 in both countries, the BCR begins to drop as the impact of the bundle lessens, as explained above.

The BCR in the Netherlands is marginally higher than that in the UK in these scenarios.

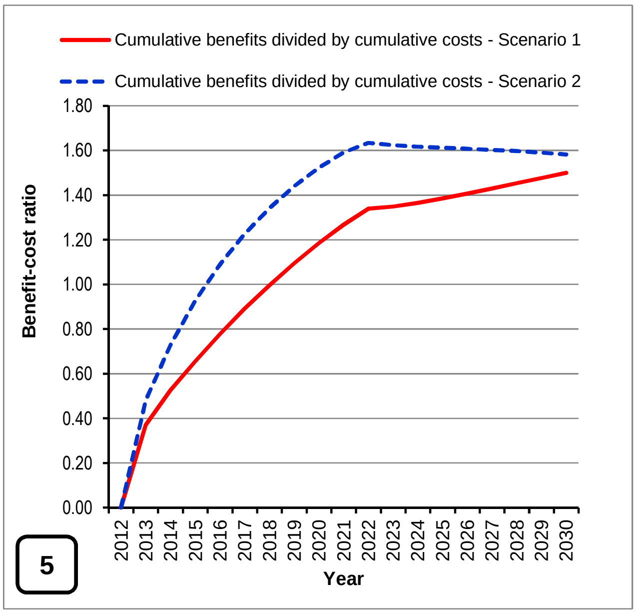


Figure 36 Local Dynamic Event Warnings –benefit cost ratio comparing the UK (Scenario 1) and The Netherlands (Scenario 2)

Conclusion

These scenarios generate positive social benefits, particularly in terms of fuel consumption. Therefore in social cost-benefit terms, investment in this bundle could be worthwhile, although some road authorities would not consider investing in schemes with a BCR less than 1.6.

For a National Road Authority, dynamic information provision is becoming a core part of road operations. There are choices about whether such services are delivered in-vehicle or on road signs and whether by the road operator or other service providers.

Clearly the results are different in different countries because of the size of the problem and the number of vehicles involved. The UK has about 4.25 times as many vehicles and about 6 times the safety problem of the Netherlands..

4 Summary of expected impacts of each bundle

4.1 Introduction

The previous chapter detailed and explained the results from the tool with specific examples of scenarios of cooperative systems to deliver services in three ‘bundles’ of functions:

1. Local Dynamic Event Warnings: hazardous location notification, road works warning, traffic jam ahead warning and post-crash warning (eCall)
2. In-vehicle Speed and Signage: in-vehicle signs, dynamic speed limits and Intelligent Speed Adaptation
3. Travel Information and Dynamic Route Guidance: traffic information and recommended itinerary, multi-modal travel information and truck parking information and guidance.

This chapter summarises the expected impacts of each bundle and identifies the most promising business cases.

4.2 Local Dynamic Event Warnings

The bundle of cooperative services called “Local Dynamic Event Warnings” (hazardous location notification, road works warning, traffic jam ahead warning and post-crash warning) generate positive social benefits, particularly in terms of fuel consumption and safety.

If the services are delivered through cellular network communications to smartphone apps, such that there are no additional in-vehicle costs, and communication costs are negligible, then the benefit cost ratio is positive and increases over time. If the service is delivered through beacons, then the costs greatly exceed the benefits, due to the investment in the roadside beacons.

If the operating costs are sufficiently modest, this scenario offers a very good social cost-benefit from an early stage of deployment and investment in this bundle could be very worthwhile; however it is important to bear in mind that it was assumed that there would be no additional costs for equipping further sections of the network with fixed sensors and in practice such investment might be needed. The benefit of this bundle is higher in the UK than the Netherlands because of the larger problem size relative to the number of vehicles between the two countries.

For a National Road Authority, dynamic information provision is becoming a core part of road operations. There are choices about whether such services are delivered in-vehicle or on road signs and whether by the road operator or other service providers. It is likely that the back office requirements to deliver the information would be similar for all delivery channels. However, there would be a relatively small additional cost of supporting an in-vehicle app in order to deliver the service through cellular networks and smartphones. This cost could be absorbed by the NRA or could be part of a public-private delivery with the app supported by a private provider.

4.3 In-vehicle Speed and Signage

The bundle of cooperative services called "In-vehicle Speed and Signage" (in-vehicle signage, dynamic speed limits and Intelligent Speed Adaptation) achieves a benefit-cost ratio slightly higher than 1 in the the examples considered where it is delivered via cellular networks. Although the bundle generates social benefits in terms of road safety with reduced fuel consumption and emissions, in monetary terms the dis-benefit of increased travel time as drivers exceeding the limit reduce their speed is almost as great as these benefits. This is because in monetary terms, the number of drivers reducing their speed as they comply with the speed limit weighted by the value of their time, produces a monetary value similar to the monetary value of accidents avoided because although accidents have a high monetary value compared with time, the incidence of accidents is low compared with the incidence of speeding. Therefore in social cost-benefit terms, investment in this bundle of services is considered marginally worthwhile.

For a National Road Authority, safety considerations may, of course, be more important than cost-benefit analysis. Also, since the ISA provides information, it is for individual drivers to decide which speed to adopt but a NRA would want to promote adherence to national speed limits.

As with the Local Dynamic Event Warnings bundle, provision of an app as a private service would slightly reduce a NRA's costs of supporting this bundle.

4.4 Travel Information and Dynamic Route Guidance

The bundle of cooperative services called "Travel Information and Dynamic Route Guidance" (traffic information and recommended itinerary, multi-modal travel information and truck parking information and guidance) is already available in some countries as a commercial service.

The bundle generates relatively small benefits to safety, mostly from increased driver awareness. The most significant benefit is delivered through saving in travel time (as a result of being aware of problems and re-routing). This, consequently, generates additional benefits in terms of fuel consumption and emissions.

In social benefit cost terms, the bundle becomes beneficial when the operating costs are about 30 Euro in-vehicle costs per year. Many drivers are prepared to pay for this service commercially at this level of subscription.

It is not appropriate to consider delivering this service using wireless beacons, because the information does not require low latency at a local level.

For a National Road Authority, information and route guidance services are becoming a core part of road operations. However, there are choices about whether such services are delivered in-vehicle or on road signs and whether by the road operator or other service providers. We know that some drivers are prepared to pay for commercial routing services.

4.5 Using the tool to inform investment decisions

The remarks above summarise the findings from analysing a very limited set of situations. These examples were developed to demonstrate the working and flexibility of the tool and should be regarded only as a starting point for examining the impact of cooperative services.

For reasons of expediency, and as explained in previous project deliverable D2, it is necessary to group cooperative services into deployment bundles and in this project we have considered three bundles of services. An actual implementation scenario under consideration may not contain an exact match with the bundles developed here.

For the bundles considered here, the impacts are calculated based on previous research and trials. As cooperative services are relatively new, it is not surprising that measurements of impacts are "patchy"; we know that results are absent in many areas and that some findings are incompatible with others. There is also the issue of overlap between services within a bundle, such that it is not possible to simply treat their effects as additive. Deliverable D3 explains how this has been dealt with, but it should be appreciated that the underlying research is far from complete and impacts need to be treated with caution.

The calculation of impacts relies on data points in the future (for, e.g. the size of congestion and safety problems, the monetary valuation of the problems, the cost of hardware, the number of vehicles). These are, of necessity, projections/estimates based on the best information available at the moment; nevertheless, these also have to be treated with caution.

The scenarios examined in these examples are based on a number of user-selected parameters such as penetration/deployment rates. As with the data, there is no certainty that the value of the parameter selected is realistic and default parameters (or the range offered) should not be assumed to be the most likely. For example, in the "medium" penetration scenario (taken in several of the situations examined above) the equipment rate increases linearly such that 75% of all vehicles are equipped to take advantage of the cooperative bundle by 2035, and it thereafter remains at 75%. Of course, the actual update by year is unknown and could be manipulated by legislative intervention, for example to speed uptake, which could greatly affect the impacts.

All the parameters can be adjusted and the data sheets can also be modified if better information becomes available or to investigate the sensitivity of the outcomes in terms of social benefits and costs to particular assumptions.

An assessment of the relative benefits and costs is just one part of an investment decision. Factors such as policy priorities, distributional effects, political will and synergy with other initiatives are also important influences on investment decisions (and are often more influential than the benefit cost analysis). Such factors are not included in this tool and road authorities will need to weigh up these non-monetised factors alongside the estimated benefits and costs, when making investment decisions.

Budgets also play a key role in decision making; the tool enables road authorities to examine the business case as well as assessing the societal benefits and costs. One of the key benefits of cellular delivery of cooperative services rather than via beacons is that the cost of implementation is much lower (even if not all of the potential benefits can be realised).

Investment decisions also need to consider business models. This tool provides an initial step in business modelling by identifying which costs are supported by a NRA under different models. It also allows a first exploration of potential cost savings. These cost savings could arise, for example, if other forms of information dissemination are withdrawn or simplified, concurrent with cooperative service deployment. However, much more work needs to be done to characterise the policy decisions involved in infrastructure provision so, results from use of the tool should be viewed as a starting point for policy decisions (e.g. about provision of VMS) rather than providing definitive policy directions.

Business models that are attractive to a NRA provide insight into the circumstances under which investment decisions can be made on a financial basis. Cooperative system deployment requires *Cooperation*. The other actors needed in provision of the cooperative service also need to examine their own business models. Only on the basis of a win-win situation among all the actors can the commitment to invest be made by the necessary actors. In short, a positive business model for NRAs is one important step in the deployment of cooperative systems.

5 Conclusions

5.1 The COBRA tool

The objective of the COBRA benefit cost analysis tool was to translate information on the expected impacts of cooperative systems into monetary terms. This is intended to enable authorities to estimate the scale of benefits and costs arising from a decision to invest in cooperative systems, and if the benefits exceed the costs, whether the benefit cost ratio is sufficiently large for investment to be considered further. This report has demonstrated how the tool can be used by National Road Authorities by means of specific examples of situations in which three bundles of cooperative systems are deployed, with different levels of involvement by the road authority.

1. The work here has verified the operation of the tool. As far as can be determined from the limited testing undertaken, the results do follow, as expected from the assumptions and data.

2. The tool is easy to use. It is very flexible and (hence) must be used with care.

3. The tool outputs depend on the data on costs and benefits. There are gaps in knowledge (as might be expected for this emerging technology); nevertheless the tool can be refined as further knowledge becomes available.

4. The tool can be used to identify potentially beneficial scenarios and explore the sensitivity of benefits to different parameters.

5. The business case analysis can be used to look at which costs might fall to National Road Authorities and can support development of business models.

5.2 Benefits and costs of cooperative systems

The limited amount of analysis summarised in this report was carried out in order to demonstrate the tool, and was not intended to provide a comprehensive assessment of the benefits and costs of cooperative systems. In addition, it is not possible to be definitive about the benefits and costs of cooperative systems. However some overall remarks can be made as follows.

For the bundles of services investigated, the business case in roadside infrastructure for cooperative systems on motorways (i.e. wireless beacons) is weak, but there may be other services (such as safety services) where the case is stronger.

There does however appear to be a case for NRAs to become involved in delivering services based on smartphones if the issues with driver distraction are overcome (e.g. if the app is used by a passenger, not the driver), particularly if third parties bear the cost of developing the apps.

The bundle of cooperative services called “Local Dynamic Event Warnings” (hazardous location notification, road works warning, traffic jam ahead warning and post-crash warning) generate positive social benefits. If the operating costs are sufficiently modest, this scenario offers a very good social cost-benefit from an early stage of deployment and investment in this bundle could be very worthwhile.

The bundle of cooperative services called “In-vehicle Speed and Signage” (in-vehicle signage, dynamic speed limits and Intelligent Speed Adaptation) generates social benefits in terms of reduced fuel consumption and emissions and improved safety, in monetary terms the benefits marginally outweigh the costs where the service is delivered via cellular networks. Therefore in social cost-benefit terms, investment in this bundle of services is considered marginally worthwhile.

The bundle of cooperative services called “Travel Information and Dynamic Route Guidance” (traffic information and recommended itinerary, multi-modal travel information and truck parking information and guidance) becomes beneficial in social cost benefit terms when the operating costs are less than about 30 Euros per year. Nevertheless, the most significant benefit is delivered through saving in travel time and many drivers are prepared to pay for this as a commercial service.

Although the COBRA tool is useful in exploring the benefits and costs of specific bundles of cooperative services and in beginning work on business models for deployment, it should be appreciated that it is built on best available but incomplete results and contains many simplifications and approximations both in terms of data and the relationships between the data. National Road Authorities are therefore encouraged to use this tool as a starting point and to invest in further research and pilot trials working towards deployment of cooperative services.

6 Suggestions for further developments

During the development and testing of the tool, and consultation with road authorities, several potential improvements in the tool were identified, which could not, for various reasons, be incorporated in the current version. In addition to improving the tool as better information on impacts of cooperative systems becomes available, these improvements include improving the way in which the model within the tool represents the way in which cooperative systems are assessed in comparison with existing services, improvements in the level of detail represented, and possible ways of expanding the scope of the tool. These are discussed briefly below.

6.1 Cooperative systems compared with existing services

Functions – Overlap of functions between existing infrastructure and the bundles

As mentioned in Section 1.2, the cooperative services are assumed to be equivalent to services delivered using existing technology; i.e. there is 100% overlap between the functions and impacts of cooperative systems and existing technologies. The scope of the impact assessment could be extended to consider the impacts of existing roadside infrastructure alongside the cooperative systems. This could involve looking at whether the overlap is 100%, and whether there are additional benefits from the cooperative systems on equipped sections. One example would be to consider to what extent in-vehicle dynamic route guidance yields additional benefits over roadside routing information. This is challenging, because amongst other things, it introduces the concept of whether in-vehicle route guidance is able to give altruistic messages, i.e. where recommendations are optimised so that the recommended is route not necessarily the best for the individual driver, but is better for overall traffic efficiency.

Additional analysis could be carried out to define the functionality of existing roadside equipment and the extent to which it relates to each bundle of services. This would need to be country-specific. An example of such a match has been carried out for the Netherlands. See the Appendix in D2 [2] for more information. Such an analysis would make it possible to carry out a more refined assessment of the bundles than has been possible in this first version of the tool.

Information delivery – Different types of VMS and cost savings from phasing out VMS

There could be further work to distinguish both the different functions and also the types of VMS, as introduced in Section 1.2.8.2.

The cost savings part of the module would benefit from further work to tailor it to specific situations. For example, one area for further work would be to assess the impacts of removing existing roadside infrastructure, particularly to identify the benefits which would no longer be realised and the savings in operational costs which could be achieved if they were removed.

Sensors

An assumption in the tool is that the bundles use only existing sensors and no additional sensing equipment will be deployed. If the system design of the cooperative systems requires additional sensors for them to work, then this assumption would need to be re-considered.

A benefit of cooperative systems may be cost savings from sensors. For example, emergency call systems will provide new incident detection data; this is likely to initially complement existing incident detection in the short term, but in the long term, these may replace incident detection, at least on some routes. Related to this example, is the cost savings of removing genuine legacy services to road users, such as roadside telephones.

A more complicated example is floating vehicle data (FVD); in the short term FVD has the potential to replace journey time sensors, such as ANPR (Automatic Number Plate Recognition). In the longer term, floating vehicle data may replace inductive loops; however this depends on the function of the loops: while congestion detection may be possible at a lower penetration rate; flow monitoring may only be possible at a much higher penetration rate.

6.2 Level of detail

Taking account of "congested conditions"

Data on the impacts of cooperative systems in "congestion conditions" was limited; this version of the tool therefore covers "general" traffic conditions. If further impact data, specific to congested and freeflowing traffic conditions, became available, it would be possible to refine the tool to take account of differences under different traffic conditions. However, this would require consistent definitions of what “congested conditions” are, both in the impact assessment and in the traffic forecasts.

“Hotspots”

A further refinement would be to include separate “hotspot” curves for travel time, fuel consumption and emissions; in this version of the tool it is assumed that these are the same.

6.3 Expanding the scope of the tool

Roll-out of more than one bundle

The model currently allows the user to implement one bundle at a time. A NRA may like to consider implementing more than one bundle, for example to use the cooperative system infrastructure for as many applications as possible. A possible expansion of the tool’s capabilities could be for implementation of more than one bundle at a time, and for introduction of new bundles.

Communications options

Currently it is possible to consider two communication platforms: cellular, which involves exclusively aftermarket and smartphone costs, and wireless beacons, which involves only OEM costs. It may be beneficial to extend the tool so that users can consider a scenario in which both cellular and wireless communications are used to deliver a service.

Investigate the “Safety” bundle

The bundles presented in this analysis, chosen jointly in a workshop with CEDR, can technically be implemented with either cellular or wireless beacon communication technologies. Safety applications are time-critical, requiring a low-latency, fast communication technology, which is currently available through wireless beacons (although some safety services could in future become possible via 4G cellular communications). A NRA cooperative system deployment roadmap that includes safety applications could influence the decision making over deployment of fixed infrastructure.

Time horizon

The current version of the tool enables assessments to be carried out up to 2030. With a limited amount of further work, the tool could be extended to enable assessments to be made over a longer time period.

7 Glossary

4G	4^{th} generation of cellular communications networks
ANPR	Automatic Number Plate Recognition
App	Application used to deliver a service
BCR	Benefit Cost Ratio
BM	Business model
CAPEX	Capital costs of equipment to support a service
CBA	Cost Benefit Analysis
Cellular network	Communications platform to support long range communications e.g. mobile phone
eCall	Emergency Call service in which a vehicle involved in an accident makes an automatic call to the emergency services
GDP	Gross Domestic Product
ISA	Intelligent Speed Adaptation
ITS	Intelligent Transport System
Managed motorways	An integrated set of traffic management systems to improve traffic flow and road capacity; in the UK they primarily involve variable speed limits and hard

	shoulder running.
NRA	National Road Authority
OEM	Original Equipment Manufacturer (e.g. vehicle manufacturer)
OPEX	Operational costs of running or using a service
Payback year	The first year in which the cumulative benefits of a service exceed the cumulative costs invested in it
Penetration rate	Proportion of vehicles which are equipped to participate in a service
Queue protection	Automatic traffic management system used to detect sudden traffic disruption and warn traffic approaching the scene to protect vehicles at the back of the queue from rear-end collisions
Sensor costs	Capital and operational costs of acquiring data for ITS e.g. through loop detectors, CCTV, weather detectors
Smartphone	Mobile telephone used to deliver a variety of other services to users, via Apps
Unintended impact	Dis-benefits occurring as a result of the cooperative system. In calculating the benefit: cost ratio in the tool, these are treated as if they were additional costs
Value web	A value web depicts the flows of services, money and non-monetised value between the main stakeholders involved in a service (whether as providers or users).
VMS	Variable Message Sign to display a number of messages, and which can be switched on or off as required; various types of sign are available involving different technologies and costs and performing different functions. When considering the savings from removing VMS, users of the tool will need to specify the types, costs and level of deployment to fulfil the function which is being investigated.
Wireless beacon	Communications beacon to support short range communications between vehicles and the roadside. It is assumed that each beacon has a range of 300 metres.

8 References

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