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PART 2/2

COMMISSION STAFF WORKING DOCUMENT

IMPACT ASSESSMENT

Accompanying the document

Commission Delegated Regulation

supplementing Directive 2010/40/EU of the European Parliament and of the Council with regard to the deployment and operational use of cooperative intelligent transport systems

{C(2019) 1789 final} - {SEC(2019) 100 final} - {SWD(2019) 95 final}

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Glossary

Term or acronym	*Meaning or definition*
3GPP	3rd Generation Partnership Project
5G	5th generation of communication networks
CCAM	Connected, Cooperative and Automated Mobility
CEPT	European Conference of Postal and Telecommunications Administrations
C-ITS	Cooperative Intelligent Transport Systems
CP	Certificate Policy for C-ITS security
EEA	European Environmental Agency
GDP	Gross domestic product
GDPR	General Data Protection Regulation
GSR	General Safety Regulation
IRC	Impact Reduction Container
ITS	Intelligent Transport Systems
ITS-G5	IEEE 802.11p (wifi) communications protocol for C-ITS communication
I2I	Infrastructure-to-infrastructure communication
LTE	Long Term Evolution
LTE-V2X or C-V2X	Cellular communications protocol for C-ITS communication
RISM	Road Infrastructure Safety Management
RSU	Road-side unit
SP	Security Policy for C-ITS security
CCMS	C-ITS Security Credential Management System
V2I	Vehicle-to-infrastructure communication
V2V	Vehicle-to-vehicle communication
V2X	Vehicle-to-everything communication
VOC	Volatile Organic Compounds (air pollutants)
VRU	Vulnerable Road User

Annex 1: Procedural information

1. LEAD DG, DECIDE PLANNING/CWP REFERENCES

Decide Reference	Short title	Foreseen adoption
PLAN/2017/662	Specifications for the provision of cooperative intelligent transport systems (C-ITS)	4th quarter 2018

2. ORGANISATION AND TIMING

The Inter Service Steering Group (ISSG) for the Impact Assessment was set up in April 2017 and includes the following DGs and Services: SG, SJ, CONNECT, GROW, JRC, CLIMA, ENER, ENV, RTD, COMP, REGIO and DIGIT.

Five meetings of the Steering Group were organised between 5 April 2017 and 3 September 2018. Further consultations with the ISSG were carried out by e-mail.

The ISSG approved the Inception Impact Assessment. The ISSG also discussed the main milestones in the process, in particular the consultation strategy and main stakeholder consultation activities, the task specifications to launch the contract for the external IA support study, key deliverables from the support study, and the draft impact assessment report before the submission to the Regulatory Scrutiny Board.

3. CONSULTATION OF THE RSB

The impact assessment was submitted to the Commission's Regulatory Scrutiny Board on 13 September 2018. Following the meeting on 10 October 2018, the Board issued a positive opinion with reservations on 12 October 2018. The Board made recommendations. Those were addressed in the revised IA report as follows:

Main considerations	Modification of the IA report
(1) The report does not make sufficiently clear the need for a step-wise approach to reach the objectives of the initiative. As a result, the choice of the preferred option does not clearly flow from the analysis and presentation of the report. The option concerning a stronger intervention based on V2V mandate and governance structure does not allow to address fully the issues at stake.	The distinction between the different policy options and the considerations behind them have been reviewed and clarified throughout the document, in particular in sections 5.3, 7 and 8.
(2) The report does not explain why it does not (yet) address stakeholder concerns on the safety of vulnerable road users and environmental impacts.	The impact of C-ITS on VRUs has been further clarified in section 6.1 and 6.5, while clarifying that VRU specific C-ITS services are not yet mature to be included in specifications and thus the policy options considered in this impact assessment. The stakeholder concerns have been described in more detail in Annex 2.

Further considerations and adjustment requirements	
(1) The report should show why it is advisable to address interoperability now and deployment later. The analysis should take into account the risks of such a stepwise approach, in particular in terms of collusive behaviour of the car industry. The report should further clarify that a strong intervention based on V2V mandate and governance structure (option 3) is not a standalone option. It would require an additional impact assessment and a different legal proposal to implement. In addition, the report should discuss why a strong intervention is premature or not possible at this point in time. Finally, the report should briefly explain the rationale for retaining the light intervention based on non-legislative measures (option 1), given how little it would seem to deliver on the objectives.	The distinction between the different policy options and the considerations behind them have been reviewed and clarified throughout the document, in particular in sections 5.3, 7 and 8. The need for a separate impact assessment for additional legislative measures, including a V2V mandate, is explicitly included. Rationale for PO1 as well as the step-wise approach has been reviewed.
(2) The report should better demonstrate that options are future proof. It should explain how newly emerging standards fit into the framework in the future while remaining backward compatible with older versions. It should provide more information on the role that different technologies can play in cooperative intelligent transport systems.	The role of different technologies in C-ITS is further explained in section 2.3.2. The role of the review process is further elaborated in section 5.3.3.
(3) The report should better explain how it addresses the concerns of vulnerable road users, such as pedestrians and cyclists, and how the initiative might affect them. In this context, the report should clarify what services intelligent transport systems already deliver and which ones they will plausibly deliver in the future.	The impact of C-ITS on VRUs has been further clarified in section 6.1 and 6.5, while clarifying that VRU specific C-ITS services are not yet mature to be included in specifications and thus the policy options considered in this impact assessment. Annex 2 and 4 have also been updated in this regard.
(4) The report should take care not to create unrealistic expectations with regard to safety and environmental benefits. It could make clearer that the initial focus is on road safety. This discussion should also include an explanation of how these benefits depend on the deployment of specific services (for example, Day 1 and Day 1.5 services), so that some benefits will materialise sooner than others. The report should be more transparent on the contribution (in terms of magnitude and timespan) of the preferred option to road safety and transport emissions, in comparison to what a stronger intervention on V2V (option 3) is expected to deliver.	The sensitivity analysis in section 6.5 has been expanded to all policy options, and adjustments have been made throughout the report to better differentiate the policy options. Annex 4, section 2 has been updated to reflect that day 1 services have a strong focus on safety and further clarify the limitations of the analysis.
(5) The report should elaborate on the role of road-side C-ITS infrastructure and the extent to which it is needed for C-ITS to function efficiently and effectively. This should describe the necessary contributions from and choices available to national, regional and public authorities.	The role of road-side units has been further explained in section 2.3.2. It is clarified that the decision to deploy roadside infrastructure is often expected to be made on a case-by-case basis by public authorities or road operators.
(6) The report should add information about how the initiative addresses data protection issues. The report should clarify the nature and scope of the data at stake and where additional data protection adjustments are needed when data is processed for road safety and traffic efficiency (i.e. data	Section 6.4 has been added to discuss the data protection impacts of the different policy options. Annex 6 has also been updated in this regard.

minimisation). It should also clarify what data protection the different options propose.	

4. EVIDENCE, SOURCES AND QUALITY

The starting points of the drafting of the Impact Assessment were the final reports of the C-ITS Platform Phases I and II[1]. The Platform[2] was conceived as a cooperative framework including national authorities, C-ITS stakeholders and the Commission in the form of a Commission Expert Group, in view to develop a shared vision on the interoperable deployment of C-ITS in the EU.

Information provided by the stakeholders through the stakeholder consultation activities were an important source of information (see Annex 2). It was completed by information provided ad hoc by different stakeholders to the Commission, as well as by experts appointed by MS in the ITS expert group, that met 12 times between 23 May 2016 and 5 September 2018.

The Commission sought external expertise through a contract for a support study with RICARDO Energy & Environment, supported by TRT and TEPR, which was launched in September 2017. The findings of the impact assessment report build on the final report from this contract.[3]

Overall, the sources used for the drafting of the Impact Assessment report are numerous, diverse and representative of the different stakeholder groups.

1 Available at: https://ec.europa.eu/transport/themes/its/c-its_en
2 http://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupDetail&groupID=3188
3 Final report to be published together with the Impact Assessment

Annex 2: Stakeholder consultation synopsis report

1. INTRODUCTION

In the context of the preparation of the Impact Assessment, various stakeholder consultation activities were carried out. Consultation activities sought both qualitative (opinions, views, suggestions) and quantitative (data, statistics) information. Some of these activities were part of the Impact Assessment support study (by an external contractor, RICARDO), which was launched in September 2017.

This annex provides an overview of the stakeholder groups that were consulted as well as a summary and analysis of the responses received. The consultation covered all aspects of the Impact Assessment (problem definition, EU dimension, options and potential impacts).

The consultation process[4] engaged main target groups through different methods, combining:

- Work in the C-ITS Platform
- Publication of the Inception Impact Assessment
- a Public Consultation
- Targeted consultations included in-depth interviews for EU and international case studies
- a stakeholder workshop with follow-up survey
- meetings with experts appointed by Member States

Throughout the period of preparing the Impact Assessment, Commission services have additionally met with a wide variety of stakeholders, and received several position papers.

2. CONSULTATION METHODS

Work in the C-ITS Platform

In early 2014, the Commission decided to take a more prominent role in the deployment of connected driving, by setting up the C-ITS Deployment Platform. The Platform was conceived as a cooperative framework including national authorities, C-ITS stakeholders and the Commission, in view to develop a shared vision on the interoperable deployment of C-ITS in the EU.

The Platform consisted of an expert group (E01941), with experts representing key stakeholder groups selected following an open call for application. The work of the plenary (8 meetings in 2014-2017) was supported by 18 working groups working on specific topics during the two phases.

The first phase of the C-ITS platform (2014-2016) provided policy recommendations for the development of a roadmap and a deployment strategy for C-ITS in the EU and identify potential solutions to some critical cross-cutting issues.

The second phase (2016-2017) of the platform further developed a shared vision on the interoperable deployment of C-ITS towards connected and automated mobility (CCAM) in the European Union.

4 More detail can be found in Annex A of the support study

The final reports of both phases, endorsed by the plenary of the Platform, and all its deliverables can found on the Commission website.[5]

Publication of the Inception Impact Assessment

The Inception Impact Assessment[6] for the initiative was published on 22 May 2017 and was open for feedback until 19 June 2017. Two responses were received through the feedback mechanism, one from a public authority and one from a business association. The responses were generally favourable of the initiative and asked for the following additional aspects to be considered: the link to automation, the need for harmonization and ensure equal access to data.

Public Consultation (PC)

The Public Consultation was launched on the Commission website on 10 October 2017 and was open for responses until 12 January 2018 (13 weeks).[7] The questionnaire for the consultation was prepared by DG MOVE, together with the members of the steering group and the consultant for the support study. It invited stakeholders' opinions on the key elements of the Impact Assessment: the main problems, their drivers, possible policy measures and their likely impacts and the relevance of EU level action. The consultant summarised the results of the public consultation in a detailed report.[8]

5 https://ec.europa.eu/transport/themes/its/c-its_en

6 http://ec.europa.eu/info/law/better-regulation/initiatives/ares-2017-2592333_en

7 https://ec.europa.eu/info/consultations/public-consultation-specifications-cooperative-intelligent-transport-systems_en

8 Published online in March 2018: https://ec.europa.eu/transport/sites/transport/files/2017-c-its-opc-analysis.pdf and included in annex E of the support study

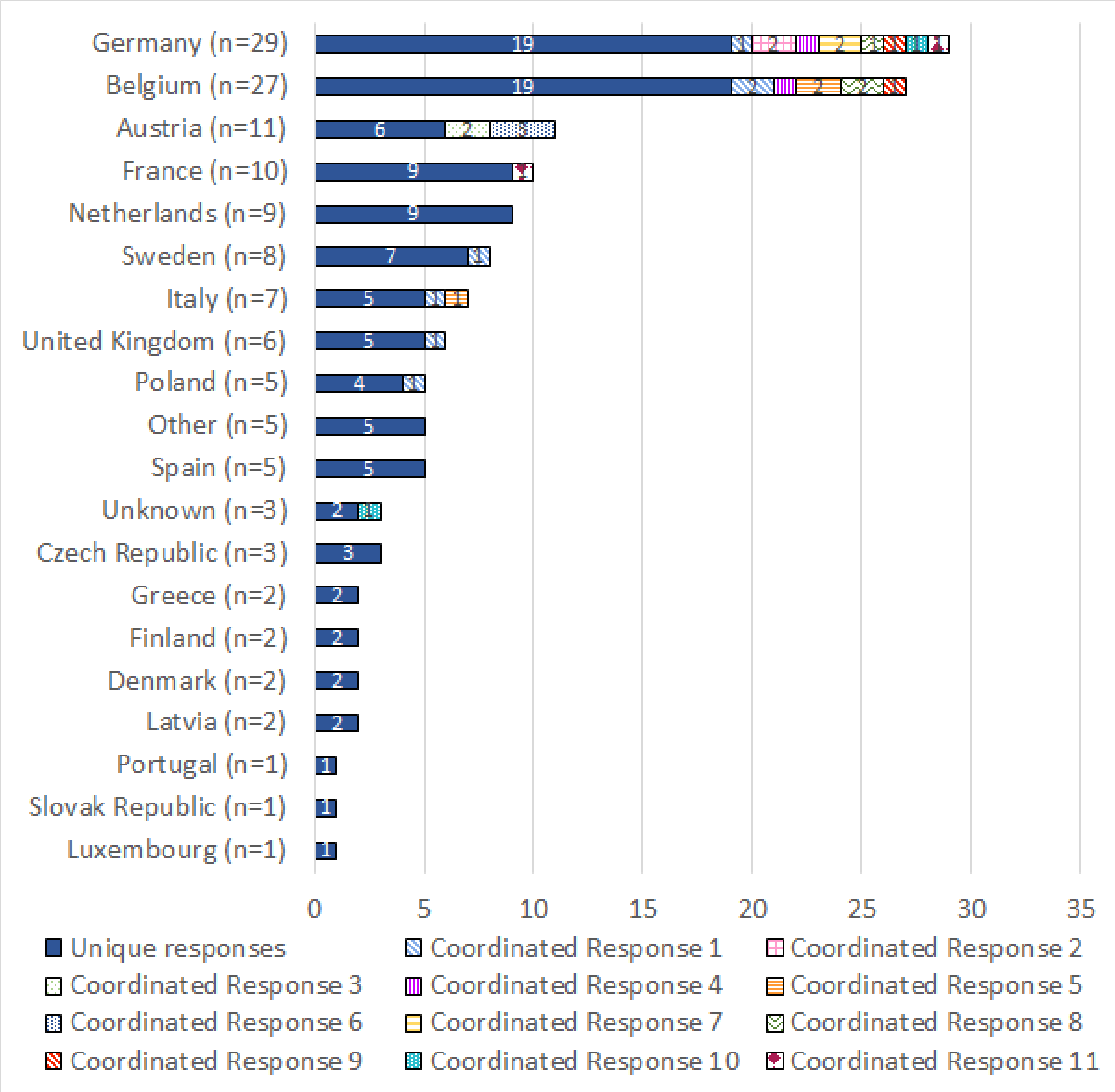


Figure 1: Overview of participants to PC according to main country of operation/residence

The public consultation received 138 responses from 18 EU Member States, of which 40 by companies, 37 by associations, 32 by public authorities, 11 by individual citizens and 8 by NGOs.

Table 1: Overview of participants to PC according to main interest (multiple options possible)

Stakeholder type[9]	**Stakeholder engagement activity**		
	Public consultation	Case studies & data requests	Stakeholder workshop[10]
Vehicle and equipment manufacturers/suppliers/repairs	33	3	25

9 Stakeholder type based on most frequently indicated categories of interest in the Public Consultation (the total of 142 is higher than the amount of responses (considering that some stakeholders indicated multiple interests). In other consultation activities this was not explicitly asked and the figures are only indicative of the different interests represented.

10 Signed in participants only

Road/transport operators	18	-	2
Regional or local public authorities	14	-	9
National Public Authorities	14	9	14
Societal interests and/or consumer rights	11	-	6
Research/Academia/Consultancies	9	-	28
ITS service providers	9	3	8
Telecom service providers	6	1	6
Road authorities	4	4	2
Other	24	-	9

The geographical distribution of respondents (Figure 2) shows a particular strong response from front-runner countries in C-ITS deployment as can be expected (e.g. Germany, Austria, France, Netherlands, Sweden), plus many responses from Belgium, including EU-level organisations.

The analysis of the responses also suggested that a total of 30 responses (22% of total responses, with the largest coordinated response consisting of 7 responses) were coordinated, following a template for answers. Since respondents were free to adapt the answers to express their own views, coordinated responses have been analysed individually.

The indicated interests (Table 1) shows a diverse coverage of interests with a particularly strong response from vehicle and equipment manufacturers/suppliers/repairs and road/transport operators, which fits with the expectation that these stakeholders are expected to make the most substantial investment into C-ITS stations.

In addition to the responses to the questionnaire, 46 additional contributions and position papers were submitted, which have also been analysed.

Targeted consultations included in-depth interviews for EU and international case studies

As part of the support study, a number of case studies where carried out: 9 on EU C-ITS deployment projects (plus 1 for the coordination C-ROADS platform) + 3 case studies on international C-ITS deployment (US, Australia and Japan), which included interviews with senior representatives (see Table 1) between October 2017 and February 2018. All case studies focused on the objectives, progress, barriers and data collection on cost and performance of C-ITS deployment within the case study subject; for the EU case studies respondents were additionally asked to provide feedback on the problem definition, policy measures & options, and monitoring & evaluation for this policy initiative.

To complement the information of the case studies on cost and input data for the modelling, the consultant carried out 7 additional interviews / surveys with key stakeholders.

Stakeholder workshop with follow-up survey

A stakeholder workshop was held on 9th February 2018, to gather specific information and data and obtain views and suggestions from experts and stakeholders. The workshop was well attended with more than 140 participants.

In the morning session the project team presented the overview and status of the study and the results of the online public consultation. In the Q&A important elements, including the design of the draft policy options, were discussed. 23 stakeholders presented their views on C-ITS, including among others C-ITS deployment initiatives, car manufacturers, technology and telecommunications providers, organizations representing road users, public transport and cities, and researchers.

The afternoon session consisted of an interactive presentation on the modelling framework for the study, in which the approach and assumptions used in the study were discussed, allowing stakeholders to offer detailed views and help to correct or amend the analytical approach. Some key elements discussed were the cost data and the uptake scenarios in vehicles and infrastructure. The presentations from the consultant and the stakeholders can be found on the Commissions C-ITS webpage[11].

The discussion in the workshop was complemented by an online survey of attendees to get individual responses on the discussion items. The survey was open for two weeks following the workshop, during which time 19 completed responses were submitted.

Meetings with experts appointed by Member States

In the preparation of this initiative, 12 meetings have been held with an expert group (E01941)[12] consisting of experts appointed by Member States plus Norway and Switzerland, between May 2016 and September 2018, with the aim to assist the Commission in the preparation of the initiative and to coordinate and exchange views on C-ITS. As part of these meetings, the experts have been closely informed on the methodology and progress of the Impact Assessment and consulted on key elements, including the problem definition, policy measures & options and the modelling approach.

3. RESULTS OF CONSULTATION ACTIVITIES

The remainder of the report presents the main findings from the analysis of stakeholder contributions to the consultation process. These are structured following the areas of a) problem definition, b) objectives & need for EU action, c) policy measures & options and d) impacts

Problem definition

In the public consultation, a large majority (81%) of respondents in the PC (strongly) agreed with the **main problem definition** that *"deployment is being delayed due to several barriers and uncertainties... Without a clear legal framework, C-ITS deployment is expected to remain slow and fragmented, resulting in interoperability issues and hindering continuity of services. This in turn will hinder the deployment and uptake of C-ITS and the realization of their full benefits, in particular with regards to road safety and traffic efficiency."* The assessment is similar across

11 https://ec.europa.eu/transport/themes/its/events/stakeholder-workshop-cooperative-intelligent-transport-systems_en

12http://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupDetail&groupID=1941&NewSearch=1&NewSearch=1

stakeholder groups, with at least 77% in each main stakeholder group (strongly) agreeing. In the other consultation activities, the problem definition received a similar support and comments.

Several stakeholders considered however, that additional issues should get more consideration, in particular the investment costs and funding for C-ITS, the need for action on access to in-vehicle data and the need to make C-ITS relevant for vulnerable road users & public transport. Associations representing cities and public transport also emphasized the latter during the stakeholder workshop.

Regarding the **problem drivers**, a large majority of respondents across groups (strongly) agreed (70-80%) with all drivers identified. Several stakeholders considered that the uncertainty on costs & benefits (and attention to user needs), access to in-vehicle data and liability should be more prominent in the problem analysis. While the agreement was high across all stakeholder groups, private companies scored the importance of problem drivers lower that other stakeholder categories. While respondents agreed that "incompatible communication technologies" are an important driver of the problem, stakeholder were divided on how this driver should be tackled, with some arguing that a clear technology choice should be made to create certainty to investment, while others arguing that this should be left to the market. In the other consultation activities, the problem definition received a similar support and comments.

Objectives

Regarding the **objectives**, a large majority of respondents across groups (68-90%) in the PC considered all objectives identified as absolutely essential or very important. However, for the objective "ensure a forward-looking hybrid communication approach", there were a large number of comments on how this objective should be interpreted or achieved, which is strongly linked to the discussion on communication technologies. Several respondents considered that the initiative should also consider the ownership of (personal) data and the importance of informing and engaging consumers.

A large proportion of respondents across groups (68-86%) indicated as well that it was absolutely essential or very important for all **objectives to be achieved at EU level**, as opposed to only at national level or international standardisation.

In the position papers and other responses received during the Impact Assessment process, as well as in the discussions with MS experts, much emphasis was put on the objectives of interoperability and the forward-looking hybrid communication approach, and the perceived trade-off between them (discussed further below).

Policy measures & options

At the stage of the public consultation, the policy measures & options were not yet defined in detail. Respondent were rather asked what they considered the most appropriate type of action to achieve the objectives: (1) Legally binding EU specifications (2) Soft legislation (3) Industry-led approach.

Table 2: stakeholder response on type of action

	Legally binding EU specifications	**Soft legislation**	**Industry-led approach**
Ensure **continuous availability** of C-ITS	55 (most appropriate)	43	35
	23 (moderately	68	32

services for users across the EU, by clearly defining a set of priority C-ITS services	appropriate)		
	55 (least appropriate)	18	59
Ensure **security** of C-ITS communications by establishing common rules	76	27	28
	16	84	22
	39	18	73
Ensure the practical application of **Data Protection** in the area of C-ITS	80	33	18
	20	82	22
	31	14	86
Ensure a forward looking **hybrid communication approach**	37	40	52
	30	69	23
	61	17	48
Ensure **interoperability of C-ITS services** by establishing common rules	66	39	26
	13	73	35
	51	13	64
Ensure **seamless deployment of C-ITS** service by establishing a compliance assessment	56	50	24
	25	64	34
	50	12	68

When analysing these responses, it becomes clear that legally binding specifications are often seen by the largest group of respondents to be most appropriate, but at the same time it is also seen by many respondents as the least appropriate. This difference is also seen in the comments that indicated a need for further clarification of how the objectives would effectively be addressed and to ensure that legal measures are proportionate. Important splits can be seen in relation to security where many respondent groups prefer binding specifications, but ITS service providers prefer an industry-led approach and interoperability, where many also prefer binding specifications, but none of the ITS service and telecommunications providers.

When asked if C-ITS equipment should be mandated in vehicles and/or on different parts of the road network to accelerate deployment, respondents were moderately favourable (45-64% (strongly) agreed), with many respondents indicating that mandates would provide the needed certainty about deployment, but specific circumstances and the maturity of the system should be considered when defining mandates. However, some respondents noted that mandating deployment can be difficult given the pace of technological change in the industry, and the lack of agreement on which communications technology to use.

In the later consultation activities (case studies, stakeholder workshop, expert group meetings), stakeholder were consulted on the policy measures & options. In terms of the scope, several stakeholders considered that the topics of investment costs and funding for C-ITS, the need to make C-ITS relevant for other modes & public transport and the need for action on access to in-vehicle data should receive added attention. Where relevant and within the scope of this initiative, this feedback has been used to further fine-tune the policy measures & options.

Regarding the proposed policy measures, several government stakeholders considered that a mandate for C-ITS equipment in vehicles should be explicitly considered. On interoperability (including communication technologies) there was very substantial stakeholder input from the automotive industry, technology suppliers and telecommunications industry, including through many stakeholder-initiated meetings and position papers, with strongly diverging positions. These largely reflect a similar divergence of opinions, with clear support from many stakeholders (including vehicle manufacturers, technology suppliers and road operators) on clear rules for interoperability starting from mature implementations, while others (including manufacturers, technology suppliers and telecommunications companies) argued for a technological-neutral framework where the choice of technology is left to the market through industry-led standardisation.

In discussions with MS experts, some MS argued for a technological-neutral framework where the choice of technology is left to the market, but a strong majority agreed with the need for clear rules for interoperability starting from mature implementations, and including a clear and transparent path for the inclusion of future solutions and technologies.

Impacts

In the Public Consultation, respondents were asked to give feedback on the initial assessment of impacts by the Commission (which was largely based on the previous deployment study). While most respondents agreed on most of the initial assessments, in particular that the deployment of C-ITS would have positive impacts on road safety, traffic efficiency and research and innovation, this was less the case for the costs associated with C-ITS, with several respondents indicating costs items that they considered very uncertain and which should be further addressed.

Some stakeholders also indicated that the impacts on modal shift, vulnerable road users and the link with automation should get more consideration, including possible negative impacts on the safety of vulnerable road users (e.g. if drivers would get distracted by or too reliant on C-ITS information) and environmental impacts (e.g. if the improvements through C-ITS would lead to a rebound effect with increasing road traffic).

While there is currently no evidence of these negative impacts[13], and they would also be influenced by the exact implementation of C-ITS in vehicles (e.g. on how to combine C-ITS information with other information and how to present this to the driver), and wider transport policies, which are beyond the scope of the current initiative, these issues should be considered in the deployment of C-ITS and in future research.

Regarding impact on SMEs, a large majority indicated that they (strongly) agreed with the assessment that *"common specifications for C-ITS will help ensure that progress is made by all actors across the value chain in a consistent and harmonised manner. This in turn is expected to reduce administrative burden and to broaden the C-ITS market and make it more accessible, in particular for Small and Medium Enterprises.",* although some respondents considered that this benefit is not specific to SMEs and that the link with administrative burden should be further clarified.

Around the stakeholder consultation workshop, stakeholders were consulted on the main assumptions underlying deployment of C-ITS and its cost and benefits, inter alia through a survey. The feedback received was used by the consultant to further refine the assumptions used in the modelling framework.

4. CONCLUSION AND USE OF RESULTS

In general, the stakeholder consultation process has shown a strong support for a legal framework to support the deployment of C-ITS.

The findings from the consultation activities have been used to analyse the problems, define the right policy alternatives and fine-tune the proposed measures. Input from stakeholders with a high level of technical expertise also served to validate the information from existing reports and studies. Where relevant, references have been made in the Impact Assessment Report to the outcome of the stakeholder consultations.

[13] See also annex B.2.3 of the support study on C-ITS service impact data.

In particular, qualitative and quantitative feedback was used to update the modelling framework and the assumptions behind the policy scenarios (more details in annex B of the support study). Also, while a large number of stakeholders have been strongly supportive of (elements of) the preferred policy option of legally binding specifications, the scope and details of the measures, in particular on items with diverging stakeholder positions (e.g. interoperability (including communication technologies), the use of data, and the scope of services) have been carefully adjusted to be both effective and proportionate for the aim to be achieved:

- **Interoperability:** the system profiles, and their application, have been extensively reviewed and discussed with MS experts and the industry, to ensure that they are limited to the minimum requirements needed to ensure interoperability, in line with the principle of technology neutrality. While interoperability requirements can only be based on mature and tested implementations, a clear link to the integration of future technologies and services has been made through the inclusion of a clear review process.
- **Use of data:** on the use of data, the consultation process helped clarify the scope of the initiative (e.g. that the scope of this initiative does not include access to in-vehicle data) and that the requirements for lawfully processing personal data are provided by horizontal legislation, in particular the GDPR, and that measures under this initiative rather only facilitate the compliance of data controllers with these requirements, and are thus more limited in scope. As data protection remains a key element in C-ITS, further cooperation on this has been explicitly included in the implementation provisions of the specifications.
- **Scope of services:** The consultations made it clear that the inclusion of C-ITS services related to VRUs and public transport would further enhance the relevance of C-ITS, in particular in urban areas. While legally binding rules can necessarily only be based on the mature Day 1 services, specific emphasis on the development of C-ITS related to VRUs and public transport is put in the supporting measures, such as R&I.

5. FURTHER INFORMATION

Further information on the process of stakeholder consultation is provided in the External Support Study for this Impact Assessment, in particular in its annexes A and E.

Annex 3: Who is affected and how?

1. Practical implications of the initiative

For clarity, this section includes the measures foreseen in PO2 (equivalent to the first step in the step-wise approach in PO3), as the measures foreseen in the second step of PO3 require a follow-up initiative.

	Measure	Obligations for whom?	Costs
1	Definition of Day 1 services and their profiles in binding specifications + requirement for other services to be compatible with all Day 1 services	C-ITS station installers (vehicle manufacturers / road operators / local authorities)	Minor compliance costs (to ensure technological compatibility) Not quantified
2	Mandate compliance with EU-wide system profiles in specifications	C-ITS station installers (vehicle manufacturers / road operators / local authorities) & technology providers	Minor compliance costs (technological compatibility) Not quantified
3	Mandate to EU level standardisation organisations for further standardization.	ESOs / Commission	Cost to Commission (payment to ESOs), typically mandate costs approx. 1 million euro (depending on tasks)
4	Binding rules on the European Union C-ITS Security Credential Management System (EU CCMS)	C-ITS station operators (vehicle manufacturers / road operators / local authorities)	Set-up, management and operation of the secure communications architecture. Estimated at around 3 euros per C-ITS station per year (noted: secure communication needed regardless of requirement) Implementation of Phase I of the EU C-ITS Security Credential Management System 2018-2021 is financed through the CEF (4 million euros)
5	Definition of compliance assessment criteria for Day 1 C-ITS services + conformity assessment procedure based on internal production control	C-ITS station manufacturers (charged to vehicle manufacturers / road operators / local authorities)	Costs for carrying out compliance assessment (considered limited compared to C-ITS station costs)
6	Define the purposes for lawfully processing personal data as traffic safety & efficiency, restricting other uses.	None (substantial requirements already imposed by GDPR)	None (substantial requirements already imposed by GDPR)
7	Coordination & Policy Advice through stakeholder platform	Commission to manage platform	Costs of participation (all) Costs of organisation (Commission)
8	Enhanced deployment coordination + Fund EU deployment coordination after current piloting phase	Commission & MS manage platform	Costs of participation (all) Costs of organisation (Commission & MS, possible through EU funding)

9	Definition of needed roles in specifications + requirement to report to the Commission on the bodies/authorities in charge.	Set-up of bodies to fulfil tasks (MS or industry) Reporting obligation when setting up bodies (MS or industry)	Cost of operating bodies (MS or industry) (considered limited compared to C-ITS station costs)
10	Funding for development of services beyond the Day 1 list	None	EU research funding
11	Strengthen funding of deployment based on specifications to enable quicker uptake, including requirement on data reporting and exchange for deployment projects	Data reporting on co-funded deployment projects (MS & industry)	Cost of reporting (considered limited compared to C-ITS station costs) EU deployment funding

2. SUMMARY OF COSTS AND BENEFITS

I. Overview of Benefits (total for all provisions) – Preferred Option		
Description	***Amount***	***Comments***
Direct benefits		
Casualties prevented (fatal, serious and slight) by safety measures	EUR 15 billion	Estimates for PO2, benefit for transport users
Reduced costs of urban travel time due to increased traffic efficiency	EUR 11 billion	benefit for transport users
Reduced fuel costs	EUR 11 billion	benefit for transport users
Reduced CO_2 emissions	EUR 3.2 billion	benefit for whole society
Reduced pollutant emissions	EUR 0.2 billion	benefit for whole society
Indirect benefits		
Potential for harmonisation of technical requirements for C-ITS services	*Not quantified*	Reduced costs for variants due to standardisation, benefits for C-ITS station installers and technology providers that can be reflected in lower prices.

II. Overview of costs – Preferred option							
		Citizens/Consumers		Businesses		Administrations	
		One-off	Recurrent	One-off	Recurrent	One-off	Recurrent
Measures 1/2	Direct costs			Minor compliance costs (not quantified)			
Measure 3	Direct costs					EUR 1 million (Commissio n	
Measure 4	Direct costs			Secure communication costs (only when deployed, included in system costs)		EUR 4 million (CEF)	
Measure	Direct costs			Costs for			

5				carrying out compliance assessment (not quantified)			
Measures 7/8/9/	Indirect costs			Costs of participation & organisation (not quantified)			
Measures 10/11						R&I and deployment funding	

Annex 4: Analytical methods

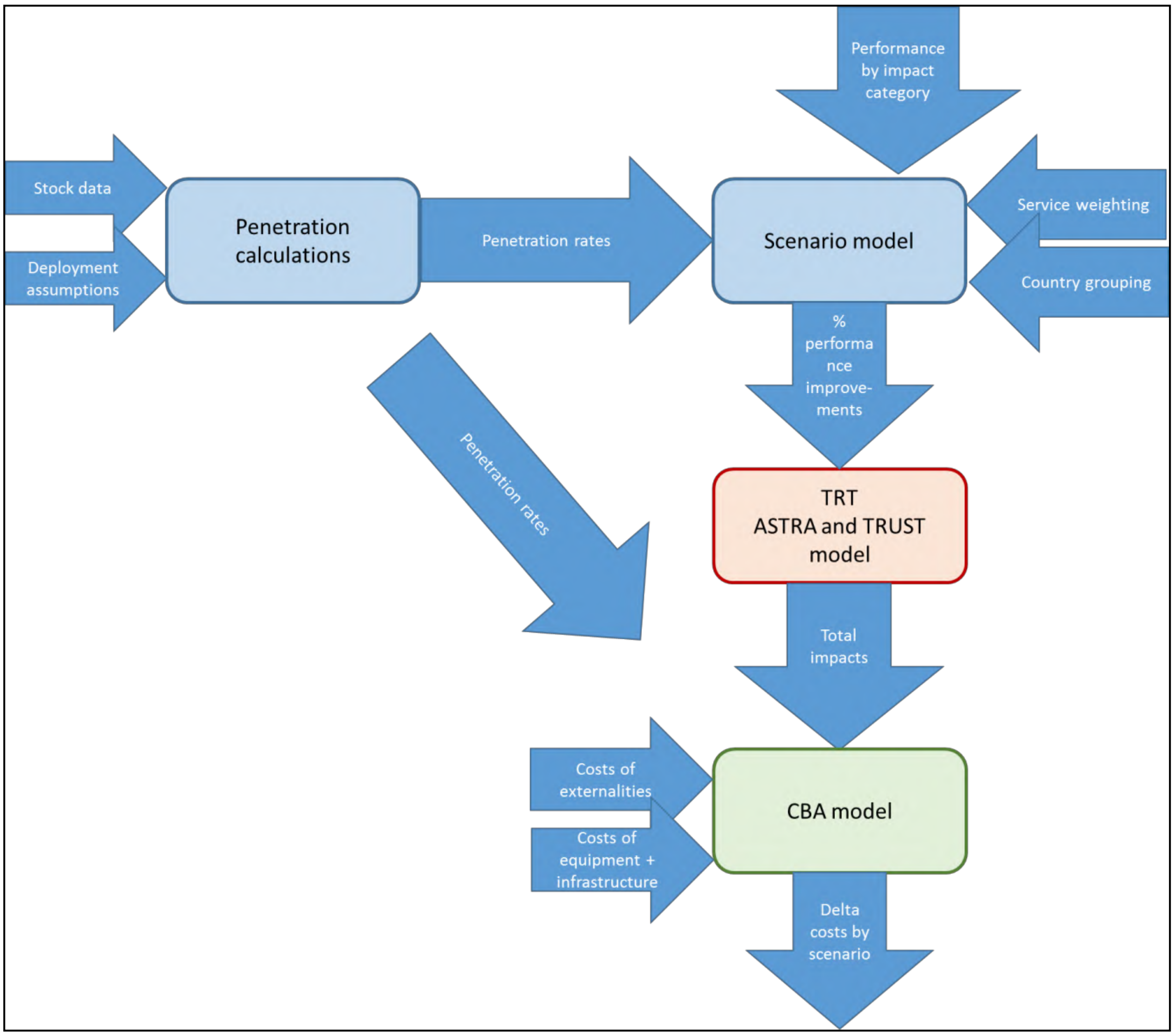
1. Description of analytical models used

A series of steps were required to produce the modelling outputs for this Impact Assessment. This involved an extensive data collection exercise (described in more detail in Annex B.2.3 and B.2.4 of the support study) and definition of a series of deployment assumptions (described in Annex B.2.2 of the support study), followed by a series of modelling steps centred around the ASTRA and TRUST models, as shown in Figure 1-1.

Figure 1-1: Key steps in producing CBA modelling outputs

The following figure shows the data flows for the modelling framework, which consists of several sub-models. The first module of the pre-processing is a calculation of penetration rates for vehicles, personal C-ITS devices and infrastructure. These are based on uptake assumptions and stock data. The penetration rates are then combined with impact data in the scenario module. The outputs from the scenario module, namely percentage improvements across the different policy options and country groupings, are then run through the macro-economic ASTRA/TRUST modelling framework. The outputs from these two models were then processed and combined into the RICARDO cost-benefit analysis (CBA) model to produce final outputs.

Figure 1-2: Data flows in the modelling



1.1. Pre-processing of data to calculate impacts

The pre-processing modules were developed in the context of the 2016 C-ITS deployment study by Ricardo. It has been revised and updated in the context of the Support Study for this Impact Assessment. The tool is a spreadsheet-based model implemented in Microsoft Excel.

Penetration rate estimates are made in the penetration calculation module of the modelling framework as shown in Figure 1-2.

Uptake rates are used to estimate the penetration of C-ITS services into the total vehicle fleet, through new vehicles and personal C-ITS stations. Different uptake rates across cars, trucks and buses are considered. Total annual vehicle fleet size and annual vehicle sales for EU28 countries were provided by TRT from their ASTRA model run for the baseline scenario as well as EUROSTAT data for 2015. In the ASTRA model, car stock is modelled as well as new cars entering the fleet each year. Both stock and new vehicles are segmented by fuel, Euro standard and vehicle age.

Penetration rates of C-ITS services can be consistently applied on new or existing vehicles by vehicle age as the size of vehicle fleet stock and annual sales are not affected by the assumptions on C-ITS. In fact, the development of the car fleet in the ASTRA model does not depend on the penetration of C-ITS solutions nor C-ITS services equipment is included among the characteristics of vehicle fleet segmentation in the ASTRA model. These input uptake assumptions (in terms of percentage penetration of the fleet) are unaffected by the ASTRA/TRUST modelling but the resulting impacts (in terms of percentage change) are combined in ASTRA/TRUST with the actual activity/fleet for each Member State.

Similarly, uptake rates are used to estimate the extent of roads equipped with C-ITS supporting infrastructure. Separate rates are defined for C-ITS that is delivered through cellular and ITS-G5 (RSU) technologies. Different uptake rates for TEN-T Core, TEN-T Corridor, other motorways and other inter-urban roads are also considered. Total network road length by road type was provided by TRT based on the TRUST model road network for the EU28countries.

The detailed uptake assumptions for the baseline and policy options can be found in Annex B.2.2 of the support study.

The penetration rates obtained from the penetration calculation module are further processed in the scenario model, which combines uptake with impacts for different C-ITS services, covering: reductions in fuel consumption, reductions in CO_2 and pollutant emissions, reduction of accident rates and change in average speed.

The full list of impact inputs considered in the model is presented in Annex B.2.3 of the support study. Since a number of C-ITS services covered in this study have similar functionality, multiple services are likely to overlap and be applicable to the same driving scenarios. The approach for accounting for the overlap between services in order to avoid double-counting impacts is described in Annex B.2.3.5 of the support study.

For each policy option and country grouping combination the module calculates the percentage improvements over time. This information is then further processed in the ASTRA/TRUST modelling framework.

1.2. ASTRA and TRUST modelling

ASTRA is a strategic model based on the Systems Dynamics Modelling approach, which simulates the EU transport system in combination with the economy and the environment. It is calibrated to reproduce major indicators such as fuel consumption, CO_2 emissions and GDP according to the main European reference sources such as Eurostat until 2015. On the other hand, TRUST is a European transport network model that can compute energy consumption, pollutant emissions and accidents by road classification (TEN-T Corridors, Core TEN-T etc.). The following sections provide details of the two models.

1.2.1. ASTRA Model

ASTRA is a strategic model based on the Systems Dynamics Modelling approach simulating the transport system in combination with the economy and the environment. The model is made of different modules that are linked to each other.

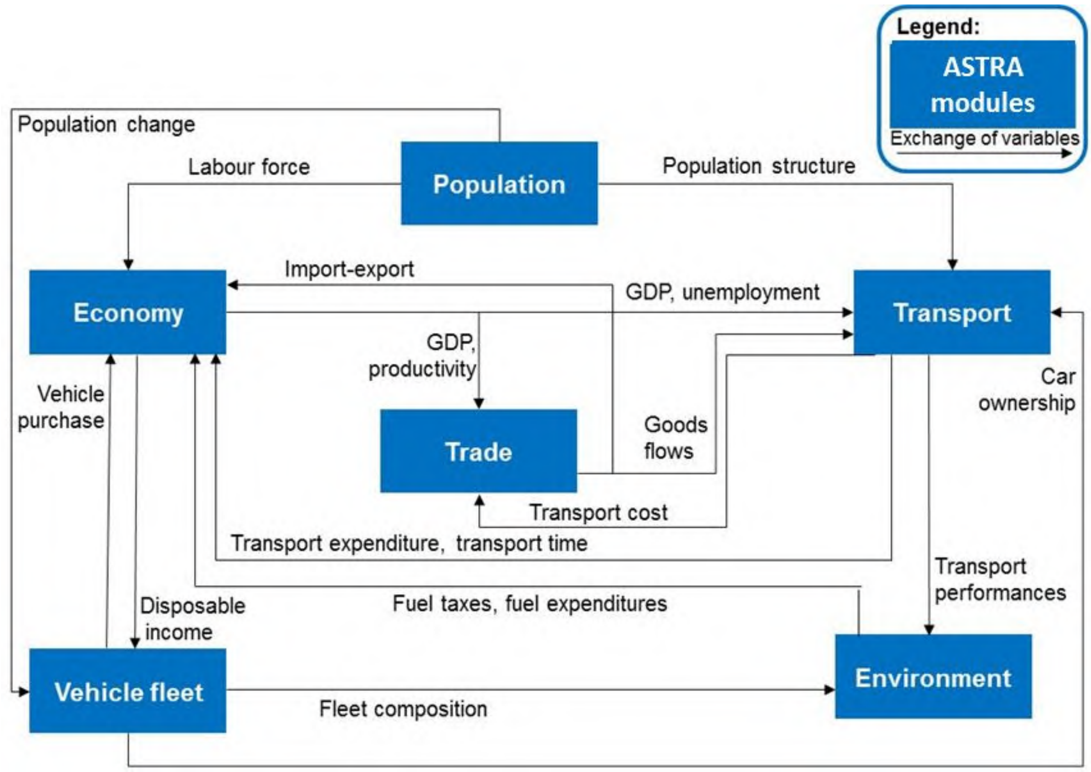
As illustrated in Figure 1-3, ASTRA consists of different modules, each related to one specific aspect such as the economy, transport demand or the vehicle fleet. The main modules cover the following aspects:

- Population and social structure (age cohorts and income groups)
- Economy (including input-output tables, government, employment, consumption and investment)

- Foreign trade (inside EU and to partners from outside EU)
- Transport (including demand estimation, modal split, transport cost and infrastructure networks)
- Vehicle fleet (passenger and freight road vehicles)
- Environment (including pollutant emissions, CO_2 emissions, fuel consumption).

Geographically, ASTRA covers all EU 28 Member States[14] plus Norway and Switzerland.

Figure 1-3: Overview of linkages between the modules in ASTRA



The macro-economic module simulates the fundamental economic variables. Some of these variables (e.g. GDP) are transferred to the transport generation module, which uses the input to generate a distributed transport demand. In the transport module, transport demand is split by mode of transport. The traffic performance by mode is associated with the composition of the fleet (computed in the vehicle fleet module) and the emissions factors (defined in the environmental module), in order to estimate total emissions.

Several feedback effects take place in the model. For instance, the economic module provides the level of income to the fleet module, in order to estimate vehicle purchase. The economic module then receives information on the total number of purchased vehicles from the fleet module to account for this item of transport consumption and investment. Furthermore, changes in the economic system feed into changes of the transport behaviour and alter origins, destinations and volumes of European transport flows.

The treatment of the linkage between transport and the economy is particularly detailed due to some 'micro-macro bridges'. For instance, transport expenditures in the transport module produce

14 Croatia has recently been added to the model.

changes in sectoral consumption and GDP at the national level: closing the feedback loop therefore implies to establish either macro-micro bridges (e.g. from GDP and sectoral output to goods flows) or vice versa micro-macro bridges (e.g. from transport investments into vehicle fleets to overall investments). This is important in this study, as ASTRA allows us to carry out analysis of the macro-economic impacts of the proposed policy options.

The main micro-macro bridges link:

- Passenger transport and sectoral consumption
- Transport and sectoral investment
- Transport and sectoral employment
- Freight transport and total factor productivity
- Transport and intermediate inputs of input-output tables
- Transport and exports.

In addition, government revenues and expenditures are differentiated as far as possible into categories that can be modelled endogenously by ASTRA and one category covering other revenues or other expenditures. Categories that are endogenous comprise, for example, VAT and fuel tax revenues, revenues from transport charges, and transport investments. Intermediate demand is modelled by means of an explicit Input-Output mechanism that describes the technical coefficients between the economic sectors.

The environment module uses input from the transport module (in terms of vehicle-kilometres-travelled per mode and geographical context) and from the vehicle fleet module (in terms of the technical composition of vehicle fleets), in order to compute fuel consumption, greenhouse gas emissions and air pollutant emissions from transport. ASTRA also estimates the upstream emissions (well-to-tank) due to fuel production and vehicles production. Therefore, well-to-wheel emissions can be provided as well.

In terms of road transport time, ASTRA simulates the impacts of traffic and/or infrastructure network in a simplified way. In fact, the effect of speed-flow functions is included in the model indirectly: in other words, the increase of traffic flow has an impact on transport time but the functions and capacity values are not implemented directly in the tool. The road network is differentiated into three "categories": Urban, Non-Urban – short distance, Non-Urban - long distance. For each category, the impact of speed-flow functions is simulated separately.

ASTRA is calibrated to reproduce major indicators such as transport performance, fuel consumption, CO_2 emissions and GDP according to the main European reference sources such as Eurostat until 2015. For future trends, it builds on the updated EU Reference scenario 2016 used in the impact assessments accompanying the new General Safety Regulation and Road Infrastructure Safety Management Directive proposals (GSR/RISM)[15], but includes additional policy measures and initiatives related to C-ITS.

More details on the ASTRA model and its applications can be found at the ASTRA website: http://www.astra-model.eu/.

Recent developments

[15] SWD(2018) 175 final.

Compared to the version of ASTRA used in the 2016 C-ITS deployment project, the current version includes two recent developments.

First, the model has been expanded in terms of geographical coverage to now cover Croatia.

Second, the simulation of the impacts of TEN-T projects in terms of time and cost variations is improved and directly linked to the TRUST network model results (where the physical changes are implemented in the road and rail network), taking into account different demand segments and geographical dimensions.

Finally, the model has been recalibrated to reproduce observed statistics of transport activity, energy consumption, accidents until 2015. For future years, it builds on the updated EU Reference scenario 2016 used in the impact assessments accompanying the new General Safety Regulation and Road Infrastructure Safety Management Directive proposals (GSR/RISM), but includes additional policy measures and initiatives related to C-ITS.

Baseline

In the baseline scenario the ASTRA model estimates that in EU28 countries passenger transport activity (in terms of pkm) will grow as much as 24% between year 2015 and year 2035 (1.1% per year). At the same time. freight transport activity for road and rail modes (in terms of tkm) is estimated to increase by 39% between 2015 and 2035 (1.66% per year), with road transport (HDV and LDV) increasing by 37.5% (1.7% per year).

In the year 2015, the annual number of fatalities, serious and slight injuries in EU28 countries for motorised road modes[16] is about 1,051,000 accidents. According to the ASTRA baseline projections, the number of total accidents[17] is expected to decrease by 11.3% by 2035 relative to 2015, i.e. about 932,000 accidents in 2035. The decrease is different according to the seriousness of the accidents: the number of fatalities would decrease by 17.9%, while the reduction in the serious and slight injuries would be lower at 11.3% and 11.2%. Adding in the analysis also non-motorised modes (cyclists and pedestrians), the number of total accidents is about 1,460,400 in 2015, projected to decrease to 1,294,200 in 2035 (by 11.4%).

In terms of energy consumption, according to the ASTRA baseline, the road transport modes[18] are expected to decrease their energy use by 9.3% by 2035 (-0.5% per year), relative to 2015. As a consequence, tank-to-wheel annual CO_2 emissions from road transport would fall by 15% by 2035 relative to 2015 (-0,8% per year)[19]. Reduction of CO_2 emissions is larger than reduction of energy consumption because of a different energy mix, with larger shares of low-carbon fuels.

With reference to road safety, the ASTRA model covers the following categories of accidents: fatalities, serious injuries, and slight injuries. The estimation is endogenously performed for cars, vans, buses and heavy goods vehicles, while exogenous parameters are applied to estimate accidents related to motorized 2-wheelers, cyclists and pedestrians.

16 P2W, car, bus, HDV and LDV
17 Fatalities, slight and serious injuries
18 car, bus, HDV, LDV
19 The baseline scenario developed for this impact assessment does not reflect the recent initiatives proposed by the Commission that have a direct impact on CO_2 emissions (e.g. CO_2 standards for new light duty vehicles for 2030, CO_2 standards for heavy goods vehicles for 2030, revision of the Clean Vehicles Directive, etc.)

In terms of air pollutant emissions, the ASTRA model estimates the impacts on VOC, NOx and PM. According to the ASTRA baseline projections, the pollutant emissions are expected to decrease until the year 2035 on an annual basis respectively by 2.4% for PM, 4.5% for Nox and 1.3% for VOC.

1.2.2. TRUST model

TRUST (TRansport eUropean Simulation Tool) is a transport network model developed by TRT in the VISUM software environment for the assignment of Origin-Destination matrices at the NUTS3 level of detail for passenger and freight demand.

The matrices of tonnes and passengers are estimated from various sources, including Eurostat, national statistics and ETIS. Intra-NUTS3 demand is not part of the matrices as it is not assigned to the network, but implicitly considered as pre-load on links.

The model is calibrated to reproduce tonnes-km and passengers-km by country consistent to the statistics reported in the Eurostat Transport in Figures pocketbook (net of intra-NUTS3 demand, which is not assigned to the network). At Member State level, the trend of road transport activity has been aligned to the trend of road transport demand in the ASTRA model.

All of Europe is covered, including Accession and Neighbouring countries. A less detailed zoning system is used for other European countries (e.g. European Russia, Ukraine).

The TRUST road network includes all the relevant links between the NUTS3 regions, i.e. motorways, primary roads as well as roads of regional and sub-regional interest. Also ferry connections (Ro-Ro services) between European regions and between European regions and the North Africa are explicitly modelled with their travel time and fare. Road network links are separated in different classes, each with specific features in term of capacity, free-flow speed and toll. The link types distinguish different road categories (e.g. motorways). Within the same category link types distinguish roads with other different features, in particular toll level. Specific flags are used to identify links belonging to the Core TEN-T Network, to each TEN-T corridor and to the Comprehensive network.

Matrices are in terms of trips or tonnes in an average day (24 hours). Trips and tonnes are endogenously translated into vehicles loaded onto the road network by means of average occupancy and load factors.

Table 1-1: Occupancy / Load factors in the TRUST road model

Demand segment	Occupancy factor / Load factor
Passenger	
Short distance (< 100 km) commuting	1.5 pers/veh
Short distance (< 100 km) non-commuting	1.8 pers/veh
Long distance (> 100 km)	1.9 pers/veh
Freight	
Domestic Short distance (<= 50 km)	4 t/veh (empty trips are considered)
Domestic average distance (50 – 150 km)	10 t/veh (empty trips are considered)
Domestic Long distance (>= 150 km)	10 t/veh (empty trips are considered)
International	14 t/veh (empty trips are considered)

Source: TRT, TRUST model

For each Origin/Destination pair, the model distributes demand among available alternative routes using a logit algorithm. The utility of each path is measured in terms of generalised cost i.e. the sum of monetary costs and monetary equivalent of travel time[20]. Travel time on each link of the road network depends on link features and on the level of congestion through specific speed-flow functions. Travel cost depends on link-based tolls and on cost parameters representing the variable operating costs (fuel and, for trucks, driver costs) relevant for path choice. Variable operating costs are different across freight demand segments to reflect that lighter vehicles are used on short distances rather than on long distances. In addition, values of travel time, used to compute the generalised cost, are different among the freight demand segments.

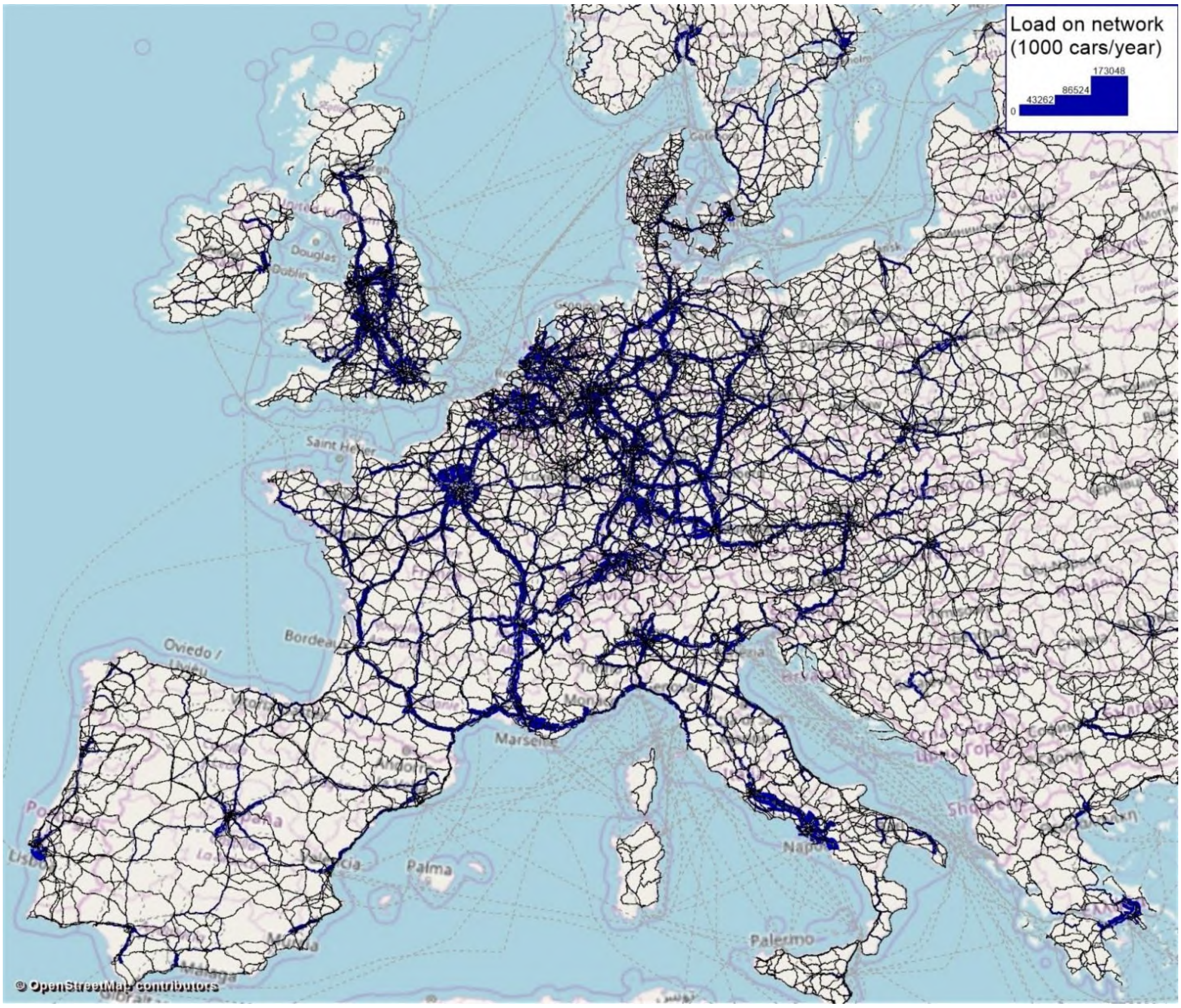
The main output of the model is the load on network links in terms of vehicles per day (see example below, Figure 1-4).

Using traffic load as an input parameter, the model also provides emissions by link for VOC, NOx, CO, PM and CO_2. Emissions factors based on COPERT functions and on the average fleet composition are used in the model to estimate total emissions. When the model is run for forecasting purposes for future years, the emission factors are updated considering the ASTRA projections regarding the evolution of the fleet in the selected year.

Accidents are estimated based on traffic load by link with the application of accident rates.

Figure 1-4: TRUST model link flows

20 Value of Time parameter is estimated by mode (car or truck), distance band (short, long) and country based on HEATCO D5, Developing Harmonised European Approaches for Transport Costing and Project Assessment (2006)



Source: TRUST model

Recent developments

The TRUST model underwent two main revisions since 2016. First, the classification of roads has been updated. In particular, the identification of the TEN-T comprehensive network has been improved and made fully consistent to the official TENtec classification[21]. Second, the model has been re-calibrated for future years; it builds on the updated EU Reference scenario 2016 used in the impact assessments accompanying the new General Safety Regulation and Road Infrastructure Safety Management Directive proposals (GSR/RISM), but includes additional policy measures and initiatives related to C-ITS.

1.2.3. Application of the modelling tools

In carrying out the modelling analysis, the different scenarios are translated into specific inputs for the two models.

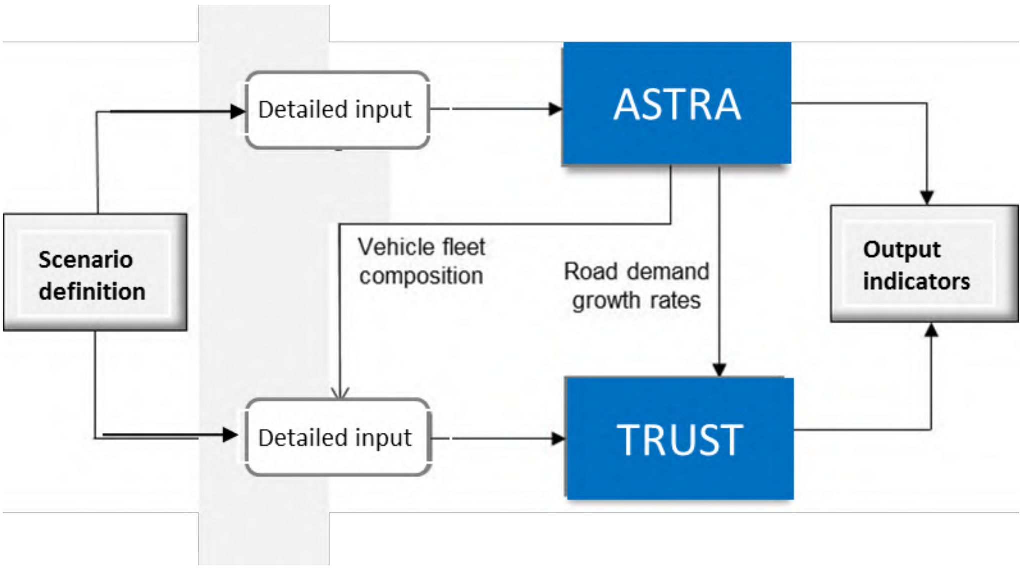
The **ASTRA model** is used to produce indicators at the national level, including e.g.: mode split, transport energy demand, CO_2 emissions, pollutant emissions (VOC, NOx and PM), road

21 http://ec.europa.eu/transport/infrastructure/tentec/tentec-portal/site/en/maps.html

accidents, average individual expenditure for mobility, macro-economic impact on GDP. ASTRA is run on an annual basis until the year 2035: the impacts of each scenario are observed over time in terms of aggregated indicators.

The **TRUST network model** is used to produce indicators by mode (cars and trucks) based on road network links, such as fuel consumption, CO_2 emissions, pollutant emissions (NOx, VOC and PM) and accidents. Four different categories of road network are considered: TEN-T Corridors, Rest of TEN-T Core network, TEN-T comprehensive, other interurban roads. TEN-T comprehensive roads are considered representative of ‘other motorways’, which is the designation used in this study. The TRUST model is run every five years from 2015 to 2035, simulating the relevant changes on the supply side (evolution of road network over time due to the completion of TEN-T core and non-core network) and on the demand side (i.e. updated origin-destination matrix). The matrix update is based on the growth rates of demand by mode, country, Origin-Destination and spatial domain provided by ASTRA.

Figure 1-5: Use of the modelling tools for scenarios simulation



1.3. Cost Benefit Analysis Model

A specific cost benefits analysis model had been developed in the context of the 2016 C-ITS deployment study by Ricardo. It has been revised and updated in the context of the Support Study for this Impact Assessment. The tool is a spreadsheet-based model implemented in Microsoft Excel.

In the CBA, the EU-level impacts determined in the ASTRA & TRUST models are converted to monetised benefits using typical values for the external cost of transport from the Handbook on External Costs of Transport.[22]

[22] Ricardo-AEA, TRT, TEPR, DIW Econ, CAU (2014), Update of the Handbook on external costs of transport, available at https://ec.europa.eu/transport/sites/transport/files/handbook_on_external_costs_of_transport_2014_0.pdf

Cost data are combined with the uptake and penetration rates for different services for the different scenarios determined in the scenario model to be translated into costs.

2. Reliability and Appropriateness of the Models Used

This impact assessment, which examines the future impacts of technologies not yet in place beyond trial projects has some necessary limitations in terms of the information available on potential deployment and associated costs and benefits. This is also why existing transport models used in isolation would not be useful to analyse the impacts of policy options to speed up the deployment of C-ITS, as these models do include neither detailed C-ITS measures nor impacts. A excel-based cost-benefit tool as the one used for this Impact Assessment has the advantage of providing a transparent understanding of links between inputs, assumptions and outputs, more closely related to the reality of deploying C-ITS services.

To address the limitations in data availability and other uncertainties, an extensive review of documentation available on deployment projects, case study interviews and other wider stakeholder engagement activities were carried out to gather further information, and various policy options/deployment scenarios were tested with different C-ITS uptake profiles between 2019 and 2035.

The assessment of the potential impacts of different C-ITS service offerings is based on existing research, and in some cases, where there is no research available, an estimate based on comparable C-ITS services. Once large-scale deployment is under way, it may be that the actual impacts of the various C-ITS services are different than those estimated in this impact assessment. A related aspect to this is the fast-moving nature of the technology itself. For example, no benefits of time-critical safety services for personal C-ITS devices were modelled, but in the future, this technology may be available in such devices.

It has to be considered that this Impact Assessment has a strong focus on Day 1 services, which are predominantly services for road safety. For most V2V services, it was expected that non-safety impacts would be minimal, and this was confirmed by other studies that often did not consider non-safety impacts or found them to be insignificant. For example, the Drive C2X study concluded that non-safety impacts were insignificant for 'Traffic jam ahead warning' (TJW). More non-safety related impacts were identified in the literature for I2V services, although safety impacts remain the most common primary objective. While it should be expected that impacts from Day 1 services will be mainly related to safety, it is appreciated that other impacts may be underestimated due to less of a focus in existing studies.

In section 7.2 of the Impact Assessment support study, a number of simplifications made for modelling purposes and their effects are discussed. As the methodology, inputs and assumptions behind the modelling have been developed together with relevant experts, and consistently consulted with stakeholders both in this Impact Assessment process and the preceding deployment study, the results are considered to be robustly displaying the relevant trends in the baseline and in the policy options, and provide the appropriate means for comparing the baseline and the policy options between themselves.

3. DETAILED RESULTS PER MEMBER STATE

This section presents the detailed social, economic and environmental impacts by Member State for each policy option.

The model suite used for this analysis was primarily designed to calculate EU level impacts. While impacts per MS can be extracted from the modelling output, these are the result of input assumptions mostly at the EU level, and thus have to be considered with significant caution. Due to limitations in the modelling, these disaggregated impacts can only be presented in monetary terms.

Country	PO1	PO2	PO3	Baseline
		Cost of accidents in 2035		
AT	€ 4.529.719.861	€ 4.155.504.079	€ 4.073.726.467	€ 4.670.883.320
BE	€ 5.046.610.575	€ 4.612.569.311	€ 4.511.005.145	€ 5.259.803.909
DK	€ 720.949.859	€ 666.789.693	€ 652.271.405	€ 744.623.671
ES	€ 8.589.160.725	€ 7.994.902.278	€ 7.866.610.124	€ 8.866.592.513
FI	€ 989.315.598	€ 913.548.008	€ 897.301.605	€ 1.017.309.889
FR	€ 10.671.275.102	€ 9.812.744.238	€ 9.631.257.973	€ 10.997.055.651
UK	€ 17.737.894.525	€ 16.328.285.029	€ 16.071.371.196	€ 18.496.375.457
DE	€ 33.475.892.865	€ 30.831.692.147	€ 30.307.773.509	€ 34.475.451.723
EL	€ 1.837.910.245	€ 1.713.137.546	€ 1.687.653.943	€ 1.893.547.889
IE	€ 890.891.845	€ 829.534.850	€ 813.652.343	€ 922.962.368
IT	€ 18.863.763.974	€ 17.495.028.888	€ 17.206.597.693	€ 19.532.141.688
LU	€ 230.263.265	€ 211.057.386	€ 207.259.436	€ 241.778.233
NL	€ 2.514.318.730	€ 2.308.111.061	€ 2.265.504.392	€ 2.595.720.591
PT	€ 2.475.034.404	€ 2.300.856.614	€ 2.261.654.943	€ 2.556.003.303
SE	€ 1.782.919.099	€ 1.641.233.497	€ 1.617.392.537	€ 1.841.108.182
BG	€ 782.321.157	€ 733.792.975	€ 719.356.054	€ 804.449.817
CY	€ 103.255.703	€ 97.359.449	€ 95.512.460	€ 105.659.282
CZ	€ 1.866.499.133	€ 1.724.287.212	€ 1.687.184.649	€ 1.928.288.584
EE	€ 107.243.239	€ 98.849.552	€ 96.834.389	€ 111.719.185
HU	€ 1.330.170.754	€ 1.245.671.113	€ 1.220.809.233	€ 1.366.687.973
LV	€ 288.895.202	€ 270.729.852	€ 266.220.595	€ 298.071.331
LT	€ 323.616.749	€ 304.641.301	€ 300.239.798	€ 332.694.186
MT	€ 46.095.015	€ 42.593.363	€ 41.809.479	€ 48.339.771
PL	€ 4.301.998.692	€ 4.055.260.003	€ 3.982.792.631	€ 4.399.124.512
RO	€ 2.671.982.213	€ 2.502.119.733	€ 2.455.644.526	€ 2.742.301.558
SI	€ 724.203.864	€ 667.019.395	€ 656.577.383	€ 752.772.030
SK	€ 781.021.797	€ 725.430.653	€ 708.166.100	€ 804.462.520
HR	€ 879.468.151	€ 826.114.620	€ 814.035.696	€ 906.689.861
EU28	**€ 124.562.692.341**	**€ 115.108.863.847**	**€ 113.116.215.704**	**€ 128.712.618.998**

Country	PO1	Urban travel time costs in 2035 PO2	PO3	Baseline
AT	€ 10.419.049.499	€ 10.359.038.957	€ 10.257.985.360	€ 10.425.968.708
BE	€ 17.367.761.973	€ 17.177.294.661	€ 16.962.458.980	€ 17.433.329.489
DK	€ 3.798.066.341	€ 3.776.845.989	€ 3.740.823.754	€ 3.801.696.843
ES	€ 53.542.886.573	€ 53.068.373.014	€ 52.569.750.217	€ 53.706.963.601
FI	€ 5.475.639.695	€ 5.455.031.584	€ 5.410.656.662	€ 5.476.902.597
FR	€ 100.928.537.013	€ 100.631.906.658	€ 99.775.081.583	€ 100.904.222.177
UK	€ 114.566.701.184	€ 114.116.246.945	€ 113.082.969.511	€ 114.561.271.909
DE	€ 118.370.601.066	€ 117.506.993.290	€ 116.358.895.841	€ 118.567.420.096
EL	€ 10.745.767.135	€ 10.645.642.286	€ 10.554.341.720	€ 10.781.845.424
IE	€ 4.819.549.610	€ 4.803.968.636	€ 4.764.476.357	€ 4.817.272.587
IT	€ 62.191.258.255	€ 61.817.320.711	€ 61.268.143.551	€ 62.284.898.401
LU	€ 1.121.867.076	€ 1.116.100.835	€ 1.104.909.906	€ 1.122.184.289
NL	€ 23.204.425.705	€ 23.131.371.721	€ 22.938.196.966	€ 23.202.295.743
PT	€ 6.105.569.958	€ 6.088.363.491	€ 6.039.473.758	€ 6.102.672.928
SE	€ 11.626.802.673	€ 11.594.413.066	€ 11.505.471.171	€ 11.625.072.043
BG	€ 3.605.797.246	€ 3.603.591.295	€ 3.582.592.551	€ 3.601.962.836
CY	€ 92.600.988	€ 92.323.845	€ 91.676.647	€ 92.588.603
CZ	€ 13.255.858.875	€ 13.109.139.140	€ 12.955.212.739	€ 13.311.477.901
EE	€ 943.661.466	€ 935.160.838	€ 924.784.983	€ 947.003.553
HU	€ 6.570.467.983	€ 6.473.140.514	€ 6.397.968.282	€ 6.622.427.387
LV	€ 2.777.326.878	€ 2.764.653.921	€ 2.744.162.883	€ 2.780.325.823
LT	€ 4.928.837.450	€ 4.921.181.210	€ 4.891.573.727	€ 4.924.118.686
MT	€ 422.892.250	€ 419.557.270	€ 415.019.798	€ 423.925.446
PL	€ 31.246.601.342	€ 31.013.690.504	€ 30.754.262.369	€ 31.329.217.115
RO	€ 9.444.525.876	€ 9.362.638.112	€ 9.272.429.540	€ 9.470.578.100
SI	€ 2.272.405.576	€ 2.258.365.394	€ 2.236.607.753	€ 2.275.230.659
SK	€ 4.751.140.648	€ 4.723.778.987	€ 4.677.742.474	€ 4.759.986.882
HR	€ 1.836.490.523	€ 1.830.634.878	€ 1.815.736.501	€ 1.833.265.674
EU28	**€ 626.433.090.856**	**€ 622.796.767.753**	**€ 617.093.405.585**	**€ 627.186.125.500**

Country	PO1	PO2	PO3	Baseline
		CO2 emission costs in 2035		
AT	€ 1.821.708.171	€ 1.805.941.199	€ 1.801.024.868	€ 1.826.153.539
BE	€ 2.458.233.392	€ 2.433.716.401	€ 2.422.206.393	€ 2.466.166.937
DK	€ 933.996.335	€ 924.981.349	€ 921.127.319	€ 936.686.693
ES	€ 6.646.551.310	€ 6.589.306.215	€ 6.566.055.883	€ 6.664.379.966
FI	€ 867.020.804	€ 859.554.905	€ 856.262.792	€ 868.874.326
FR	€ 9.880.621.143	€ 9.797.997.079	€ 9.770.712.645	€ 9.902.614.014
UK	€ 8.504.866.956	€ 8.433.965.789	€ 8.411.498.196	€ 8.527.364.137
DE	€ 10.440.868.941	€ 10.344.201.435	€ 10.318.476.393	€ 10.466.405.363
EL	€ 1.292.905.578	€ 1.284.011.997	€ 1.280.522.603	€ 1.295.191.935
IE	€ 1.081.353.104	€ 1.072.943.128	€ 1.069.526.714	€ 1.084.070.935
IT	€ 7.382.622.905	€ 7.321.154.892	€ 7.303.182.427	€ 7.404.712.865
LU	€ 697.384.275	€ 691.277.107	€ 688.382.653	€ 700.518.796
NL	€ 2.214.936.929	€ 2.195.152.042	€ 2.188.219.312	€ 2.220.443.535
PT	€ 1.219.575.323	€ 1.210.522.813	€ 1.207.986.473	€ 1.221.916.252
SE	€ 1.697.149.091	€ 1.682.995.805	€ 1.678.637.122	€ 1.700.988.675
BG	€ 594.344.548	€ 590.278.850	€ 588.043.319	€ 595.325.028
CY	€ 132.210.767	€ 131.032.061	€ 130.630.319	€ 132.614.811
CZ	€ 1.484.716.134	€ 1.470.026.104	€ 1.463.390.756	€ 1.488.977.118
EE	€ 176.845.028	€ 175.291.360	€ 174.518.984	€ 177.487.929
HU	€ 909.474.355	€ 902.047.281	€ 898.295.790	€ 911.893.675
LV	€ 209.876.228	€ 208.576.049	€ 207.974.536	€ 210.340.930
LT	€ 328.840.739	€ 327.053.232	€ 326.263.725	€ 329.317.405
MT	€ 37.405.589	€ 37.059.261	€ 36.877.831	€ 37.428.864
PL	€ 4.847.479.329	€ 4.812.129.608	€ 4.797.449.175	€ 4.857.761.252
RO	€ 1.380.197.255	€ 1.369.422.574	€ 1.364.848.987	€ 1.383.187.473
SI	€ 433.827.962	€ 429.534.297	€ 428.121.638	€ 435.295.311
SK	€ 614.504.574	€ 609.148.095	€ 606.613.939	€ 616.190.233
HR	€ 505.061.073	€ 501.695.985	€ 500.542.498	€ 505.989.669
EU28	**€ 68.794.577.840**	**€ 68.211.016.912**	**€ 68.007.393.289**	**€ 68.968.297.664**

Country	Other pollutant emissions costs (NOx, VOC, PM) in 2035 PO1	PO2	PO3	Baseline
AT	€ 443.720.317	€ 445.334.005	€ 447.183.505	€ 444.393.013
BE	€ 499.222.366	€ 496.994.422	€ 496.015.943	€ 500.748.497
DK	€ 109.057.344	€ 108.767.061	€ 108.629.333	€ 109.213.263
ES	€ 640.745.238	€ 639.173.060	€ 638.706.724	€ 641.856.807
FI	€ 54.478.567	€ 54.330.800	€ 54.284.450	€ 54.544.100
FR	€ 2.757.394.009	€ 2.750.873.228	€ 2.749.164.004	€ 2.760.577.047
UK	€ 1.503.418.939	€ 1.501.159.991	€ 1.501.322.340	€ 1.504.295.196
DE	€ 3.632.507.225	€ 3.623.687.454	€ 3.621.534.935	€ 3.636.734.725
EL	€ 95.835.677	€ 96.258.296	€ 96.447.674	€ 95.601.062
IE	€ 111.089.928	€ 110.943.814	€ 110.913.557	€ 111.175.700
IT	€ 1.731.867.954	€ 1.731.845.201	€ 1.736.006.487	€ 1.733.873.863
LU	€ 86.691.164	€ 86.351.027	€ 86.224.216	€ 86.992.225
NL	€ 365.962.074	€ 365.206.935	€ 365.081.125	€ 366.371.057
PT	€ 87.492.220	€ 87.679.068	€ 87.772.783	€ 87.454.416
SE	€ 120.762.716	€ 120.418.473	€ 120.350.477	€ 120.920.860
BG	€ 140.473.187	€ 140.438.724	€ 140.332.821	€ 140.437.728
CY	€ 5.768.867	€ 5.747.401	€ 5.737.129	€ 5.777.332
CZ	€ 432.200.774	€ 430.725.973	€ 430.124.835	€ 432.966.242
EE	€ 15.594.570	€ 15.537.168	€ 15.514.215	€ 15.634.169
HU	€ 281.741.070	€ 280.832.413	€ 280.478.371	€ 282.268.079
LV	€ 33.473.676	€ 33.454.416	€ 33.444.574	€ 33.489.474
LT	€ 49.288.820	€ 49.276.216	€ 49.281.389	€ 49.292.077
MT	€ 4.411.890	€ 4.407.134	€ 4.402.390	€ 4.393.241
PL	€ 1.193.243.290	€ 1.191.056.920	€ 1.190.503.347	€ 1.194.863.077
RO	€ 408.606.110	€ 407.979.698	€ 407.714.864	€ 408.787.631
SI	€ 70.989.749	€ 70.696.880	€ 70.602.870	€ 71.153.533
SK	€ 224.952.562	€ 224.108.128	€ 223.735.668	€ 225.406.125
HR	€ 93.890.896	€ 93.858.139	€ 93.858.623	€ 93.921.043
EU28	**€ 15.194.881.198**	**€ 15.167.142.042**	**€ 15.165.368.649**	**€ 15.213.141.583**

	PO1 - Annual 2035			PO2 - Annual 2035			PO3 - Annual 2035		
Country	Total Costs	Total Benefits	Net Benefits	Total Costs	Total Benefits	Net Benefits	Total Costs	Total Benefits	Net Benefits
AT	€ 18.434.363	€ 169.519.455	€ 151.085.092	€ 75.754.399	€ 675.801.483	€ 600.047.084	€ 94.715.966	€ 879.610.541	€ 784.894.575
BE	€ 25.090.408	€ 316.195.522	€ 291.105.114	€ 106.878.502	€ 1.053.438.092	€ 946.559.590	€ 139.015.434	€ 1.422.113.330	€ 1.283.097.897
DK	€ 11.560.205	€ 40.151.004	€ 28.590.799	€ 48.564.307	€ 158.190.729	€ 109.626.422	€ 63.117.291	€ 226.715.758	€ 163.598.466
ES	€ 55.415.704	€ 523.818.023	€ 468.402.320	€ 241.501.888	€ 1.854.852.601	€ 1.613.350.713	€ 295.918.081	€ 2.586.630.378	€ 2.290.712.297
FI	€ 7.034.126	€ 38.294.222	€ 31.260.097	€ 30.691.252	€ 170.727.928	€ 140.036.676	€ 36.587.582	€ 247.044.942	€ 210.457.360
FR	€ 99.173.927	€ 404.501.820	€ 305.327.893	€ 437.862.721	€ 1.941.051.670	€ 1.503.188.950	€ 565.621.650	€ 3.103.417.062	€ 2.537.795.411
UK	€ 127.177.685	€ 858.032.527	€ 730.854.842	€ 536.556.433	€ 3.045.493.645	€ 2.508.937.213	€ 697.004.884	€ 4.436.094.542	€ 3.739.089.658
DE	€ 141.648.511	€ 1.318.892.436	€ 1.177.243.925	€ 585.276.872	€ 5.282.970.085	€ 4.697.693.214	€ 752.198.686	€ 7.073.041.819	€ 6.320.843.133
EL	€ 5.753.787	€ 102.200.299	€ 96.446.513	€ 23.237.615	€ 367.767.566	€ 344.529.951	€ 23.064.782	€ 500.146.736	€ 477.081.954
IE	€ 15.400.836	€ 42.219.813	€ 26.818.977	€ 43.888.277	€ 157.151.633	€ 113.263.357	€ 53.472.110	€ 227.647.222	€ 174.175.112
IT	€ 80.098.808	€ 869.024.715	€ 788.925.907	€ 320.681.118	€ 2.903.244.593	€ 2.582.563.476	€ 380.961.889	€ 3.821.023.218	€ 3.440.061.329
LU	€ 8.749.715	€ 26.375.225	€ 17.625.510	€ 17.330.024	€ 79.318.804	€ 61.988.780	€ 20.638.108	€ 107.350.691	€ 86.712.583
NL	€ 22.260.719	€ 105.387.111	€ 83.126.392	€ 93.010.124	€ 477.597.646	€ 384.587.521	€ 117.253.950	€ 745.174.967	€ 627.921.017
PT	€ 8.581.262	€ 88.882.476	€ 80.301.214	€ 39.433.936	€ 322.057.712	€ 282.623.776	€ 48.548.481	€ 421.736.499	€ 373.188.019
SE	€ 20.124.933	€ 75.039.593	€ 54.914.660	€ 84.859.833	€ 317.517.095	€ 232.657.262	€ 108.597.489	€ 451.411.000	€ 342.813.511
BG	€ 11.326.094	€ 22.725.058	€ 11.398.964	€ 23.803.159	€ 91.835.494	€ 68.032.335	€ 23.469.905	€ 137.297.465	€ 113.827.560
CY	€ 6.782.570	€ 4.200.415	-€ 2.582.155	€ 9.025.481	€ 15.618.773	€ 6.593.292	€ 9.221.940	€ 19.864.103	€ 10.642.162
CZ	€ 14.924.225	€ 137.555.862	€ 122.631.637	€ 60.390.022	€ 494.691.157	€ 434.301.135	€ 72.508.968	€ 716.018.959	€ 643.509.991
EE	€ 7.861.602	€ 10.642.450	€ 2.780.847	€ 12.987.882	€ 34.286.387	€ 21.298.505	€ 13.915.410	€ 49.973.319	€ 36.057.909
HU	€ 13.705.027	€ 100.099.209	€ 86.394.182	€ 34.699.670	€ 316.740.611	€ 282.040.941	€ 38.364.762	€ 433.912.294	€ 395.547.532
LV	€ 8.048.784	€ 14.235.147	€ 6.186.363	€ 13.131.679	€ 50.787.567	€ 37.655.888	€ 13.827.272	€ 78.404.917	€ 64.577.645
LT	€ 8.187.817	€ 6.465.836	-€ 1.721.981	€ 13.641.818	€ 40.969.879	€ 27.328.061	€ 14.396.296	€ 78.397.805	€ 64.001.510
MT	€ 6.566.463	€ 3.380.943	-€ 3.185.520	€ 8.027.444	€ 11.735.635	€ 3.708.192	€ 8.227.712	€ 17.849.914	€ 9.622.202

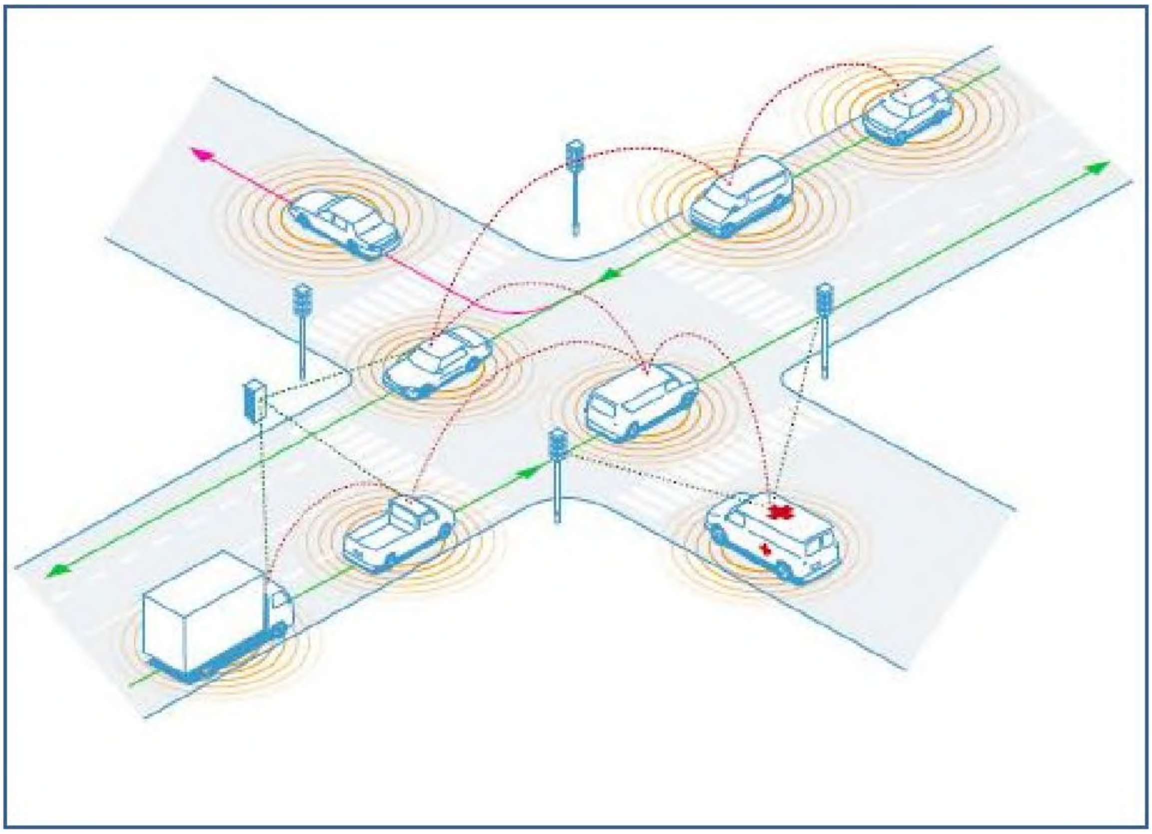
PL	€ 38.967.639	€ 228.447.722	€ 189.480.083	€ 132.449.267	€ 872.032.685	€ 739.583.418	€ 138.803.183	€ 1.270.916.688	€ 1.132.113.505
RO	€ 16.072.944	€ 110.063.293	€ 93.990.349	€ 43.388.952	€ 410.931.772	€ 367.542.819	€ 44.903.133	€ 568.071.852	€ 523.168.719
SI	€ 3.401.654	€ 38.384.960	€ 34.983.306	€ 13.664.851	€ 129.809.905	€ 116.145.053	€ 17.094.538	€ 168.516.278	€ 151.421.740
SK	€ 12.398.361	€ 40.430.651	€ 28.032.290	€ 31.104.159	€ 148.567.888	€ 117.463.729	€ 35.281.020	€ 223.598.317	€ 188.317.297
HR	€ 10.021.718	€ 28.233.728	€ 18.212.010	€ 19.817.588	€ 102.711.640	€ 82.894.052	€ 21.112.324	€ 134.856.306	€ 113.743.982
EU28	**€ 804.769.887**	**€ 5.723.399.516**	**€ 4.918.629.630**	**€ 3.101.659.272**	**€ 21.527.900.675**	**€ 18.426.241.403**	**€ 3.847.842.845**	**€ 30.146.836.923**	**€ 26.298.994.078**

Annex 5: Key aspects of C-ITS

1. INTRODUCTION

This Annex provides a description of key aspects of Cooperative Intelligent Transport Systems (C-ITS). C-ITS enable cooperation between transport participants (including vehicles, vulnerable road users, road operators and others), based on the exchange of messages, to improve road safety and traffic efficiency. It is important to note that C-ITS services, stations and communications can evolve over time, and that this description is thus informative and does not preclude the further development C-ITS in any way.

Figure 7: Illustration of typical interactions existing within a C-ITS network



Every unit of a C-ITS network, being mobile, standing roadside or central, sends data and exploits the data received from other devices to generate strategic warnings, tactical advices and driver information. While vehicle units broadcast data about their position, speed and driving direction or event-driven information, such as an obstacle or changing environmental conditions, roadside units deliver local data such as speed limits, signal phases and timing of traffic lights or information about traffic diversion.

The vehicle units integrate all data received to form a picture of the local traffic situation and generate information and warnings directly relevant for the drivers. For example, based on the exchanged data between vehicles and vehicles and vehicles and infrastructure a driver would receive information via an ergonomic Human Machine Interface (HMI) about works blocking the road ahead or would be warned regarding situations requiring attention.

Using the sensors of the vehicle' driver assistance systems and the communication capabilities of cooperative systems, hazardous locations like slippery roads or black ice and aquaplaning areas detected by one vehicle can be communicated to other approaching vehicles.

C-ITS services are provided through the exchange of messages between C-ITS stations in the C-ITS network. This should be distinguished from value-added services that can be based on C-ITS services (e.g. through aggregation and analysis of data), or other complementary ITS services that can be provided through the wider internet (such as infotainment).

2. C-ITS SERVICES AND MESSAGES

The communication architecture underlying C-ITS in principle allows the exchange of a wide variety of data and services. However, the current work puts emphasis on the deployment of the so-called "Day 1" services, which are considered to be mature in the EU from 2019 and thus ready for quick deployment. Day 1.5 C-ITS services are considered to be mature, but not quite ready for a large-scale deployment due to a lack of full specifications or standards, and so would be deployed in a second phase from 2025 onwards.[23] An overview of both the Day 1 and Day 1.5 services in the scope of this Impact Assessment is presented in the table below.

The Day 1 services have a relatively strong focus on vehicle-to-vehicle and infrastructure-to-vehicle communication to improve road safety on highways. However the industry already has plans for building a large number of progressively more sophisticated services based on the same C-ITS architecture, which would also add more emphasis on other environments (urban, secondary roads), users (public transport and vulnerable road users) and impacts (traffic efficiency and environmental impacts), which is already evident in the Day 1.5 services.

The Day 1 services are primarily based on the exchange of a number of standardized messages: CAM, DENM, IVIM, SPATEM, MAPEM. In particular the cooperative awareness message (CAM) and the dynamic environmental notification message (DENM) play an essential role in many of the services.

CAMs are messages exchanged in the C-ITS network between C-ITS stations to create and maintain awareness of each other and to support cooperative performance of vehicles using the road network. A CAM contains status and attribute information of the originating C-ITS stations. The content varies depending on the type of the C-ITS stations. For vehicle C-ITS stations the status information includes time, position, motion state, activated systems, etc. and the attribute information includes data about the dimensions, vehicle type and role in the road traffic, etc.

From both the short and midterm perspectives, the CAM will increase the vehicle's capability to better anticipate traffic situations due its greater line of sight range and its ability in non-line of sight conditions to "see" around the corner or "through" other vehicles than any other current sensor. These performance features are already usable in current Advanced Driver Assistance Systems (ADAS) applications like Adaptive Cruise Control (ACC), Blind Spot Monitor, Lane

[23] Ricardo, 2016. Study on the deployment of C-ITS in Europe: Final report, available at: http://ec.europa.eu/transport/sites/transport/files/2016-c-its-deployment-study-final-report.pdf

Change Assistant, Collision Avoidance Systems, etc. as they extend the visibility on the neighboring horizon ("e-horizon"). There is furthermore a real interest not only to create awareness of potential hazards to supplement driver awareness but to maintain awareness to stabilize the traffic flow of a limited number of vehicles as well as there is interest to increase the safety of Vulnerable Road Users (VRUs) such as pedestrians. Therefore, some capabilities are not only needed to improve service operations in the first few years of deployment, but will also be necessary for more advanced partially- or full-automated driving and VRU safety.

The time-critical provision of state information received from surrounding vehicles to alert or warn the driver of potential crashes would be the primary and most beneficial use of the CAM for road safety improvement. **Thus CAMs need to be sent frequently and continuously.** When a distance between current and past position has been changed more than 4 meters or the speed is changed more than 0.5 m/s compared to the last time, a CAM is sent but at least once a second and at the most 10 times per second under normal conditions.

In contrast, DENM messages are event-based. It is only sent if a vehicle senses special conditions or incidents such as black ice or sudden upcoming fog. It is meant for emergency situations. A vehicle DENM is sent in addition to, not instead of. the CAM. DENM can also be sent from the infrastructure to vehicle, to inform traffic participants on special conditions, such as road works or closed lanes.

Table 4: overview of Day 1 and Day 1.5 services

Service	Description	Service Time-frame	V2V/ V2I	Impact			
				Safety	Fuel Consumption	Pollutant Emissions	Congestion / Travel time
Emergency electronic brake light (EBL)	Aims to prevent rear end collisions by informing drivers of hard braking vehicles ahead. Drivers will be better prepared to adjust their speed accordingly.	Day 1	V2V	+ +	o	o	o
Emergency vehicle approaching (EVA)	Gives an early warning of approaching emergency vehicles, prior to the siren or light bar being audible or visible. This should allow vehicles extra time to clear the road for emergency vehicles and help to reduce the number of unsafe manoeuvres.	Day 1	V2V	+	o	o	o
Hazardous location notification (HLN)	Gives drivers an advance warning of upcoming hazardous locations in the road. E.g. a sharp bend in the road, steep hill, pothole, obstacle, or slippery road service.	Day 1	V2V	+ +	o	o	+[24]
Slow or stationary vehicle(s) (SSV)	Intended to deliver safety benefits by warning approaching drivers about slow or stationary/broken down vehicle(s) ahead, which may be acting as obstacles in the road.	Day 1	V2V	+	o	o	o

24 The eSafetyForum Intelligent Infrastructure Working Group estimated a lower bound of a 2% increase in average speed for this service.

Service	Description	Service Time-frame	V2V/ V2I	Impact			
				Safety	Fuel Consumption	Pollutant Emissions	Congestion / Travel time
	The warning helps to prevent dangerous manoeuvres.						
Traffic jam ahead warning (TJW)	Provides an alert to the driver on approaching the tail end of a traffic jam at speed. This gives the driver time to react safely to traffic jams by giving them more time to react.	Day 1	V2V	+ +	o	o	o
In-vehicle signage (VSGN)	Informs drivers of relevant road signs in the vehicle's vicinity, giving advance warning of upcoming hazards and increasing driver awareness.	Day 1	V2I	+	o	o	o
In-vehicle speed limits (VSPD)	Intended to prevent speeding and bring safety benefits by informing drivers of speed limits. Speed limit information may be displayed to the driver continuously, or targeted warnings may be displayed in the vicinity of road signs.	Day 1	V2I	+ +	+ +	+ / -[25]	-[26]
Probe vehicle data (PVD)	The purpose of probe vehicle data is to collect and collate vehicle data, which can then be used for a variety of applications. For example, the data can be used to inform drivers about adverse road or weather conditions.	Day 1	V2I	+ +	o	o	o
Road works warning (RWW)	Enables road operators to communicate information about road works and restrictions to drivers. This allows drivers to be better prepared for upcoming roadworks and potential obstacles in the road, therefore reducing the probability of collisions.	Day 1	V2I	+	o	o	o
Shockwave Damping (SWD)	Shock wave damping aims to smooth the flow of traffic, by damping traffic shock waves.	Day 1	V2I	+ +	o	o	o[27]
Weather conditions (WTC)	Aims to increase safety through providing accurate and up-to-date local weather information. Drivers are informed about dangerous weather conditions ahead, especially	Day 1	V2I / V2V	+ +	o	o	o

25 The impact of VSPD varies across pollutants. There is a slight reduction in CO and NOx, a slight increase in VOC and while there is a small reduction in PM on motorways, on other interurban roads there is a significant increase in PM.
26 The available evidence shows a reduction in speeds in urban areas.
27 In TRT's ASTRA model, traffic efficiency impacts are only modelled on urban roads. This service is not expected to have an impact on urban roads, therefore the impact on traffic efficiency for the purpose of this study was assumed to be zero.

Service	Description	Service Time-frame	V2V/ V2I	Impact			
				Safety	Fuel Consumption	Pollutant Emissions	Congestion / Travel time
	where the danger is difficult to perceive visually.						
Green Light Optimal Speed Advisory (GLOSA) / Time To Green (TTG)	Provides speed advice to drivers approaching traffic lights, reducing the likelihood that they will have to stop at a red light, and reducing the number of sudden acceleration or braking incidents.	Day 1	V2I	+	+	+	o
Signal violation / Intersection Safety (SigV)	The primary objective of this service is to reduce the number and severity of collisions at signalised intersections, by warning drivers of possible red light violations.	Day 1	V2I	++	o	o	o
Traffic signal priority request by designated vehicles (TSP)	Allows drivers of priority vehicles (for example emergency vehicles, public transport, HGVs) to be given priority at signalised junctions.[28]	Day 1	V2I	o	++	++	++
Information on fuelling & charging stations for alternative fuel vehicles (iFuel)	The objective of this service is to broadcast electric vehicle charging point availability and AFV fuelling point information to relevant vehicles.	Day 1.5	V2I	o	o	o	o
Off street parking information (Pinfo)	Intended to bring efficiency benefits to drivers and help to reduce emissions in urban areas by reducing the time spent 'cruising' at low speeds.	Day 1.5	V2I	o	+	+	+
On street parking management and information (PMang)	Intended to bring efficiency benefits to drivers and help to reduce emissions in urban areas by reducing the time spent 'cruising' at low speeds.	Day 1.5	V2I	o	+	+	+
Park & Ride information (P&Ride)	Intended to reduce congestion in urban areas and also shift travel from cars to public transport.	Day 1.5	V2I	o	+	+	o
Traffic information & Smart routing (SmartR)	The provision of traffic information and smart routing services to vehicles is intended to improve traffic efficiency and aid traffic flow management.	Day 1.5	V2I / V2V	o	++	+	++
Vulnerable Road user protection (VrU)	This is a safety focussed service, which is intended to protect vulnerable road users. In this case vulnerable road users are considered to be pedestrians and cyclists only.	Day 1.5	V2X	+	o	o	o

28 Only applied to buses in urban areas

3. C-ITS STATIONS

The C-ITS architecture distinguishes between different types of C-ITS stations, which have different roles in the C-ITS network.

- **Vehicle C-ITS stations,** which are fully integrated in the vehicle, thus having secure and instant access to vehicle information, such as speed, direction, lights and breaks. This allows them to send messages to support safety-critical C-ITS services (such as the CAM message and collision warnings). In this Impact Assessment, Vehicle C-ITS stations are assumed to be equipped with hybrid communication capabilities, i.e. both short-range and long-range communication.
- **Personal C-ITS stations,** which can either be used stand-alone, e.g. by pedestrians or cyclists, or in a vehicle, to enable C-ITS in vehicles that are not yet equipped with a vehicle C-ITS station. In this Impact Assessment, personal C-ITS stations are assumed to be integrated in devices already owned by consumers for other purposes (e.g. smartphones or navigation devices). As personal C-ITS stations are not fully integrated in the vehicle typically they won't have secure and instant access to vehicle information and thus are currently not capable to support safety-critical C-ITS services.
- **Roadside C-ITS stations,** which are integrated into roadside infrastructure. Roadside units can provide local C-ITS services based on short-range communication which cannot be replicated with long-range communication, or not with the same quality level. A good example is local traffic management at intersections, which could depend on local radars and radio signals from nearby vehicles, in particular priority vehicles. Roadside units can also replace other transport infrastructure and save costs in the medium to long term. Examples here include induction loops (used to detect vehicles at traffic lights) or variable message signs (electronic traffic signs typically used to display special events).

  It is important to note that roadside C-ITS stations are not intended to cover the whole transport network. They will only be used in areas where they have a clear added value, such as busy roads and intersections, at the discretion of the road authority and/or operator. The rest of the infrastructure are expected be covered by C-ITS services based on long-range communication reusing existing networks.
- **Central C-ITS stations,** which are not directly linked to vehicles or infrastructure, but rather provide C-ITS messages from a central point. These stations could for example be integrated in a traffic management system, provide trusted and secure messages based on the aggregation of traffic data collected from a variety of sources. These message can then be distributed in different, for instance directly to vehicle and personal C-ITS stations through long-range communication, or forwarded through Roadside C-ITS stations using short-range communication.

4. TRUSTED AND SECURE COMMUNICATION

In many C-ITS communication scenarios, an ad-hoc network with many-to-many communication is used, which is very different from other communications, such as peer to peer communication or broadcast (one to many). As the receiver needs to be able to able to process with no delay, the first message received from transmitting equipment that appears in range, it is essential that the authenticity and integrity of the messages containing information such as position, velocity and heading can be quickly and consistently verified. This authenticity and integrity allows to assess the trustworthiness of the sent information. At the same time the impact on privacy of road users should be minimized.

To ensure those main objectives, an EU security architecture with support of a Public Key Infrastructure (PKI) using commonly changing pseudonym certificates, has been developed which allows all C-ITS stations to operate within one single trusted C-ITS network in Europe, regardless of the technology used. The requirement of ensuring authenticity and integrity of all C-ITS messages being exchanged between C-ITS stations through their enrolment in one single trust domain ensures trust of C-ITS messages to all actors in the C-ITS network at all times.

Annex 6: The use and protection of personal data in C-ITS

This annex describes some of the key aspects of the use of personal data in C-ITS, the associated risks, and the measures taken to mitigate these risks. This section builds on expert input from the CAR2CAR consortium[29], but should nonetheless be considered only a preliminary analysis to clarify the issue in the scope of this impact assessment, and in no case as a data protection impact assessment. Under the GDPR, data controllers (so also those implementing C-ITS services) are required to perform a data protection impact assessment when introducing new forms of processing personal data which present high risks to the rights and freedoms of individuals (Article 35 GDPR).

Processing operations and purpose of the processing

The day 1 services are primarily based on the exchange of a number of standardized messages: CAM, DENM, IVIM, SPATEM, MAPEM (see Annex 5 for more details on C-ITS services). IVIM, SPATEM and MAPEM messages are originated by (road-side) infrastructure and do not contain personal data, whereas CAM and DENM messages can include personal data. The content of the messages is determined by the relevant standard for the message type and the service profile for the individual service. All Day 1 services have clearly defined purposes of road safety and/or traffic efficiency.

Data sent by C-ITS services from vehicles often qualifies as personal data - as data can be directly linked to the vehicle identification and indirectly to the identity of the vehicle owner - and is therefore related to an identified or identifiable natural person. When this information is sent in an ad-hoc network with many-to-many unencrypted communication (as foreseen for short-range communication), there exists a risk for the misuse of personal data as this information can be received by any C-ITS station in their direct communication range, which ranges between 300 and 500 meters in average conditions. This issue concerns both CAM and DENM messages, but is particularly relevant for the CAMs (as they are send frequently and continuously (a CAM message is sent at least once a second and at the most 10 times per second under normal conditions), where DENMs are event based and only sent when there is an important road safety related event.

Necessity and proportionality of the processing operations

The CAM message supports the need for every vehicle in the vicinity to permanently maintain awareness about the status and presence of other vehicles to avoid crash imminent situations and to optimize / stabilize the flow of traffic. To limit the CAM to only certain vehicles (e.g. to vehicles just behind a transmitting vehicle) would exclude vehicles posing danger from a lateral side.

Allowing the option to choose to transmit or not transmit a CAM while keeping the rest of the system active, or to exchange only partial messages without sending the full CAM message would be detrimental to the functioning of the system for 2 reasons:

29 https://www.car-2-car.org/fileadmin/documents/General_Documents/C2CCC_TR_2051_Data_Protection.pdf

- Incomplete state and other definition from the CAM would in turn lead to incomplete information on the movement of the target vehicles and would decrease the effectiveness of the CAM to prevent collision between two moving vehicles.

- It would undermine the cooperative principle and design of C-ITS, which is based on a contribution-to-benefit principle. Withholding sending of a full CAM would cause the transmitting vehicle to accrue some benefit without giving a similar contribution. For example, one could consider transmitting CAMs only when receiving a DENM. However, this approach is unrealistic, because DENM emission is in turn dependent on receiving CAM information.

What are the key risks associated to the use of personal data in C-ITS? Are there specific high risks cases?

In order to address the risk of a personal data breach due to the transmission and subsequent reception of single CAMs, CAMs and DENMs in the single trusted C-ITS network in Europe are only transmitted in a pseudonymised form, i.e. in a form that cannot be attributed to a data subject with the use of data that is publicly available or available to a single entity. Pseudonymisation means that the CAMs and DENMs include a pseudonym, i.e. and identifier that can only be related to an individual with the collusion of two certification authorities, and only if those certification authorities previously archived information related to the issuing of the certificates to the vehicle or road equipment. This implies that the risk of a data breach either to outsiders or insiders is low. Additionally, CAMs and DENMs should be deleted or stripped of the identifiers after reception and processing in order to ensure that they do not contain personal data so to avoid further data breaches to insiders.

An additional risk that has been identified is that of location linking, i.e. the risk of re-attributing the CAMs to a vehicle/person due to the transmission and subsequent reception of a chain/trace of CAMs during the entire duration of an individual's trip. Therefore, it is planned that the data that would enable the attribution of single positions as a trace to an individual, appropriately changes during the trip, so to prevent the linking of the CAMs.

The CAM contains data elements that never directly identify a concrete vehicle, its owner or its driver, unlike readily available alternative sources such as license plates, registration information, vehicle VIN. CAM have been conceived to exclude as much as possible data that might be used to reasonably link – as a practical matter - a CAM to a specific person "*on a persistent basis without unreasonable cost or effort, either in real time or retrospectively, given available data sources*"[30].

In how far, and in which cases, are these risks additional to already available means of identification?

Already available means of identification *"include physical surveillance (i.e., following a car by visual observation), placement of a specialized GPS device on a motor vehicle, physical access to Onboard GPS logs, electronic toll transactions, cell phone history, vehicle specific cell connections (BT signals), traffic surveillance cameras, electronic toll transponder tracking, and*

30 These and following quotation are taken from the Privacy Impact Assessment carried out by the US National Highway Traffic Safety Administration for the Notice of Proposed Rulemaking on V2V Communications. Available at: https://www.transportation.gov/individuals/privacy/vehicle-vehicle-v2v-nprm-—-december-20-2016

databases fed by automated license plate scanners … many of these non V2V tracking methods may be cheaper, easier, require less (and/or no skill) under certain scenarios".

What data protection measures have been taken in the current specifications?

Data minimization was addressed in European standards for CAM & DENM messages (see EN 302 367-2 for CAM and EN 302 637-3 for DENM). Data minimization is already required by the system due to the size of the frequency bandwidth, which does not allow the exchange of a large amount of data. Other data are also broadcasted only in specific situations (e.g. size of the vehicle is only displayed in dense traffic situations and the weight is not provided).

Data likely to identify a vehicle has been specifically studied and minimized. As an example, in the aforementioned European standards, the vehicle size is defined at a precision level which does not enable the recipient to precisely recognize a model within a very broad range of car dimensions.

The current security mechanisms in the C-ITS communications are designed to fulfil the requirements of road safety applications, i.e. **satisfying the needs for real-time, low-latency communications and high data reliability and integrity**. The design of the C-ITS security system provides solution for authentication and authorization of C-ITS entities to access safety-based services and send messages on the communication network. Privacy and Cyber Security features have been realized by design by defining the EU Certificate and Security Policy (which is an integral part of the specifications) based on PKI management and pseudonymizing of the messages.

Why pseudonymizing (rather than anonymizing) is needed for the functioning of the system:

- A short period of vehicle tracking is absolutely necessary for road safety purposes as an important C-ITS design component to enable the system and make applications work;
- The AT (pseudonym certificate) shows that the user is recognized by the system and can be trusted;
- The system also allows the so-called 'revocation of trust', which removes senders of unauthentic or unauthorized messages from the system by refusing the provision of new authorization tickets.

How the issue of data retention is addressed in the standards & specifications:

- A received CAM shall not be forwarded/broadcast.
- A received DENM may be forwarded/ broadcast only within a limited predefined geographical area.
- Driving conditions data are kept in memory from a few seconds to a few minutes, depending on the need of the service. They are erased as soon as their emission conditions are over, and at each start of the engine.
- No CAM is relayed to a vehicle manufacturer back-end.

Were additional mitigation measures considered?

There exists a risk of vehicle tracking by establishing the relation between 2 successive ATs used by the same device which disappear / appear in the same time (pseudonym change-over). This risk could be mitigated by **introducing a silent period between 2 certificates, or a cryptographic protection of the change period.**

These solutions can be studied, although they are not included in the current ETSI release 1 standards or in deployment specifications. However, these solutions would have a negative impact in terms of safety because in the silent period, the vehicle would not deliver CAM information to its direct environment, significantly affecting the effectiveness of some C-ITS services.

Encryption of the C-ITS basic communications (i.e. safety messages such as CAM and DENM) has been considered but found not to provide any benefit. This because of the nature of the system that is an ad-hoc network with a many to many communication, which is very different to the normal cases where encryption is used, such as peer to peer communication or broadcast (one to many). As the receiver needs to be able to able to process with no delay the first message received from transmitting equipment that appears in range, the receiver would have to know the decryption key in advance. However, the receiver has no knowledge of who the sender is, so it is not possible to use different keys for different transmitters, thus everyone will have the same keys. This very wide distribution of the same key in combination with the short messages means that the encryption will be broken relatively fast and the encryption would be worthless.

Residual risks

There are two kinds of residual risk against data protection in C-ITS:

- The risk that a legitimate data controller uses the data for other purposes
- The risk that an illegitimate data controller (eavesdropper) takes possession of the data.

A legitimate controller in C-ITS is a controller that operates at least one ITS-Station that is enrolled with the C-ITS Security Credential Management System and that has an active role in road safety and traffic efficiency.

The first risk is mitigated by applicable data protection laws (GDPR). Any controller, i.e. a company needs to operate some sort of information security / data protection management system that ensures that data is not processed for other purposes and which should be properly audited.

The second risk is addressed in the C-ITS Security Credential Management System, especially against local eavesdroppers and long-range spot-check attackers

Both those threat scenarios are deemed possible (i.e., with likelihood >0) and have an impact. The impact however is reduced to almost zero by the AT change strategy in most cases.

No other threat scenarios with a significant likelihood have been identified. The threat scenario of ubiquitous eavesdropping is deemed as not probable (i.e., probability ~ 0) unless an illegitimate controller (i.e. an unofficial or unlawful organization – in C-ITS terms) can be demonstrated to have both the resources and the interest to build up an ubiquitous network to survey an area of interest such as a region or city.