COBRA Cooperative Benefits for Road Authorities

ERA-NET ROAD

Mobility:

Getting the most out of Intelligent Infrastructure

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Tool User Guide

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Revision and history chart

Version	Date	Reason
0.1	2013-01-14	SB / JH – First draft
0.2	2013-01-15	SB/JH – circulated to team for comment
0.3	2013-01-22	JH – amendments to take account of comments from TNO and AIT
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0.5	2013-01-30	PV - Technical Review; diagrams updated to reflect changes in the tool
0.6	2013-02-12	Minor corrections
0.7		
0.8		
0.9		
1.0		

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1 Introduction

1.1 Overview

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 spreadsheet-based decision support tool which enables the costs and (monetised) benefits of cooperative services to be compared in various contexts.

The business case for road authorities depends not only on these benefits and costs, but also on their business model for delivering services. The tool enables road authorities to compare the case for investment under different business models, represented by variations in the responsibility for the costs of setting up and operating the services.

1.2 This document

This document is the user guide to accompany the COBRA decision support tool v1.01. It 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.

It is envisaged that the tool may be used at two different levels. At a ‘policy’ level, the national road authority is expected to work with the ‘default’ values for the parameters and assumptions in the tool which are based on the best available evidence. At a ‘detailed’ level, the national road authority is expected to investigate the effect of changing some of the parameters and assumptions in order to make a more refined assessment based on local knowledge.

The user guide therefore consists of two main sections: Section 2 for policy users and Section 3 for those who wish to work at a more detailed level within the tool. Section 3 includes a diagram (Figure 9 on page 17) which summarises the information used in the tool, and how the various elements are brought together to produce cost benefit analysis and business case analysis for road authorities. The guide also includes an appendix setting out the data on individual countries which is needed to populate the tool. Section 2 is also included within the tool itself on the ‘Instructions’ worksheet.

2 How to use the tool at a policy level

2.1 Overview

2.1.1 Background

This spreadsheet is a tool which enables National Road Authorities to compare the costs and monetised benefits of cooperative systems in various contexts to support investment decisions under different deployment scenarios. These deployment scenarios are for cooperative systems which are implemented in addition to any existing services base on roadside infrastructure. It also enables the business case to be investigated for delivering services under different business models, in which the road authority has different degrees of responsibility for setting up and operating the services.

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.

The tool enables road authorities to consider investment in cooperative systems involving communication between vehicles and infrastructure to deliver services in three 'bundles' of functions. The bundles are listed below; further details are provided in Section 2.3 of the User Guide.

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.

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 for this bundle.

The parameters and assumptions in the tool have been developed on the basis of the best available evidence on the impacts, costs, and potential deployment scenarios which have been assembled in a collaborative research project carried out by TNO, AIT and TRL under the ERA-NET programme.

2.1.2 Uses of the tool

The tool can be used in several different ways, including:

- Help decision-makers in national road authorities to make top level investment decisions which can then be used to define further more specific investigations into the services which appear to offer the greatest potential
- Support local decisions, e.g. on investment for a specific route or region
- To explore the potential for using cooperative systems to replace existing infrastructure-based services
- To assess the relative impact of key parameters, providing an understanding of which factors have the greatest and least influence on the business case
- To investigate different business models for delivery, with varying roles for the road authority and the private sector
- To assess the potential impact of changes affecting deployment (such as an EC mandate on equipping vehicles).

This version of the tool includes data for the UK and The Netherlands as examples. An 'Additional Country' area of the tool has been set aside in which users can insert data for another country or a specific route or region. Details of the information required are provided in the Appendix to the User Guide.

Although based on the best available evidence, the tool includes many assumptions and parameters; these can be readily updated as better information becomes available. However it is important to use the tool with care – it is intended to provide an input into decision-making, but not to provide the sole basis for investment decisions.

2.2 Instructions for using the tool

The tool is laid out on a number of pages or worksheets within the spreadsheet. Click on one of the five buttons which appear at the top of the main pages to navigate between the pages (see Figure 1).

Figure 1 Navigation buttons at the top of the main pages

2.2.1 Input: Scenarios

This is the main input page – see Figure 2. Select options from the drop down menus in the scenario columns to define particular scenarios; these scenarios are for the case where cooperative systems are deployed in addition to any services based on existing roadside infrastructure and technologies.

Two scenarios can be compared at the same time. The options available are listed below. Further information about these options is available in Section 3 of the User Guide.

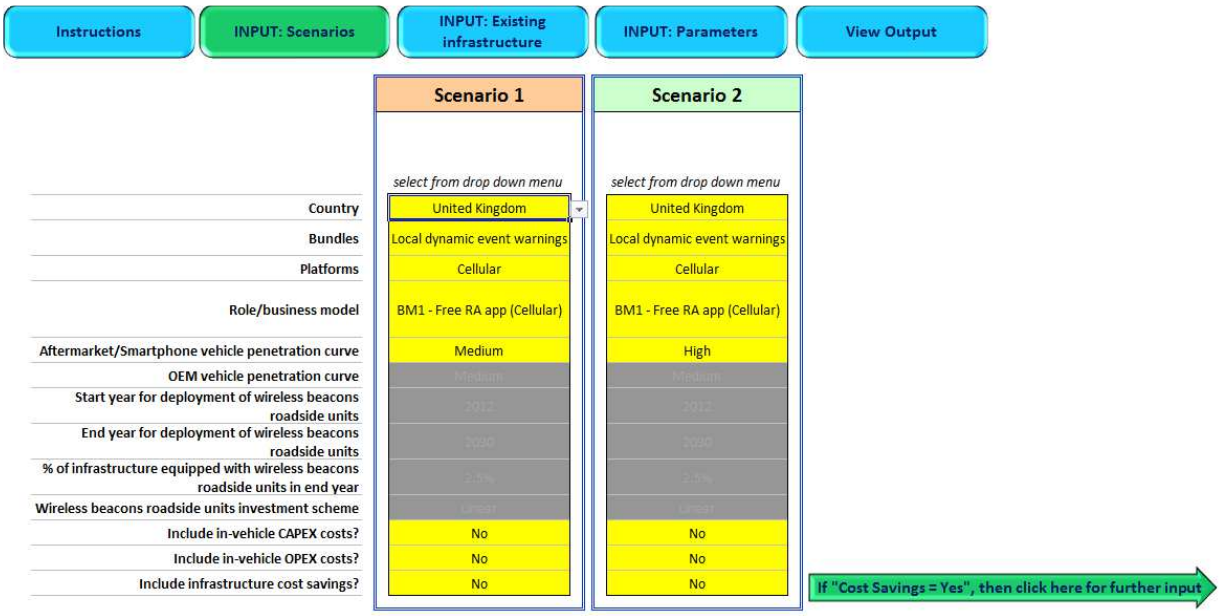


Figure 2 Input: Scenarios page

Note that if an 'incompatible' combination of options for the bundle, the platform and the business model is selected, an error message will appear at the top of the scenario column; an example is circled in red in Figure 3. Once a compatible combination is selected, the error message will disappear.

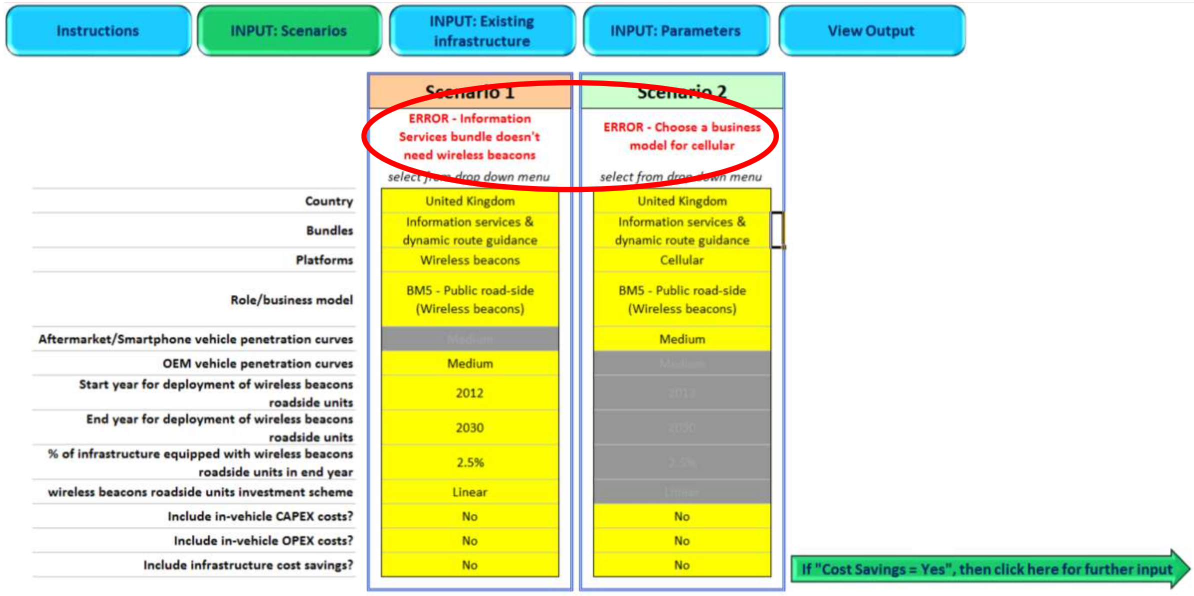


Figure 3 Error message on Input: Scenarios page

Country

- Netherlands
- United Kingdom
- Additional Country 1 – for user to enter data

Bundles

- Local dynamic event warnings
- In-vehicle signs and ISA
- Information services and dynamic route guidance

Platform

- Cellular
- Wireless beacons

Role/business model: specifies which elements of the costs are borne by the road authority, private service provider and users. Further information about the business models is included in D2 [2].

- BM1 - Free road authority app (Cellular)
- BM2a - Commercial app costing 1$ (Cellular)
- BM2b - Navigation extended (Cellular)
- BM3 - Public travel time information (Cellular)
- BM4 - Private dynamic navigation (Cellular)
- BM5 - Public road-side (Wireless beacons)
- BM6a – Private & Public service (road-side private; app by NRA) (Wireless beacons)
- BM6b – Public & Private service (road-side by NRA; app private) (Wireless beacons)
- BM7 - Private road-side (Wireless beacons)

Vehicle (Aftermarket) penetration curves: the rate at which vehicles are equipped with cellular communications (as illustrated in Figure 4).

- Low (linear increase, 0% in 2012 to 39% in 2030 and 50% in 2035)
- Medium (linear increase, 0% in 2012 to 59% in 2030 and 75% in 2035)
- High (linear increase, 0% in 2012 to 78% in 2030 and 100% in 2035)

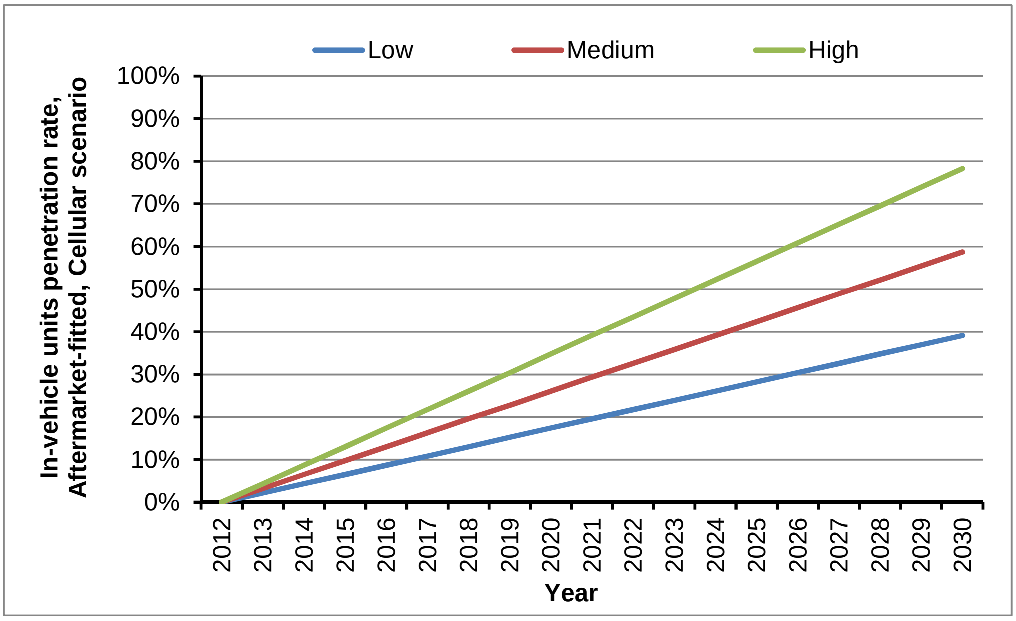


Figure 4 Three curves available to select for penetration rate of after-market in-vehicle equipment with cellular communications

Vehicle (OEM) penetration curves: the rate at which vehicles are equipped for communication with roadside beacons (as illustrated in Figure 5)

- Low (curved increase, 0% in 2014 to 9% in 2030 and 14% in 2035)
- Medium (curved increase, 0% in 2014 to 29% in 2030 and 49% in 2035)
- High (curved increase, 0% in 2014 to 61% in 2030 and 82% in 2035)

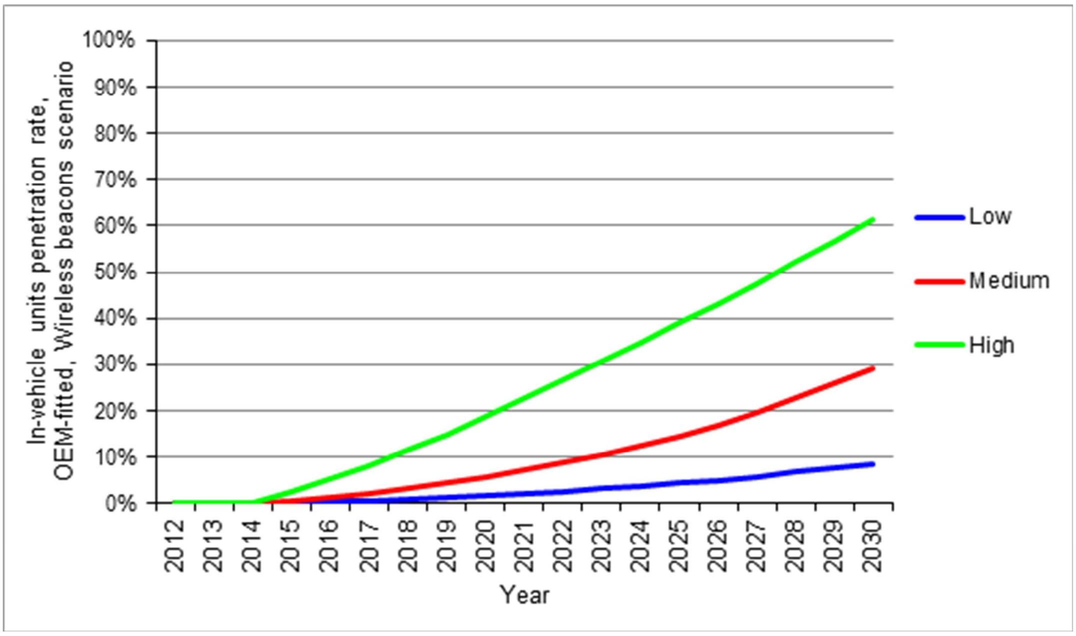


Figure 5 Three curves available to select for penetration rate of OEM in-vehicle equipment with wireless beacon communications

Start year for deployment of wireless beacon roadside units

- 2012
- 2015
- 2020

End year for deployment of wireless beacon roadside units

- 2020
- 2025
- 2030

% of infrastructure equipped with wireless beacon roadside units in end year

- 0.0%
- 1.0%
- 2.5%
- 5.0%
- 10.0%
- 20.0%
- 30.0%

Include in-vehicle CAPEX costs? (Capital costs of equipment)

- Yes
- Yes, but 1/3 of price to buyer (reflecting the actual cost to the manufacturer)
- Yes, but 1/2 of price to buyer
- No

Include in-vehicle OPEX costs? (Operating costs of service)

- Yes
- No

Include infrastructure cost savings? (If cooperative systems reduce the requirement for fixed infrastructure)

- Yes
- No

2.2.2 Input: Existing infrastructure

This is the 'reference case' or 'base case' for the planned future deployment of infrastructure-based systems using existing technologies. This can be used to represent continuation of, or changes to, the level of deployment of these systems, reflecting national policies and plans. The three infrastructure-based systems are:

- 'Roadside travel and routing information' (assumed to deliver the Travel Information and Dynamic Route Guidance bundle)
- 'Queue Protection' (assumed to deliver the Local Dynamic Event Warnings bundle)
- 'Managed Motorways / Variable Mandatory Speed Limits' (assumed to deliver the In-vehicle Speed and Signage bundle).

The 'Roadside travel and routing information' area is at the top of the page - scroll down the page to see the queue protection and managed motorways deployment.

To define the planned deployment of existing infrastructure, the tool requires a value for the percentage of the road authority's network which is expected to be equipped in future years. This represents the percentage of the network where it is assumed that cooperative systems will provide no additional benefits.

If any of these systems are not deployed or planned for a particular country, then simply enter 0 for all years in the yellow coloured cells the table, as highlighted by the red oval in the extract in Figure 6. The definition of the colour usage is explained in Section 3.1.3 of the User Guide.

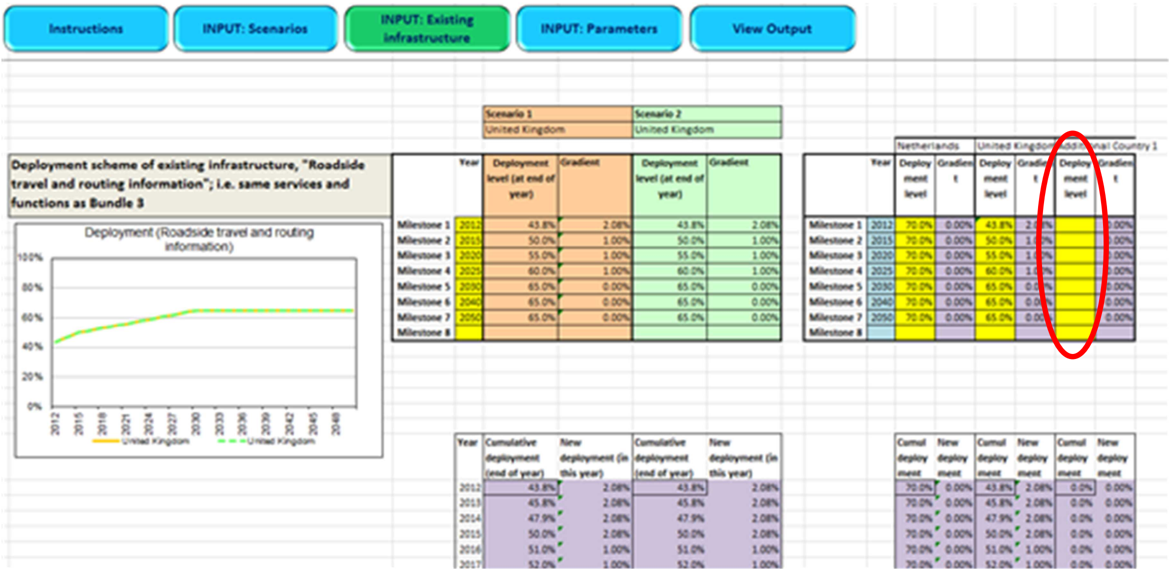


Figure 6 Input: Existing Infrastructure page – extract from section on deployment of roadside travel and routing information

2.2.3 Input: Parameters

This page contains the key parameters; default values are provided based on information on deployment in the UK and research-based estimates, but there is a column where user-defined values can be entered. Any user-defined values will 'over-ride' the default parameters. For more detailed manipulation, there are links to other parameters in the 'Country data' and 'Component costs' pages. Further information about entering user-defined values in the parameter page is provided in Section 3.3 of the User Guide.

2.2.4 View Output

Click on the 'View Output' button to see the output graphs for comparing the two scenarios which have been selected on the 'Input: Scenarios' page.

The first five output graphs summarise the results of the social cost benefit analysis – the benefits and costs to society as a whole.

- Graph 1 – monetary value of the main types of benefit and cost in each scenario, including the unintended impacts which are the benefits which may be seen as negative (such as additional travel time)
- Graph 2 – total monetary value of the benefits and costs
- Graph 3 – total costs and total benefits over time
- Graph 4 – cumulative costs and cumulative benefits over time
- Graph 5 – benefit: cost ratio over time (cumulative benefits divided by cumulative costs).

The output page then shows the payback year for each scenario – i.e. the year in which the cumulative societal benefit: cost ratio exceeds 1.0.

The remaining output graphs show the results of the business case analysis for the road authority.

- Graph 6 – business case for the road authority, showing the monetary value of the infrastructure cost savings (benefits) and the main types of cost to the road authority
- Graph 7 – total monetary value of the benefits and costs to the road authority
- Graph 8 – cumulative benefits and costs to the road authority over time
- Graph 9 – cumulative net costs to the road authority over time.

Below Graph 9, the output page shows the payback year for the national road authority – i.e. the first year in which the net benefits for the road authority exceed the net costs.

See Section 3.5 of the User Guide for examples of each of these graphs.

Individual values or points on the graphs on the output page can be viewed by hovering the mouse over them.

To print the output, print as normal on the 'View Output' worksheet, which will print two sheets in A3 by default. Set the printer to print in colour to maximise the clarity of the graphs. It is possible to save to pdf in Excel 2007 or using pdf printing software.

The output page includes tables (numbered 10) which provide a record of how the scenarios have been defined and the values which have been set for any parameters which are open to users to vary. Thus a printed or exported copy of the output page is a self-contained summary of the analysis. However, it is also recommended to save a copy of the entire workbook for particular model runs using 'Save As'.

2.2.5 Input: Infrastructure Costs Savings

If 'Include Infrastructure Costs Savings?' is set to "Yes" on the 'Input: Scenario' page, further input is required on the extent to which existing infrastructure-based systems are phased out, depending on policies and plans. This takes place on the 'Input: Infrastructure cost savings' page. There is a link to this page on the 'Input: Scenarios' page. Section 3.3.3.3 of the User Guide describes this in more detail.

2.2.6 Further parameters

Click on the arrows at the bottom of the 'Input: Parameters' page to view or modify key input data: 'Further parameters: Country data' and 'Further parameters: Component costs'; see Section 3.3 of the User Guide for further information.

2.3 Bundles of cooperative systems available for assessment

Table 1 summarises the functions which are included in the bundles of cooperative systems which are available for assessment in the tool.

Table 1 Bundles of cooperative systems available for assessment

Bundle	System	Description
Bundle 1 – Local Dynamic Event Warnings	**Hazardous location notification**	Warns drivers approaching potentially hazardous areas. These areas statistically have more collisions and incidents, requiring more attention from the driver. This is particularly beneficial in dynamic situations such as changing weather conditions.
	Road works warning	Temporary traffic management at road works usually involves deploying signs and equipment. A vehicle-infrastructure system offers more flexibility, enabling faster reconfiguring of the work zone and precise alerts and instructions to drivers about lane choices, speeds, close following of preceding vehicles etc.
	Traffic jam ahead warning	Warns drivers approaching the tail end of a traffic jam.
	E-Call	If sensors in the vehicle detect that a collision has occurred, the vehicle can automatically call the emergency services to provide information about the vehicle and its location, opening a voice channel to communicate with the emergency call centre. The post-crash warning warns drivers approaching a crashed vehicle.
Bundle 2 – In-vehicle Speed and Signage	**In-vehicle signage**	A vehicle-infrastructure link gives information or a warning to a driver about the content of an upcoming roadside sign which is beyond the line-of-sight. Drivers can also be informed of features such as roundabouts, traffic calming and segregated lanes. Information can be both static and dynamic.
	Intelligent speed adaptation	ISA monitors a vehicle's speed and the speed limit on the road and intervenes if the vehicle exceeds that limit. In addition to this

Bundle	System	Description
		'advisory' service, ISA can influence driver behaviour by e.g. feedback to the driver via a haptic throttle – termed 'voluntary' ISA in the tool. It is assumed that it is an advisory ISA for the cellular platform and a voluntary ISA for the wireless beacons platform. The voluntary version can be given a higher compliance rate.
	Dynamic speed limits	Provides drivers with information in the vehicle about the current dynamic speed limit.
Bundle 3 – Travel Information & Dynamic Route Guidance	**Traffic info and recommended itinerary**	Recommends a route for the vehicle navigation system to direct the driver around congested locations and dangerous roads and to distribute the traffic load on alternative routes.
	Multimodal traffic information	Provides drivers with information relevant to using alternative modes or interchanging with other modes during their journey.
	Truck parking information and guidance	Provides truck drivers with information to enable them to optimise their search for a parking space.

3 How to use the tool – detailed users

3.1 Technical explanations

3.1.1 System requirements

The tool was created in Microsoft Excel 2010, but has been saved to be compatible with earlier versions of Excel (i.e. as an '.xls' file). The tool has been tested to work on Microsoft Excel 97 or later, but has not been tested with other spreadsheet packages.

The tool does not require macros to be enabled.

3.1.2 Two versions

There are two versions of the tool:

- 'COBRA Tool v1.01 OVERVIEW.xls' – for the policy-level user, with some sheets hidden
- 'COBRA Tool v1.01 UNHIDDEN.xls' – for the detailed user, with no sheets hidden.

3.1.3 Colour code for cells

The following colour code has been used for cells:

Yellow	User input
Green	Default input data (alternative values can be inserted if available to the user)
Purple	Calculated by Tool
Blue	Copied from elsewhere in the Tool
Tan	Scenario 1
Light green	Scenario 2
Brown	Comment/ explanation
Grey	Not used in this version of the tool – available to enable enhancements to be added in future

Thus, the detailed user should only modify yellow cells or the green cells where better data is available. Modifying any other cells may have a detrimental effect on the functioning of the tool.

3.2 Overview of how the spreadsheet works

An overview for how the tool works is shown in Figure 7 below.

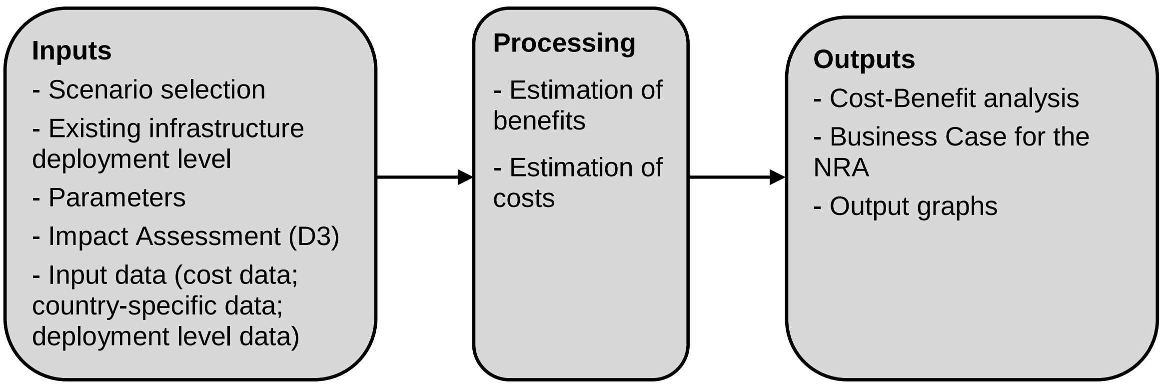


Figure 7 Overview of how the tool works

Each of these elements is discussed in turn below.

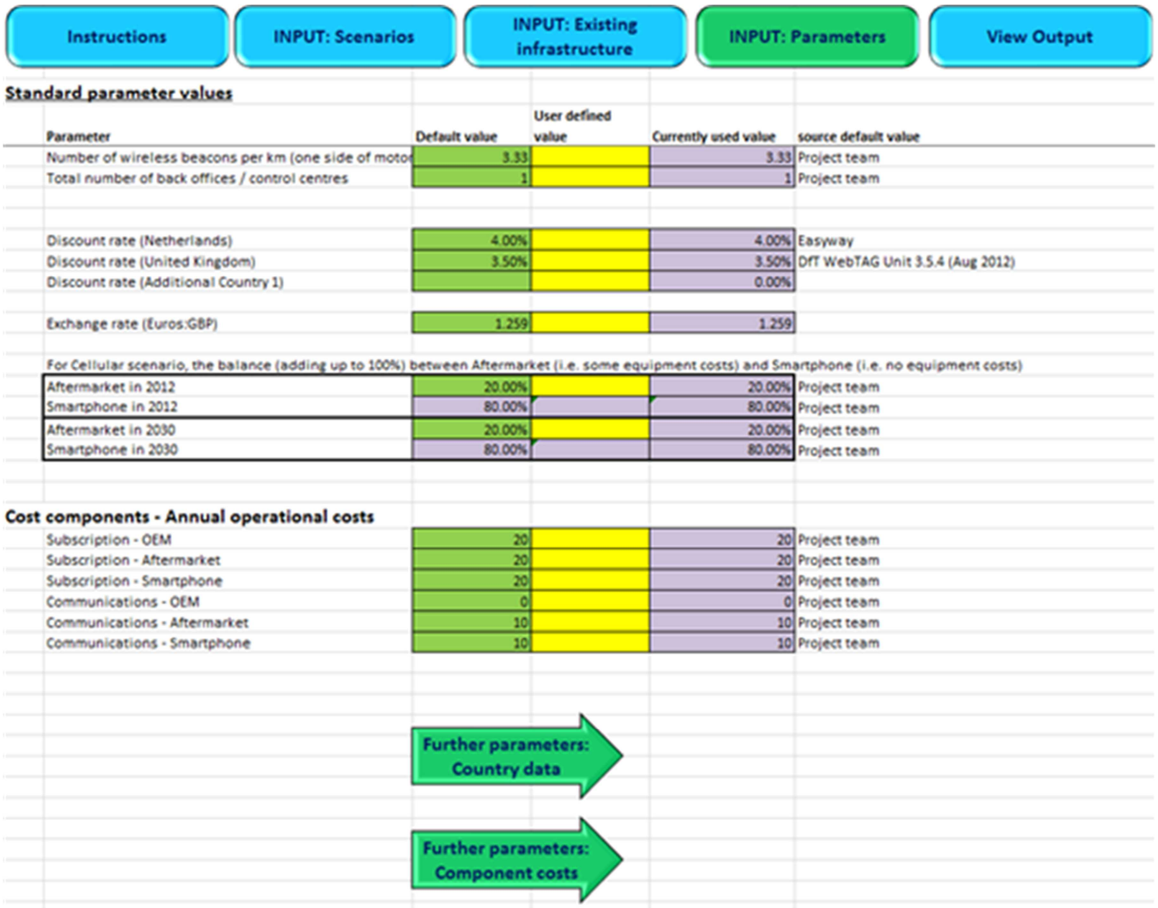
3.3 Inputs

The 'Input: Scenarios' and 'Input: Existing infrastructure' worksheets are discussed earlier in Section 2.2.1 and Section 2.2.2, respectively.

3.3.1 Input: Parameters

Several key parameters can be set on the 'Parameters' worksheet in the 'User defined value' column as shown in Figure 8. These are the main 'high level' variables which users may wish to amend.

Note that users may also wish to input data for other variables at a more detailed level on the country, costs and deployment level – see Section 3.3.3 for further information.



Standard parameter values

Parameter	Default value	User defined value	Currently used value	source default value
Number of wireless beacons per km (one side of moto	3.33		3.33	Project team
Total number of back offices / control centres	1		1	Project team
Discount rate (Netherlands)	4.00%		4.00%	Easyway
Discount rate (United Kingdom)	3.50%		3.50%	DfT WebTAG Unit 3.5.4 (Aug 2012)
Discount rate (Additional Country 1)			0.00%	
Exchange rate (Euros:GBP)	1.259		1.259	
For Cellular scenario, the balance (adding up to 100%) between Aftermarket (i.e. some equipment costs) and Smartphone (i.e. no equipment costs)				
Aftermarket in 2012	20.00%		20.00%	Project team
Smartphone in 2012	80.00%		80.00%	Project team
Aftermarket in 2030	20.00%		20.00%	Project team
Smartphone in 2030	80.00%		80.00%	Project team
Cost components - Annual operational costs				
Subscription - OEM	20		20	Project team
Subscription - Aftermarket	20		20	Project team
Subscription - Smartphone	20		20	Project team
Communications - OEM	0		0	Project team
Communications - Aftermarket	10		10	Project team
Communications - Smartphone	10		10	Project team

Figure 8 Input: Parameters page

The parameters on this worksheet are:

- Number of wireless beacons per km (one side of motorway)
- Total number of back offices / control centres
- Discount rate
- Exchange rate (Euros: GBP) – all monetary values in the tool are in Euros; although some cost estimates were originally in GBP.
- For Cellular scenario, the balance (adding up to 100%) between 'Aftermarket' and 'Smartphone' – it is assumed that the Smartphone scenario has zero equipment costs (i.e. the user already owns them), whereas the Aftermarket scenario has non-zero equipment costs (i.e. in-vehicle modification to the dashboard)
- In-vehicle annual operational costs – the subscription costs and communication costs are parameters that can be modified here; NOTE the model is very sensitive to these parameters (when 'Include in-vehicle OPEX costs?" is set to "Yes"), because there are very large numbers of vehicles.

Note that a few of these parameters are repeated on other worksheets (the discount rate appears on the 'Country data' worksheet and operational costs of in-vehicle services appear on the 'Component Costs' worksheet). The values in the cells on these other worksheets are derived from the values on the Input: Parameters' worksheet. Any modifications to the values of these parameters should be therefore be made only on the Input: Parameters worksheet.

3.3.2 Impact Assessment (D3)

The tool uses estimates for the impact of the cooperative systems which are derived on the basis of a review of previous research reported in COBRA D3 [3]. This was done for 'general conditions' (without separating congested and free-flowing traffic conditions) for each of the three bundles of services, and can be found on the 'Impacts at 100%' worksheet.

There is a parameter that can be modified for the level of compliance by drivers. Currently this parameter is only used for the In-vehicle Speed and Signage bundle. It is assumed that in the cellular scenario, because it is only an Advisory ISA, compliance is 50% - i.e. each of the impacts is multiplied by 0.5 in this scenario.

3.3.3 Input data

There are three different types of input data, which are described below. These inputs are at a more detailed level than the parameters on the 'Input: Parameters page (see Section 3.3.1).

- Country-specific data
- Cost data for existing infrastructure and cooperative systems
- Deployment level data for cooperative systems.

3.3.3.1 Country-specific data

Country-specific data can be found on the 'Country data and forecasts' worksheet. Version 1.01 of the tool includes data for the Netherlands and the UK on the following topic areas:

- Societal problem size data
- Unit cost data for values of accidents, time, fuel, environmental costs
- Additional data for value of time calculation
- Discount rate (copied from 'Input: Parameters' – not to be modified on the 'Country data and forecasts' worksheet)
- Network and vehicle ownership data
- Unit cost forecasts.

This is reproduced in Appendix A for the UK, with references to the data sources.

Depending on which country is selected in 'Input: Scenarios', the model automatically looks up the relevant data. A similar method is used on other sheets.

If the user wishes to change the data on this worksheet, this should be entered in:

- the '2012 Data' row for the relevant country below the rows for the two scenarios
- the 'Forecast Scale Factor 2030/2012' row below this (in the case of linear forecasts)
- the rows for forecasting specific years from 2013 to 2030 (in the case of non-linear forecasts).

Thus for an additional country, the data for 2012 is entered in the 'Additional Country 1' row in the 2012 data row which can be found below the area for scenarios 1 and 2. Linear forecasts for an additional country are entered in the 'Additional Country 1' row in the Forecast Scale Factor 2030/2012 row below this, for some data types. Where there are forecasts that are not linear, these are entered in for each year in the 'Additional Country 1' rows at the bottom of the worksheet.

3.3.3.2 Cost data (Component Costs)

Estimates of the cost data are included on the 'Component costs' worksheet. Further details on these can be found in the methodology deliverable, D2 [2].

Note that the values for operational costs of in-vehicle services are copied from the 'Input: Parameters' worksheet and should not be modified on the 'Component Costs' worksheet.

3.3.3.3 Deployment level data for in-vehicle equipment

Data on the forecasts for levels of deployment of in-vehicle units for cooperative systems were taken from the SAFESPOT project. These can be found on the following worksheets:

- Vehicle (OEM) fleet penetration curves – only used when the wireless beacons platform is selected – see Figure 5
- Vehicle (Aftermarket) fleet penetration curves – only used when the cellular platform is selected – see Figure 4.

Both contain estimates for 'Low', 'Medium' and 'High' deployment and can be modified by the user if better estimates become available.

3.4 Processing and key assumptions

How the tool works is set out in detail in the methodology deliverable, D2 [2], so only a brief overview is given here. Additionally, there are comments on each worksheet within the tool - colour-coded in brown. These comments explain in more detail what that sheet does and how it is connected to other worksheets.

Figure 9 on page 17 lists the key worksheets in the tool and shows which worksheets are linked.

Working backwards through the tool, the graphs on 'Output' link to the summary information on 'Cost Benefit Analysis' and 'Business Case for the NRA'. The discounting takes place here.

These worksheets then link back to the 'Costs' and 'Benefits' worksheets. The 'Benefits', 'Costs' and 'Output' worksheets are discussed below.

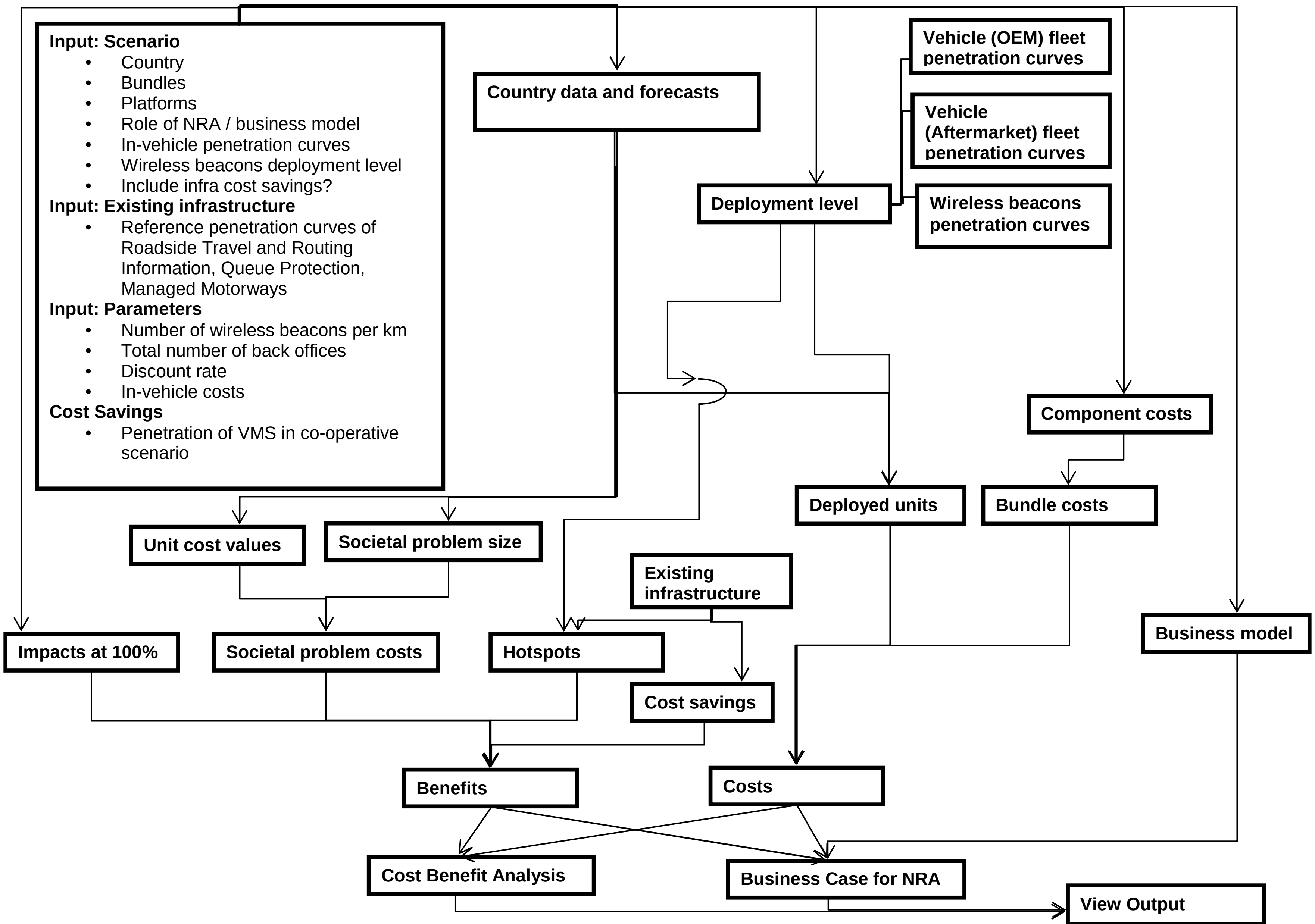


Figure 9 Links between worksheets within the tool

3.4.1 *Estimation of benefits*

A screenshot of the 'Benefits' worksheet is shown in Figure 10, which lists the monetised benefits for the two scenarios for 2012 to 2030.

	Benefits of the bundle														
				Change in societal cost due to the bundle, compared to no VMS (I)											
				Road Safety			Time spent in traffic		Fuel consumption		Noise	Emissions			
	Year	Total positive benefits	Total negative benefits (i.e. "unintended impacts" – to be recorded as	Number of fatalities	Number of non-fatally injured	Number of injury accidents	Time spent travelling	Lost vehicle hours	Petrol	Diesel	Noise emissions	CO2	NOx	PM-2.5	Cost savings from money spent on standard
Scenario	year														
Scenario 1	2012	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scenario 1	2013	3,056,909	752,901	1,066,226	88,180	151,719	0	0	528,964	741,815	0	-752,901	99,524	380,481	0
Scenario 1	2014	5,831,639	1,427,645	2,030,559	166,418	286,258	0	0	1,031,879	1,447,101	0	-1,427,645	182,343	687,081	0
Scenario 1	2015	8,327,363	2,024,775	2,901,162	235,494	404,973	0	0	1,503,245	2,108,141	0	-2,024,775	249,374	924,974	0
Scenario 1	2016	11,218,552	2,722,681	3,887,266	312,251	536,970	0	0	2,074,954	2,909,902	0	-2,722,681	321,727	1,175,482	0
Scenario 1	2017	14,140,317	3,431,996	4,865,759	386,524	664,697	0	0	2,680,944	3,759,739	0	-3,431,996	388,174	1,394,479	0
Scenario 1	2018	17,074,908	4,152,659	5,814,657	456,463	784,968	0	0	3,325,885	4,664,200	0	-4,152,659	448,389	1,580,346	0
Scenario 1	2019	20,038,586	4,885,397	6,750,928	523,305	899,915	0	0	4,008,755	5,621,853	0	-4,885,397	502,123	1,731,707	0
Scenario 1	2020	23,027,350	5,628,642	7,672,414	586,750	1,009,020	0	0	4,730,273	6,633,705	0	-5,628,642	548,877	1,846,312	0
Scenario 1	2021	26,063,045	6,395,132	8,593,624	647,746	1,113,914	0	0	5,491,158	7,700,766	0	-6,395,132	589,495	1,926,342	0
Scenario 1	2022	29,109,636	7,174,030	9,489,607	704,229	1,211,046	0	0	6,292,130	8,824,044	0	-7,174,030	622,492	1,966,089	0
Scenario 1	2023	32,171,498	7,963,645	10,365,282	756,412	1,300,783	0	0	7,133,907	10,004,547	0	-7,963,645	647,349	1,963,218	0
Scenario 1	2024	35,273,127	8,765,843	11,228,896	804,701	1,383,826	0	0	8,023,478	11,252,076	0	-8,765,843	663,842	1,916,307	0
Scenario 1	2025	38,355,644	9,579,036	12,056,463	847,171	1,456,860	0	0	8,949,689	12,550,989	0	-9,579,036	671,455	1,823,016	0
Scenario 1	2026	41,457,788	10,401,231	12,855,100	884,143	1,520,439	0	0	9,926,504	13,920,867	0	-10,401,231	669,669	1,681,066	0
Scenario 1	2027	44,540,290	11,234,902	13,621,632	915,180	1,573,813	0	0	10,940,112	15,342,345	0	-11,234,902	658,264	1,488,944	0
Scenario 1	2028	47,635,881	12,078,153	14,352,725	939,825	1,616,194	0	0	12,007,221	16,838,852	0	-12,078,153	636,718	1,244,346	0
Scenario 1	2029	50,720,661	12,928,707	15,044,872	957,597	1,646,758	0	0	13,120,997	18,400,805	0	-12,928,707	604,527	945,105	0
Scenario 1	2030	53,789,507	13,789,615	15,694,393	967,936	1,664,640	0	0	14,282,225	20,029,303	0	-13,789,615	561,448	589,502	0
Scenario 1															
Scenario 2	2012	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scenario 2	2013	3,056,909	752,901	1,066,226	88,180	151,719	0	0	528,964	741,815	0	-752,901	99,524	380,481	0
Scenario 2	2014	5,831,639	1,427,645	2,030,559	166,418	286,258	0	0	1,031,879	1,447,101	0	-1,427,645	182,343	687,081	0
Scenario 2	2015	8,327,363	2,024,775	2,901,162	235,494	404,973	0	0	1,503,245	2,108,141	0	-2,024,775	249,374	924,974	0
Scenario 2	2016	11,218,552	2,722,681	3,887,266	312,251	536,970	0	0	2,074,954	2,909,902	0	-2,722,681	321,727	1,175,482	0
Scenario 2	2017	14,140,317	3,431,996	4,865,759	386,524	664,697	0	0	2,680,944	3,759,739	0	-3,431,996	388,174	1,394,479	0
Scenario 2	2018	17,074,908	4,152,659	5,814,657	456,463	784,968	0	0	3,325,885	4,664,200	0	-4,152,659	448,389	1,580,346	0
Scenario 2	2019	20,038,586	4,885,397	6,750,928	523,305	899,915	0	0	4,008,755	5,621,853	0	-4,885,397	502,123	1,731,707	0
Scenario 2	2020	23,027,350	5,628,642	7,672,414	586,750	1,009,020	0	0	4,730,273	6,633,705	0	-5,628,642	548,877	1,846,312	0
Scenario 2	2021	26,063,045	6,395,132	8,593,624	647,746	1,113,914	0	0	5,491,158	7,700,766	0	-6,395,132	589,495	1,926,342	0
Scenario 2	2022	29,109,636	7,174,030	9,489,607	704,229	1,211,046	0	0	6,292,130	8,824,044	0	-7,174,030	622,492	1,966,089	0
Scenario 2	2023	32,171,498	7,963,645	10,365,282	756,412	1,300,783	0	0	7,133,907	10,004,547	0	-7,963,645	647,349	1,963,218	0
Scenario 2	2024	35,273,127	8,765,843	11,228,896	804,701	1,383,826	0	0	8,023,478	11,252,076	0	-8,765,843	663,842	1,916,307	0
Scenario 2	2025	38,355,644	9,579,036	12,056,463	847,171	1,456,860	0	0	8,949,689	12,550,989	0	-9,579,036	671,455	1,823,016	0
Scenario 2	2026	41,457,788	10,401,231	12,855,100	884,143	1,520,439	0	0	9,926,504	13,920,867	0	-10,401,231	669,669	1,681,066	0
Scenario 2	2027	44,540,290	11,234,902	13,621,632	915,180	1,573,813	0	0	10,940,112	15,342,345	0	-11,234,902	658,264	1,488,944	0
Scenario 2	2028	47,635,881	12,078,153	14,352,725	939,825	1,616,194	0	0	12,007,221	16,838,852	0	-12,078,153	636,718	1,244,346	0
Scenario 2	2029	50,720,661	12,928,707	15,044,872	957,597	1,646,758	0	0	13,120,997	18,400,805	0	-12,928,707	604,527	945,105	0
Scenario 2	2030	53,789,507	13,789,615	15,694,393	967,936	1,664,640	0	0	14,282,225	20,029,303	0	-13,789,615	561,448	589,502	0
Scenario 2															

Figure 10 'Benefits' worksheet

The monetised societal costs are calculated using the country-specific data on the size of the problem ('Societal problem size') and the unit cost values ('Unit cost values'). These are calculated and forecasted for all years up to 2030 for four types of cost ('Societal problem costs'):

- Fatalities, injuries and accidents
  - o Number of fatalities
  - o Number of non-fatally injured
  - o Number of injury accidents
- Travel time
  - o Time spent travelling
- Fuel consumption
  - o Petrol
  - o Diesel
- Emissions
  - o CO_2
  - o NO_x
  - o PM-2.5

The impacts of the cooperative systems ('Impacts at 100%', see Section 3.3.2) are then applied to these monetary values to estimate the benefits of the systems. These benefits are affected by the following relationships.

In the Impact Assessment, it was assumed that the impacts were for 100% deployment. It is therefore necessary to take into account the deployment level ('Deployment level'). This is calculated using two factors:

- The deployed number of in-vehicle units – this is user-defined as either 'Low', 'Medium' or 'High'

- The length of road that is equipped with communications – this is 100% in the cellular scenario and user-defined in the wireless beacons scenario.

It is assumed that there is a linear relationship between the percentage of impacts gained and the deployment level. However, a further assumption is that the most congested and dangerous roads will be equipped with these systems first ('Hotspots'). Two curves were used that relate the deployment level to the fraction of impact gained: one for road safety impacts and one for travel time, fuel consumption and emissions impacts.

It is also necessary to take into account the level of existing infrastructure ('Existing Infrastructure'). As discussed in Section 2.2.2, it is assumed that the three bundles are delivered through three types of existing infrastructure: Roadside Travel and Routing Information, Queue Protection and Managed Motorways. On road sections with existing infrastructure, it is assumed that there are no additional benefits delivered by the cooperative systems. The level of existing infrastructure over time can be set independently for the reference and the two scenarios, and benefits and costs are adapted accordingly. If the level for a scenario is lower than for the reference, then the associated infrastructure cost savings, i.e. 'negative costs', are treated as a (positive) benefit, and any associated reduced societal benefits are treated as a (positive) cost.

Any 'un-intended impacts', i.e. 'negative benefits' are treated as a cost. For example, this might be an increase in travel times or emissions due to the introduction of the cooperative system.

In addition to the benefits listed above, the tool has been designed so that benefits arising from two further factors can be included in future versions, if sufficient information becomes available to enable these benefits to be estimated: noise and lost vehicle hours. In this version of the tool, these columns are filled in grey.

3.4.2 Estimation of costs

A screenshot of the 'Costs' worksheet is shown in Figure 11 below, which lists the costs for the two scenarios for 2012 to 2030.

	Societal costs over time: in each year											
	Cost component:		Vehicle unit - OEM	Vehicle unit - After market	Vehicle unit - Smartphone	Infrastructure - Existing VMS (see cost savings)	Infrastructure - communication platform (wireless beacons)	Infrastructure - Sensors (not used; assumed no additional sensors)	Infrastructure - back office	Infrastructure - app development (1-off)	FCD from data supplier (not used)	Help desk for end users (not used)
	Year	**Total cost**	**Cost**									
Scenario	year											
Scenario 1	2012	440,000	0	0	0	0	0	0	220,000	220,000	0	0
Scenario 1	2013	38,475,801	0	13,277,822	25,157,979	0	0	0	20,000	20,000	0	0
Scenario 1	2014	70,438,270	0	19,745,224	50,653,046	0	0	0	20,000	20,000	0	0
Scenario 1	2015	102,822,100	0	26,296,899	76,485,201	0	0	0	20,000	20,000	0	0
Scenario 1	2016	135,627,290	0	32,932,845	102,654,445	0	0	0	20,000	20,000	0	0
Scenario 1	2017	168,853,841	0	39,653,064	129,160,777	0	0	0	20,000	20,000	0	0
Scenario 1	2018	202,501,752	0	46,457,555	156,004,197	0	0	0	20,000	20,000	0	0
Scenario 1	2019	236,571,023	0	53,346,318	183,184,706	0	0	0	20,000	20,000	0	0
Scenario 1	2020	271,061,655	0	60,319,353	210,702,303	0	0	0	20,000	20,000	0	0
Scenario 1	2021	305,973,648	0	67,376,660	238,556,988	0	0	0	20,000	20,000	0	0
Scenario 1	2022	341,707,000	0	74,518,239	266,748,762	0	0	0	220,000	220,000	0	0
Scenario 1	2023	384,050,041	0	88,732,417	295,277,624	0	0	0	20,000	20,000	0	0
Scenario 1	2024	420,319,750	0	96,136,176	324,143,574	0	0	0	20,000	20,000	0	0
Scenario 1	2025	457,010,820	0	103,624,207	353,346,613	0	0	0	20,000	20,000	0	0
Scenario 1	2026	494,123,250	0	111,196,510	382,886,740	0	0	0	20,000	20,000	0	0
Scenario 1	2027	531,657,041	0	118,853,085	412,763,956	0	0	0	20,000	20,000	0	0
Scenario 1	2028	569,612,192	0	126,593,933	442,978,259	0	0	0	20,000	20,000	0	0
Scenario 1	2029	607,988,704	0	134,419,052	473,529,652	0	0	0	20,000	20,000	0	0
Scenario 1	2030	646,786,576	0	142,328,443	504,418,132	0	0	0	20,000	20,000	0	0
Scenario 1	.											
Scenario 2	2012	440,000	0	0	0	0	0	0	220,000	220,000	0	0
Scenario 2	2013	38,475,801	0	13,277,822	25,157,979	0	0	0	20,000	20,000	0	0
Scenario 2	2014	70,438,270	0	19,745,224	50,653,046	0	0	0	20,000	20,000	0	0
Scenario 2	2015	102,822,100	0	26,296,899	76,485,201	0	0	0	20,000	20,000	0	0
Scenario 2	2016	135,627,290	0	32,932,845	102,654,445	0	0	0	20,000	20,000	0	0
Scenario 2	2017	168,853,841	0	39,653,064	129,160,777	0	0	0	20,000	20,000	0	0
Scenario 2	2018	202,501,752	0	46,457,555	156,004,197	0	0	0	20,000	20,000	0	0
Scenario 2	2019	236,571,023	0	53,346,318	183,184,706	0	0	0	20,000	20,000	0	0
Scenario 2	2020	271,061,655	0	60,319,353	210,702,303	0	0	0	20,000	20,000	0	0
Scenario 2	2021	305,973,648	0	67,376,660	238,556,988	0	0	0	20,000	20,000	0	0
Scenario 2	2022	341,707,000	0	74,518,239	266,748,762	0	0	0	220,000	220,000	0	0
Scenario 2	2023	384,050,041	0	88,732,417	295,277,624	0	0	0	20,000	20,000	0	0
Scenario 2	2024	420,319,750	0	96,136,176	324,143,574	0	0	0	20,000	20,000	0	0
Scenario 2	2025	457,010,820	0	103,624,207	353,346,613	0	0	0	20,000	20,000	0	0
Scenario 2	2026	494,123,250	0	111,196,510	382,886,740	0	0	0	20,000	20,000	0	0
Scenario 2	2027	531,657,041	0	118,853,085	412,763,956	0	0	0	20,000	20,000	0	0
Scenario 2	2028	569,612,192	0	126,593,933	442,978,259	0	0	0	20,000	20,000	0	0
Scenario 2	2029	607,988,704	0	134,419,052	473,529,652	0	0	0	20,000	20,000	0	0
Scenario 2	2030	646,786,576	0	142,328,443	504,418,132	0	0	0	20,000	20,000	0	0

Figure 11 'Costs' worksheet

The cost data for each of the following components is available to view or modify in the tool ('Component costs').

- Vehicle unit - OEM (wireless beacons scenario only)
- Vehicle unit - After market (cellular scenario only)
- Vehicle unit - Smartphone (cellular scenario only)
- Infrastructure - VMS
- Infrastructure - Wireless beacons
- Infrastructure - Sensors
- Infrastructure - Back office
- Infrastructure - App development

NOTE: the VMS costs are used in the 'Cost savings' part of the model, but the sensor costs are not currently used in the model, because it is assumed that each bundle uses existing sensors, rather than deploying additional sensors to deliver the bundles of services.

There is also a parameter for the number of VMS per km, but again this is only used in the 'Cost savings' part of the model. Using this part of the model involves establishing the proportion of the road network that is equipped with the type of VMS relevant to the bundles of services assessed both now and planned for the future, the number of VMS (and hence their density), the life expectancy, and the costs of installing and operating the relevant types of VMS.

The model then allows the user to select which of the component costs are included in each bundle ('Bundle costs'). It is recommended that these default values are not modified. (Note however that operational costs of in-vehicle services can be modified on the 'Input: Parameters' worksheet.)

For each of the bullet points above, it is also necessary to determine the number of units ('Deployed units'); this takes into account the lifetimes of each of these and then estimates the following:

- Cumulative number of deployed units (used for annual operational costs - OPEX)
- Number of new units deployed each year
- Number of units replaced each year
- Number of new units deployed + number of replaced units each year (used for equipment / installation costs - CAPEX)

For the in-vehicle units, the deployed number of units depends on whether 'Low', 'Medium' or 'High' deployment is selected ('Deployment level') as shown in Figure 4 and Figure 5 of this User Guide. The method for deriving the figures to represent the deployment plan is described in COBRA D2 [2].

The bundle costs are multiplied by the deployed units to obtain estimates for the total costs each year.

The costs that are borne by the NRA are determined by which of the business models is selected ('Business models').

In addition to the costs listed above, the tool has been designed so that costs of three further components can be included in future versions, if a more refined analysis is required; these are the costs of fixed sensors for gathering data, floating vehicle data and a help desk.

3.4.3 Assumptions

The key assumptions are listed in a separate worksheet in the tool, and in D2 [2].

3.5 Outputs

Click on the 'View Output' button to see the output graphs for comparing the two scenarios which have been selected on the 'Input: Scenarios' page.

3.5.1 Societal cost benefit analysis

The first five output graphs summarise the results of the social cost benefit analysis – the benefits and costs to society as a whole.

Graph 1 (see Figure 12) shows the distribution of the monetary value of the main types of benefit and cost in each scenario, including the unintended impacts which are the benefits which may be seen as negative (such as additional travel time).

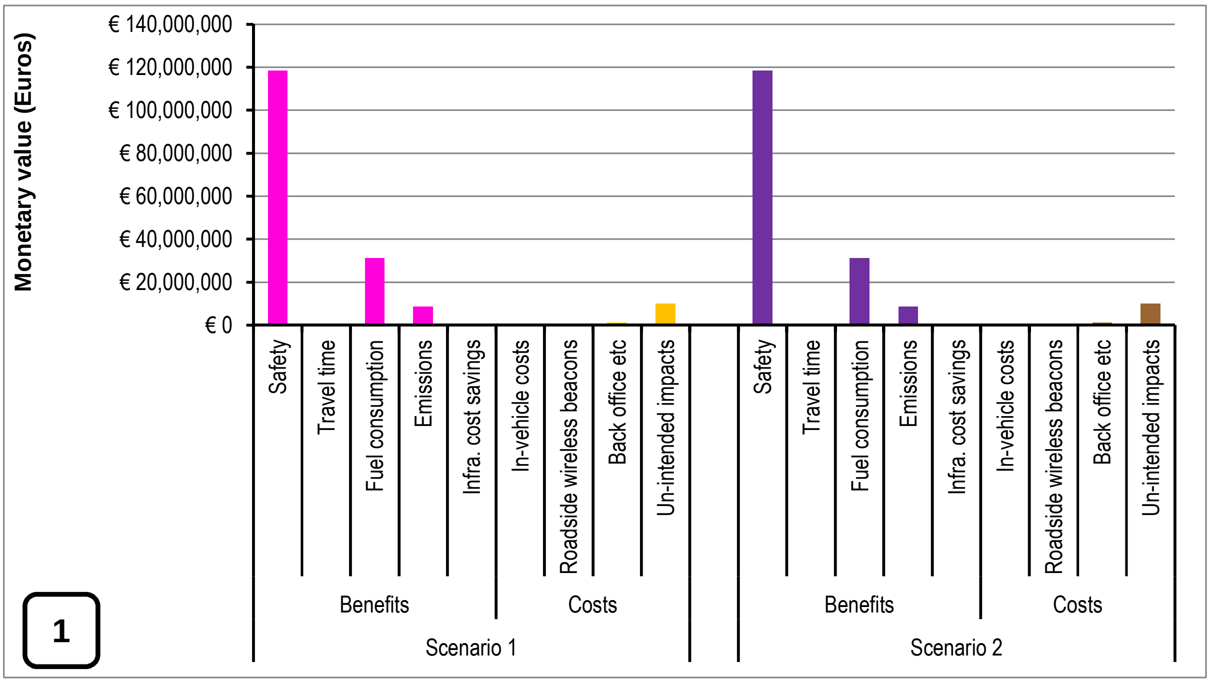


Figure 12 Graph 1 on 'Output' worksheet – distribution of monetary value of main types of benefit and cost in Scenarios 1 and 2

Graph 2 (see Figure 13) shows the total monetary value of the benefits and costs.

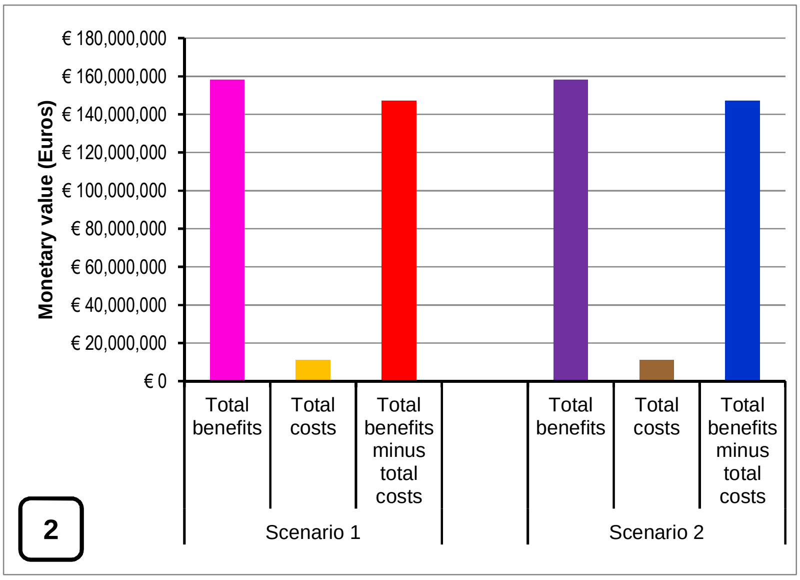


Figure 13 Graph 2 on 'Output' worksheet – total benefits and costs in Scenario 1 and 2

Graph 3 shows the total costs and total benefits in each year up to 2030 and Graph 4 shows the cumulative costs and cumulative benefits prior to each year up to 2030. These are shown in Figure 14.

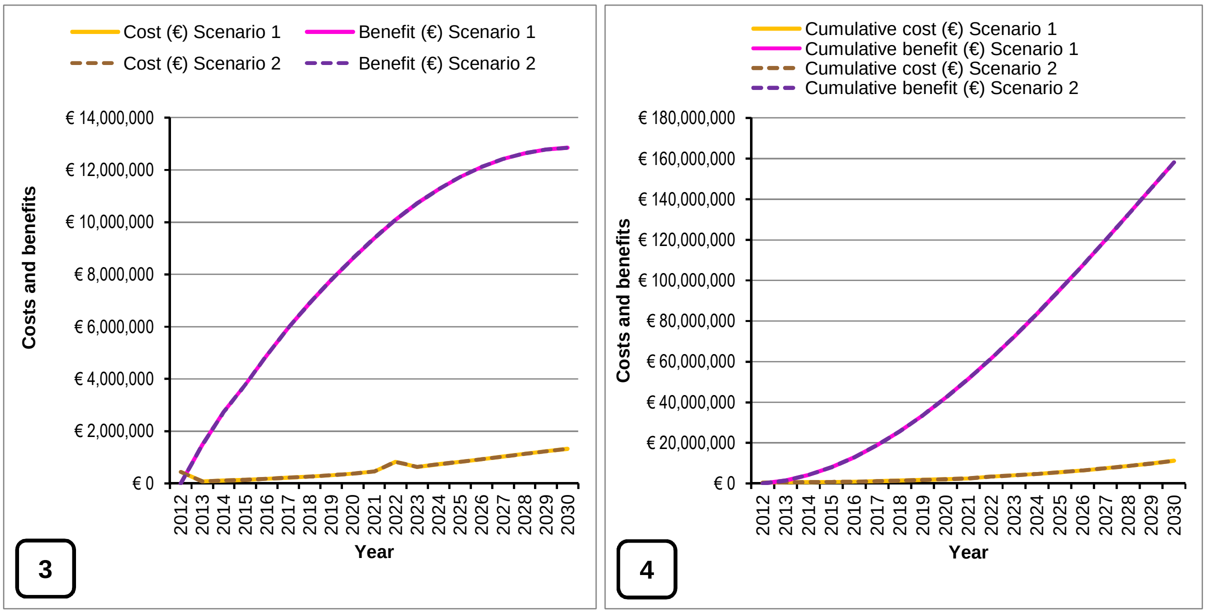


Figure 14 Graph 3 and Graph 4 on 'Output' worksheet – benefits and costs and cumulatively over time

Graph 5 (in Figure 15) shows the benefit: cost ratio over time (cumulative benefits divided by cumulative costs).

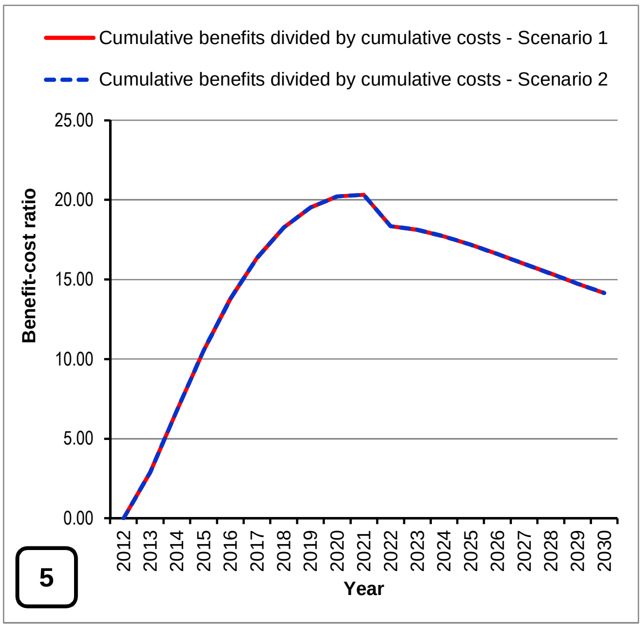


Figure 15 Graph 5 on 'Output' worksheet – cumulative benefit cost ratio over time for Scenarios 1 and 2

3.5.2 Payback year for society

The output page then shows the payback year for each scenario – i.e. the first year in which the cumulative societal benefit: cost ratio exceeds 1.0 (see Figure 16).

CBA Payback year (Scenario 1):	**2013**
CBA Payback year (Scenario 2):	**2013**

Figure 16 'Output' worksheet - payback year in social cost benefit analysis for each scenario

3.5.3 Business case for the National Road Authority

The remaining output graphs show the results of the business case analysis for the road authority, expressed in terms of the net costs to the road authority.

Graph 6 (see Figure 17) shows the monetary value of the infrastructure cost savings (benefits) and the main types of cost to the road authority.

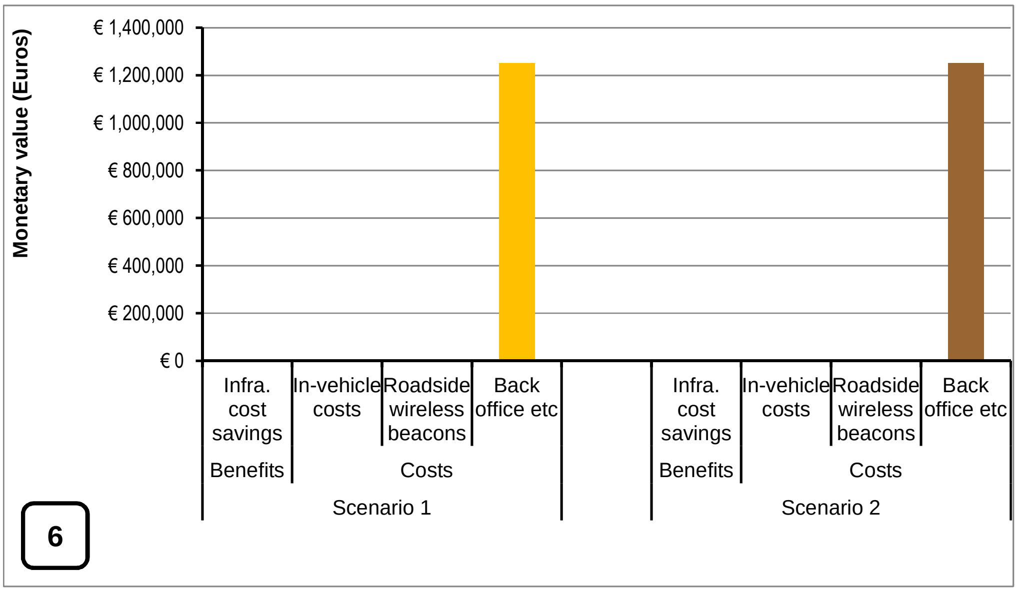


Figure 17 Graph 6 on 'Output' worksheet – distribution of benefits and costs for road authority in Scenarios 1 and 2

Graph 7 (see Figure 18) shows the total monetary value of the benefits (cost savings) and costs to the road authority and the total net costs.

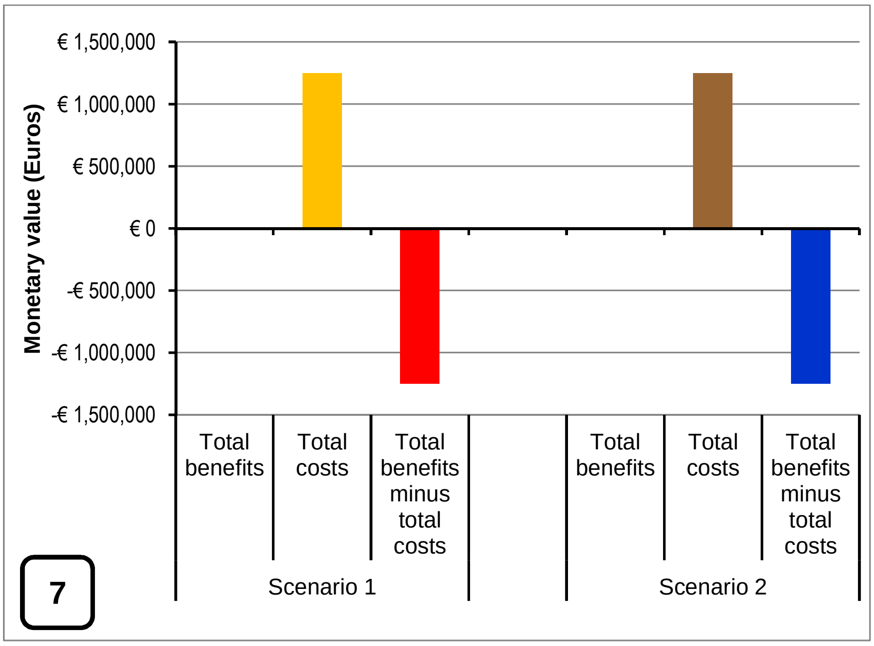


Figure 18 Graph 6 on 'Output' worksheet – total benefits and costs for road authority in Scenarios 1 and 2

Graph 8 shows the cumulative benefits and costs to the road authority over time and Graph 9 shows the cumulative net costs to the road authority over time (i.e. total benefits minus total costs); these graphs are shown in Figure 19.

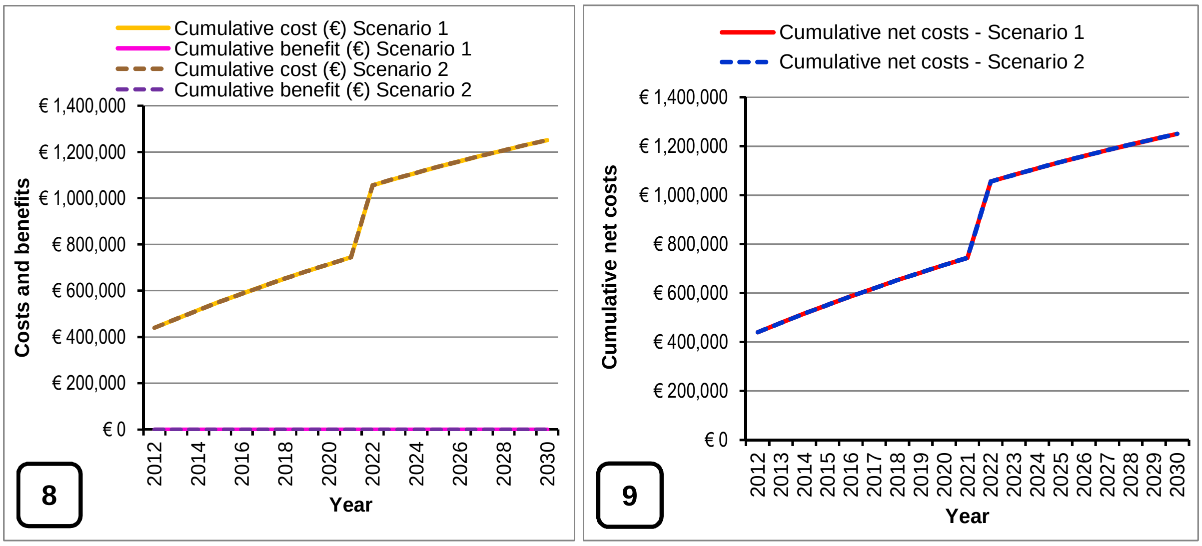


Figure 19 Graph 8 and Graph 9 on 'Output' worksheet – cumulative benefits and costs and cumulative net costs for road authority in Scenarios 1 and 2

3.5.4 Payback year for the road authority

Below Graph 9, the output page shows the payback year for the national road authority – i.e. the first year in which the cumulative net benefits for the road authority exceed the cumulative net costs (see Figure 20).

Payback year for NRA (Scenario 1):	**Not before 2030**
Payback year for NRA (Scenario 2):	**Not before 2030**

Figure 20 'Output' worksheet – payback year for road authority in Scenarios 1 and 2

3.5.5 Summary of scenario selection and parameters

The output page includes tables (numbered 10) which provide a record of how the scenarios have been defined and the values which have been set for any parameters which are open to users to vary (see Figure 21).

	Scenario 1	Scenario 2
Country	United Kingdom	United Kingdom
Bundles	Local dynamic event warnings	Local dynamic event warnings
Platforms	Cellular	Cellular
Role/business mod	BM1 - Free RA app (Cellular)	BM1 - Free RA app (Cellular)
Aftermarket/Smart	Medium	Medium
OEM vehicle penet	Medium	Medium
Start year for deplo	2012	2012
End year for deploy	2030	2030
% of infrastructure	0.025	0.025
Wireless beacons r	Linear	Linear
Include in-vehicle (	Yes, but 1/3 of price to buyer	Yes, but 1/3 of price to buyer
Include in-vehicle (	Yes	Yes
Include infrastructu	No	No

Parameters: 10	Number of wireless beacons per km= 3.3; Total number of back offices / control centres= 1; Discount rate= 3.5%; Exchange rate= 1.259; For Cellular scenario, the balance (adding up to 100%) between Aftermarket (i.e. some equipment costs) and Smartphone (i.e. no equipment costs)= 20/80 to 20/80; Subscription - OEM= 20; Subscription - Aftermarket= 20; Subscription - Smartphone= 20; Communications - OEM= 0; Communications - Aftermarket= 10; Communications - Smartphone= 10

Figure 21 'Output' worksheet – record of scenarios selected and parameters set

3.6 Sensitivity analysis

The tool enables users to compare how sensitive the results are to the effect of different options.

The options which are available on the 'Input: Scenarios' page make it possible to carry out sensitivity analysis between the scenarios defined as Scenario 1 and Scenario 2, using the graphs on the output page to illustrate the sensitivity to different factors. On this page, the following options are available:

- Cellular communications vs wireless beacons at the roadside for delivering Local Dynamic Event Warnings and In-Vehicle Speed and Signage (by making a selection in the 'Platforms row')
- Low, medium or high rates of penetration of in-vehicle equipment (by making a selection in the 'Aftermarket/ Smartphone vehicle penetration curves' row or the 'OEM vehicle penetration curves' row
- Users may choose different rates and timescales for deployment, which can be used to assess the effect of deployment following an EC mandate or a market-led roll-out of services – for example an EC mandate can be represented by selecting 100% deployment from a given date. Timescales for deployment are selected in the 'Start year for deployment of wireless beacons roadside units' and 'End year for deployment of wireless beacons roadside units' rows. The rate of deployment of roadside beacons can be varied by selecting the '% of infrastructure equipped with wireless beacons roadside units in end year' row
- The costs of in-vehicle equipment can be varied to represent different views of who bears the costs and different deployment scenarios by making selections on the 'Include in-vehicle CAPEX costs' and the 'Include in-vehicle OPEX costs' rows.

In addition there are further options on the Input: Parameters page; these options apply to both Scenario 1 and Scenario 2, so any sensitivity analysis on these parameters needs to be carried out by making visual comparisons between different 'runs' of the model. The factors which users are most likely to assess for sensitivity are:

- Delivery of cellular communications in vehicles via aftermarket in-vehicle equipment vs smartphones. Users may define the proportion of vehicles equipped with aftermarket and smartphone in 2012 and 2030 (the default values are 20% aftermarket and 80% smartphone in both years). These options can be used to represent a situation in which vehicles can accept functional upgrades, overcoming the problem that services evolve more rapidly than the replacement cycle of vehicles themselves.

- Level of deployment of fixed infrastructure – including wireless beacons
- Annual operational costs of services (subscriptions and communications)

It is also possible to carry out sensitivity analysis on:

- the discount rate used for converting the cost of future investment or benefits into current values using the 'Input: Parameters' page.

A more 'advanced' user may wish to carry out sensitivity analysis on some of the other values included in the tool, such as:

- Estimates of the component costs of the various systems – (which can be done by amending values in the 'Component Costs' page apart from annual operational costs, which are modified on the 'Input: Parameters' page)
- Underlying data on the country concerned (such as number of casualties, time spent in traffic, fuel consumption, emissions, and values for converting these into monetary terms); this can be done by amending values in the 'Country data and forecasts' page.

4 Glossary and definitions

App	Application used to deliver a service
Aftermarket	In-vehicle device fitted after purchasing the vehicle, usually permanently connected to the vehicle's systems
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
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
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. It is assumed here that these are large signs which can provide several lines of text and colour graphics, providing the existing infrastructure for information delivery for all of the three bundles of services considered here: warnings, speed limits, travel information and route guidance
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.

5 References

[1] Vermaat P, Hopkin J, van Wees K A P C, Faber F, Deix S, Nitsche P, Michael K 2012. COBRA D1 State of the Art Report. COBRA Consortium.

[2] Faber F, van Noort M, Hopkin J, Vermaat P, Nitsche P, Deix S 2012. COBRA D2 Methodology Framework. COBRA Consortium.

[3] Mocanu I, Nitsche P, Deix S, Malone K, Hopkin J, Ball S 2012. COBRA D3.1 Impact Analysis. COBRA Consortium

[4] Hopkin J, Stevens S, Palmer D, Ball S, Vermaat P, Malone K, van Noort M, Nitsche P, Deix S 2013. COBRA D4.1 Example Results of Cost Benefit Analysis. COBRA Consortium.

Appendix A. Data required for a particular country

This appendix lists the input data that is required for a particular country (or local area), using UK values as an example. Data for the UK and the Netherlands is included in Version 1.01 of the tool.

NOTE: Oil price forecasts and traded values of CO_2 (Table 6) can be used for any country. Ideally all other data should be inputted for each individual country. However, it may be sufficient to use the UK value in some instances where the data is not readily available. The source of any data should also be provided.

NOTE: grey rows are not used in the current version of the tool but are available to use in future enhancements.

Table 2 - Societal Problem size data

Type	Description	Units	Value	Source	Forecast scale factor	Source
Road Safety	number of fatalities (EasyWay network)	number/year	470	Easyway	0.592	Updated post-2010 casualty forecasts, TRL Report PPR552; Tables 3.1 and 3.4
	number of non-fatally injured (EasyWay network)	number/year	3,940	Easyway	0.437	Updated post-2010 casualty forecasts, TRL Report PPR552; Tables 3.1 and 3.4
	number of all accidents including property damage only (EasyWay network)	number/year	24,900	Easyway	0.437	Updated post-2010 casualty forecasts, TRL Report PPR552; Tables 3.1 and 3.4
Time spent in traffic	number of hours spent (EasyWay network)	million vehicle hours/ year	1,313	Easyway	1.501	Road Transport Forecasts 2011 (National Transport Model), Table 4.1
	Lost vehicle hours (EasyWay network)	million vehicle hours/ year	448	Easyway	2.065	Road Transport Forecasts 2011 (National Transport Model), Table 4.1
Fuel consumption	Gasoline (EasyWay network)	million litre/year	5,700	Easyway	1.501	use travel time forecast
	Diesel (EasyWay network)	million litre/year	7,300	Easyway	1.501	use travel time forecast

Type	Description	Units	Value	Source	Forecast scale factor	Source
Noise	Noise			no data		
Emissions	CO2	million tonne/year	42.4685	Easyway	0.8859	Road Transport Forecasts 2011 (National Transport Model), Table 4.1
	NOx	million tonne/year	0.0624	Easyway	0.2618	Road Transport Forecasts 2011 (National Transport Model), Table 4.1
	PM-2.5	million tonne/year	0.0220	Easyway	0.0714	Road Transport Forecasts 2011 (National Transport Model), Table 4.1

Table 3 - Unit cost data

Type	Description	Units	Value	Source	Forecast scale factor	Source
Accident unit costs	Fatality - value of prevention (lost output, medical and ambulance, human costs)	Euro/fatality	2,112,289	DfT WebTAG Unit 3.4.1, Table 1 (Aug 2012), 2010 value, scaled up by GDP to 2012 value		GDP forecasts used
	Serious injury - value of prevention (lost output, medical and ambulance, human costs)	Euro/ serious injury	237,366	DfT WebTAG Unit 3.4.1, Table 1 (Aug 2012), 2010 value, scaled up by GDP to 2012 value		GDP forecasts used
	Slight injury - value of prevention (lost output, medical and ambulance, human costs)	Euro/ slight injury	18,291	DfT WebTAG Unit 3.4.1, Table 1 (Aug 2012), 2010 value, scaled up by GDP to 2012 value		GDP forecasts used

Type	Description	Units	Value	Source	Forecast scale factor	Source
	Injury accidents - value of prevention (police costs, insurance and admin, property damage)	Euro/ injury accident	5,724	DfT WebTAG Unit 3.4.1, Table 3 (Aug 2012), 2010 value, scaled up by GDP to 2012 value		GDP forecasts used
Value of time	Value of time, weighted by working / non-working time	Euro/ vehicle hour	10.77	Derived using % driven as: - Car, non-working time (Commuting) - Car, non-working time (Other) - Car, working time (Business) - LGV, working time - HGV, working time		
	Cars (driver + passengers)	Euro/ hour working time (resource cost)	40.07	Derived using occupancy data		
	Cars (driver)	Euro/ hour working time (resource cost)	35.69	DfT WebTAG Unit 3.5.6, Table 1 (Oct 2012)		
	Cars (passenger)	Euro/ hour working time (resource cost)	25.57	DfT WebTAG Unit 3.5.6, Table 1 (Oct 2012)		
	Light Good vehicle (driver or passenger)	Euro/ hour working time (resource cost)	13.75	DfT WebTAG Unit 3.5.6, Table 1 (Oct 2012)		
	HGV (OGV) (driver or passenger)	Euro/ hour working time (resource	13.75	DfT WebTAG Unit 3.5.6, Table 1 (Oct 2012)		

Type	Description	Units	Value	Source	Forecast scale factor	Source
		cost)				
	All persons – non-working time, commuting	Euro/ hour non-working time (resource cost	6.90	DfT WebTAG Unit 3.5.6, Table 2 (Oct 2012)		Value of non-working time forecasts used
	All persons – non-working time, other	Euro/ hour non-working time (resource cost)	6.10	DfT WebTAG Unit 3.5.6, Table 2 (Oct 2012)		Value of non-working time forecasts used
Fuel costs	Petrol (price at pump)	Euro/ litre	1.71	DECC average retail prices of petroleum products Table 4.1.1 (Nov 2012)		
	Petrol (price at pump excluding VAT)	Euro/ litre	1.42	20% VAT		
	Fuel duty on petrol	Euro/ litre	0.7296	https://www.gov.uk/fuel-duty#rates-of-fuel-duty		
	Petrol (excluding tax and VAT)	Euro/ litre	0.70	Derived		oil price forecasts used
	Diesel (price at pump)	Euro/ litre	1.79	DECC average retail prices of petroleum products Table 4.1.1 (Nov 2012)		
	Diesel (price at pump excluding VAT)	Euro/ litre	1.49	20% VAT		
	Fuel duty on diesel	Euro/ litre	0.7296	https://www.gov.uk/fuel-duty#rates-of-fuel-duty		
	Diesel (excluding tax and VAT)	Euro/ litre	0.76	Derived		oil price forecasts used
Environmental costs	Damage cost value - CO_2	Euro/ tn	69	DfT WebTAG Unit 3.3.5, Table 2a (Aug 2012)		CO_2 forecasts used

Type	Description	Units	Value	Source	Forecast scale factor	Source
	Damage cost value - NO_x	Euro/ tn	1202	DfT WebTAG Unit 3.3.3, Table 4 (Aug 2012)		CO_2 forecasts used
	Damage cost value - PM 2.5	Euro/ tn	139,355	Easyway		CO_2 forecasts used

Table 4 - Additional data for value of time calculation

Type	Description	Units	Value	Source	Forecast scale factor	Source
Distance driven by type of vehicle	Cars and taxis	% of total driven distance	75.4%	DfT TSGB 2011, Table TRA0104		
	Motorcycles	% of total driven distance	0.3%	DfT TSGB 2011, Table TRA0104		
	Buses & coaches	% of total driven distance	0.5%	DfT TSGB 2011, Table TRA0104		
	Light vans	% of total driven distance	12.6%	DfT TSGB 2011, Table TRA0104		
	Goods vehicles	% of total driven distance	11.2%	DfT TSGB 2011, Table TRA0104		
	All motor vehicles	% of total driven distance	100.0%	DfT TSGB 2011, Table TRA0104		
Distance driven by working /	Business travel by car	% of total driven distance	7.96%	DfT NTS 2010, Table NTS0901		

Type	Description	Units	Value	Source	Forecast scale factor	Source
non-working	Commuting travel by car	% of total driven distance	23.97%	DfT NTS 2010, Table NTS0901		
	Other private travel by car	% of total driven distance	43.47%	DfT NTS 2010, Table NTS0901		
	Car travel as % of total travel	% of total driven distance	75.40%	DfT NTS 2010, Table NTS0901		
Car occupancy	average occupancy - working time	weighted average of survey respondents	1.17	DfT NTS 2010, Table NTS0906		
	average occupancy - non-working time	weighted average of survey respondents	1.73	DfT NTS 2010, Table NTS0906		

Table 5 - Discount rate

Type	Description	Units	Value	Source	Forecast scale factor	Source
	Discount rate	Percentage	3.50%	DfT WebTAG Unit 3.5.4 (Aug 2012)		

Table 6 - Network and vehicle ownership data

Type	Description	Units	Value	Source	Forecast scale factor	Source
Road	KM of 'Roadside Travel and Routing Information'	km	3,500	Estimate from Highways Agency data		

Type	Description	Units	Value	Source	Forecast scale factor	Source
	KM of 'Queue Protection' with loop detection	km	3,500	Estimate from Highways Agency data		
	Km of 'Variable Speed Limits / Managed Motorways'	km	50	Estimate from Highways Agency data		
	Total km (Easyway Network)	km	8,000	Estimate from EC data on TERN		
Vehicles	Total number of vehicles	number of vehicles	31,930,944	Derived		
	Total number of cars	Number of cars	28,635,514	DfT statistics; Vehicle Licensing Statistics; Table VEH0102 (2011 value scaled-up)	168,225	Table VEH0102; linear regression on 2005-2011; number new cars per year
	Total number of vans	Number of vans	3,295,430	DfT statistics; Vehicle Licensing Statistics; Table VEH0102 (2011 value scaled-up)	47,137	Table VEH0102; linear regression on 2005-2011; number new vans per year

Table 7 - Unit cost forecasts

Description	Units	Source	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
GDP growth	% increase per year	DfT WebTAG Unit 3.5.6, Table 3a (Oct 2012)	0.80%	2.00%	2.70%	3.00%	3.00%	2.70%	2.20%	2.20%	2.20%	2.40%	2.30%	2.30%	2.40%	2.30%	2.30%	2.30%	2.30%	2.30%	2.30%
Value of time growth (working time)	% increase per year	DfT WebTAG Unit 3.5.6, Table 3b (Oct 2012)	0.09%	1.28%	1.98%	2.30%	2.33%	2.13%	1.63%	1.64%	1.64%	1.85%	1.76%	1.77%	1.89%	1.80%	1.82%	1.83%	1.85%	1.87%	1.88%
Value of time growth (non-working time)	% increase per year	DfT WebTAG Unit 3.5.6, Table 3b (Oct 2012)	0.07%	1.02%	1.58%	1.84%	1.86%	1.70%	1.30%	1.31%	1.31%	1.48%	1.41%	1.42%	1.51%	1.44%	1.45%	1.46%	1.48%	1.49%	1.50%
Oil price (central value)	$ per barrel (2012 prices)	DECC Fossil Fuel Price Projections (Oct 2012)	115.0	116.0	117.1	118.1	119.2	120.2	121.3	122.4	123.5	124.6	125.7	126.8	128.0	129.1	130.3	131.4	132.6	133.8	135.0
Oil price (central value) - growth	% increase per year	DECC Fossil Fuel Price Projections (Oct 2012)	0.00%	0.87%	0.95%	0.85%	0.93%	0.84%	0.92%	0.91%	0.90%	0.89%	0.88%	0.88%	0.95%	0.86%	0.93%	0.84%	0.91%	0.90%	0.90%
Non-traded values of CO_2 (central value)	£ per Tonne (2010 prices)	DfT WebTAG Unit 3.3.5, Table 2a (Aug 2012)	55.2	56.0	56.9	57.7	58.6	59.5	60.4	61.3	62.2	63.2	64.3	65.3	66.3	67.4	68.4	69.4	70.5	71.5	72.6
Non-traded values of CO_2 (mid value) - growth	% increase per year	DfT WebTAG Unit 3.3.5, Table 2a (Aug 2012)	1.49%	1.50%	1.50%	1.49%	1.51%	1.50%	1.50%	1.51%	1.49%	1.67%	1.65%	1.60%	1.59%	1.57%	1.53%	1.52%	1.50%	1.46%	1.45%