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IMPACT ASSESSMENT REPORT

Accompanying the document

Proposal for a Directive of the European Parliament and of the Council

amending Directive 2010/40/EU of the European Parliament and of the Council of 7 July 2010 on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport

{COM(2021) 813 final} - {SEC(2021) 436 final} - {SWD(2021) 475 final}

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Glossary

Term or acronym	*Meaning or definition*
ASTRA	ASsessment of TRAnsport Strategies (modelling tool)
CAV	Connected and Automated Vehicle
CCAM	Cooperative, Connected and Automated Mobility
CEF	Connecting Europe Facility
C-ITS	Cooperative Intelligent Transport System
CO_2	Carbon Dioxide
Day 1	Mature C-ITS services (deployed)
Day 1.5	Close to mature C-ITS services (partially deployed)
Day 2	C-ITS services under development (not yet deployed)
Day 3	Future (automation support) C-ITS services
eCall	Automated 112-based in-vehicle emergency call system
EU CCMS	EU C-ITS Security Credential Management System
GDPR	General Data Protection Regulation
GLOSA	Green Light Optimal Speed Advisory
IIA	Inception Impact Assessment
ITS	Intelligent Transport System
KPI	Key Performance Indicator
LNG	Liquefied Natural Gas
MaaS	Mobility as a Service
MDM	Multimodal Digital Mobility
MMTIS	Multi Modal Travel Information Service
MS	Member State
NAP	National Access Point
NOx	Nitrogen oxides

OEM	Original Equipment Manufacturer
OPC	Open Public Consultation
PM	Particulate Matter
PND	Personal Navigation Device
PO	Policy Option
PRM	Person with Reduced Mobility
RSI	Road Side Infrastructure (supporting ITS)
RSU	Road Side Unit (supporting C-ITS)
RTTI	Real-Time Traffic Information
S&S	Safe and secure
SME	Small or Medium Enterprise
SRTI	Safety Related Traffic Information
SSMS	Sustainable and Smart Mobility Strategy
SUMP	Sustainable Urban Mobility Plan
TMC	Traffic management centre
TRUST	TRansport eUropean Simulation Tool (modelling tool)
UVAR	Urban Vehicle Access Restrictions
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
VMS	Variable Message Sign
VOC	Volatile Organic Compound
VRU	Vulnerable Road Users

1. INTRODUCTION

1.1. Political context

The Commission's Communication on a **Sustainable and Smart Mobility Strategy (SSMS)**[1] puts forward a fundamental transformation of the European transport system to achieve the objective of a sustainable, smart and resilient mobility. The strategy is clear: in order to make transport truly more sustainable we need to deliver effective multi-modality, using the most efficient mode for each leg of the journey. In addition, each mode needs to become more efficient; for road this means that shared solutions increasingly provide a viable alternative for private vehicle ownership. Digitalisation is an indispensable driver to making the entire system seamless and more efficient, as well as further increasing the levels of safety, security, reliability, and comfort. The Strategy identifies the deployment of Intelligent Transport Systems (ITS) as a key action in achieving a connected and automated multimodal mobility. The latter combines new developments such as Mobility as a Service (MaaS) and Cooperative, Connected and Automated Mobility (CCAM). CCAM transforms a driver into a user of a shared fleet of vehicles, fully integrated in a multi-modal transport system, made seamless by Multimodal Digital Mobility (MDM) services such as MaaS. ITS deployment has the potential to improve significantly the functioning of the whole transport system as they better inform transport users and enable them to make safer, more coordinated and 'smarter' use of transport networks.

The SSMS reaffirmed that the death toll for all modes of transport in the EU should be close to zero by 2050[2]. Cooperative Intelligent Transport Systems (C-ITS)[3], which allow vehicles, transport infrastructure and other road users to communicate and coordinate their actions, have an important role in the **next steps towards Vision Zero**[4]. Building on existing synergies (such as eCall) with the **General Safety Regulation**[5] ITS will increasingly complement and provide support to advanced driver assistance systems (e.g. Intelligent Speed Assistance (ISA)). This will mark a move from passive and active safety, to cooperative safety, and is expected to bring a much needed step-change to bring evolutions in road fatalities back on track.

The Commission's Communication on **a European Strategy for Data**[6] recognizes that data-driven innovation will bring enormous benefits for citizens through its contribution to the Green Deal, as well as help making Europe fit for the digital age. It announced the revision of the ITS Directive, including some of its delegated regulations, as well as the intention to establish in 2021 a stronger coordination mechanism for the National Access Points (NAPs)[7] established under the ITS Directive through an EU-wide CEF Programme Support Action.

[1] COM(2020)789 final
[2] COM(2011)144 final
[3] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52016DC0766
[4] https://ec.europa.eu/transport/road_safety/sites/default/files/move-2019-01178-01-00-en-tra-00_3.pdf
[5] https://eur-lex.europa.eu/eli/reg/2019/2144/oj
[6] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0066
[7] https://ec.europa.eu/transport/themes/its/road/action_plan/nap_en

Improved functioning of the entire transport system is a key element to deliver a 90% reduction in the transport sector emissions by 2050, a target needed to achieve climate neutrality. The **European Green Deal**[8] is the new growth strategy for Europe by placing climate action at the core of the EU's policies and the European Parliament and the Council have found a provisional political agreement on the **European Climate Law**[9], setting into law the objective of a climate-neutral EU by 2050 and of the collective net greenhouse gas emission reduction target of at least 55% below 1990 levels by 2030. On 14 July 2021 the Commission adopted a package of proposals, "the Fit for 55 package", to achieve this target.[10] This revision will complement that ambitious package by fostering connected and automated multimodal mobility. This also fosters the uptake of zero-emission vehicles as in the future, based on fully interoperable data underpinning new mobility services, a user will have a whole fleet at his/her disposal. Anxiety about range or purchase cost is then mitigated, especially when that fleet can go recharge itself automatically. In other words, emerging ITS services could not only accelerate the uptake of zero-emission vehicles but also help use them more efficiently. Finally, smoothening road traffic flows (noting that zero-emission fleets should not lead to zero-emission traffic jams) will bring a smaller contribution. Such improvements come with (small) rebound effects, i.e. more efficient traffic may lead to some more traffic. This is however not an argument against efficient traffic; it does highlight that we need flanking measures to decouple the amount of traffic we want from the efficiency of remaining traffic. Ideally, shared zero emission vehicles function as feeder services to existing and even more efficient modes, for both passengers and freight, providing for seamless and more inclusive travel.

ITS and C-ITS, combined with advances in automated vehicle technologies, are not just strong enablers but an integral part of CCAM services. Europe is still leading (37% of patent applications) but countries around the world (e.g. US, Japan, Korea and China) are moving rapidly towards developing and deploying digital technologies in road transport[11]. The accelerated deployment of ITS and C-ITS would give the European automotive and ITS industry an advantage, leading to higher levels of new business opportunities and job creation, and more significant research and innovation impacts. As the jobs of millions of Europeans depend directly or indirectly on the automotive industry (12 million people, accounting for 4% of GDP)[12], it is critical that the sector is provided with the conditions to keep up with global market players.

This impact assessment (IA) accompanies a legislative proposal for the revision of Directive 2010/40/EU on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport[13], amended as regards the period for adopting delegated acts[14]. The deployment of ITS can make an important contribution to the Commission priorities, in particular to the European Green Deal and making

[8] COM(2019)640 final
[9] https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1588581905912&uri=CELEX:52020PC0080
[10] https://ec.europa.eu/commission/presscorner/detail/en/IP_21_3541
[11] https://www.epo.org/news-events/news/2018/20181106.html
[12] https://ec.europa.eu/growth/sectors/automotive_en
[13] Directive 2010/40/EU, OJ L 207, 6.8.2010, p. 1–13.
[14] Decision (EU) 2017/2380, OJ L 340, 20.12.2017, p. 1–3

Europe fit for the digital age. It is part of a package of legislative initiatives aiming at contributing to the goals of decarbonisation, digitalisation and higher resilience of transport infrastructure. Next to the revision of the ITS Directive, there will be the review of the TEN-T Regulation and the urban mobility package, also considering new provisions relating to ITS.

1.2. Legal and policy context

ITS apply information and communication technologies to transport to share transport data and information with all transport users (road authorities, public transport operators, businesses, citizens, etc.). ITS help to significantly improve road safety and traffic efficiency by helping transport users to take better decisions and adapt to the traffic situation (e.g. slow down for dangerous situations, adapt speed to ensure green light, avoid congested areas, etc.). ITS help to better use existing infrastructure, multimodality options and enhance traffic management.

The ITS Directive establishes a framework to support the coordinated and coherent deployment of ITS in the road sector and its interfaces with other modes of transport (e.g. multimodal journey planners combining road and rail). It also ensures interoperability and fosters continuity of services (i.e. it always works, for all users, everywhere) while leaving Member States the freedom to decide which ITS services to invest in. The ITS Directive provides for developing specifications (the detailed requirements needed to ensure the objectives of the Directive) in four priority areas, a description of which is provided in Annex 1 of the Directive and summarised in Table 1 below. In addition, six sets of requirements are identified as priority actions. The Directive foresees reporting by Member States every three years on all priority areas, complemented by reporting requirements in Delegated Regulations.

Table 1: Priority areas and priority actions

Priority area I: Optimal use of road, traffic and travel data	• **priority action (a)** requirements to make EU-wide multimodal travel information services (MMTIS) accurate and available across borders to ITS users • **priority action (b)** requirements to make EU-wide real-time traffic information (RTTI) services accurate and available across borders to ITS users • requirements for the collection by relevant public authorities and/or, where relevant, by the private sector of road and traffic data and making it available to service providers • **priority action (c)** requirements for the road safety related 'universal traffic information' (SRTI) provided, where possible, free of charge to all users
Priority area II: Continuity of traffic and freight management ITS services	• develop an EU ITS Framework Architecture • requirements for the continuity of ITS services, in particular for cross-border passenger and freight services • requirements for ITS applications (notably the tracking and tracing of freight along its journey and across modes of transport) for freight transport logistics • interfaces to ensure interoperability and compatibility between the urban ITS architecture and the European ITS architecture
Priority area III: ITS road safety and	• **priority action (d)** measures for the harmonised provision of an interoperable EU-wide eCall

security applications	• **priority action (e)** measures to provide information services for safe and secure (S&S) parking places for trucks and commercial vehicles • **priority action (f)** measures to provide reservation services for safe and secure (S&S) parking places for trucks and commercial vehicles
Priority area IV: Linking the vehicle with the transport infrastructure	• measures to integrate different ITS applications on an open in-vehicle platform • measures to progress the development and implementation of cooperative (vehicle-vehicle, vehicle-infrastructure, infrastructure-infrastructure) systems

So far five priority actions resulted in supplementing the Directive by a Commission Delegated Regulation (a, b, c, d and e). Regarding the provision of reservation services for safe and secure (S&S) parking places for trucks and commercial vehicles (priority action f), the Commission conducted several consultations with Member State experts and the main stakeholders, which led to the conclusion that there was no need for specifications and standards on reservation of parking areas. Four Commission Delegated Regulations ask for setting up a national access point, establishing a single access point for ITS users to discover ITS data and foster its sharing and re-use (related to priority actions a, b, c and e). A delegated regulation on C-ITS was adopted under priority area IV but never entered into force following an objection by Council.[15]

Synergies with other EU policy instruments

For in-vehicle emergency calls to 112 (eCall) a Delegated Regulation[16] under the ITS Directive combines with a specific legislative framework for the mandatory equipment of vehicles in Regulation (EU) 2015/758[17]. Such synergies are expected to increase in the area of CCAM, for example on ISA as defined in the General Safety Regulation[18] and on C-ITS[19]. The ITS Directive also has synergies with the new road safety policy framework for 2020-2030[20] and the legislative initiatives on vehicle and pedestrian safety[21] and on infrastructure safety management[22], all of which provide complementary provision to increase road safety.

Digitalisation is an important aspect of the revision of the TEN-T Regulation. Road users on the TEN-T network must benefit from the opportunities offered by developments on data collection and ITS services to increase their safety. Therefore, a provision has been added to the Regulation to ensure safety-related events are detected for re-use in safety-related traffic information services, in line with Delegated Regulation 886/2013 under the ITS Directive.

As specific legislation, expertise and programme support actions on alternative fuels infrastructure are in place, discussions on the relevant data types are (also) held within the Alternative Fuels Infrastructure Regulation (AFIR) framework.[23] To ensure complementarity

[15] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=PI_COM%3AC%282019%291789
[16] https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex%3A32013R0305
[17] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:32015R0758
[18] https://eur-lex.europa.eu/eli/reg/2019/2144/oj
[19] https://eur-lex.europa.eu/legal-content/EN/PIN/?uri=PI_COM%3AC%282019%291789
[20] https://op.europa.eu/en/publication-detail/-/publication/d7ee4b58-4bc5-11ea-8aa5-01aa75ed71a1
[21] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52018PC0286
[22] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52018PC0274
[23] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021PC0559

and transparency with the ITS Directive, it has been proposed that the AFIR covers the mandate to make data available for the related data types and further specify the data requirements. To ensure AFIR data is made accessible on the NAPs in a standardised format, a reference to Delegated Regulation 2015/962 under the ITS Directive is made.

Most ITS data is not personal (e.g. speed limits, traffic rules, maps) but some personal data is needed for some critical road safety services (e.g. vehicles sharing they are braking hard warn oncoming traffic of a potentially dangerous situation). Despite measures such as anonymization and data aggregation, data generated through the usage of vehicles can be considered personal and in those cases the General Data Protection Regulation (GDPR)[24] applies.

The upcoming multimodal digital mobility (MDM) services initiative announced in the SSMS aims at increasing the deployment and operational use of MDM services within and across modes, to significantly improve multimodality, inclusiveness and sustainability. In view of identified market imbalances and difficulties to share commercially sensitive data, this proposal seeks to address market challenges hampering the development of MDM services and to establish a framework for commercial agreement for services reselling mobility products.

The provisions of the Platform to Business (P2B) Regulation[25] are applicable to several ITS service providers, such as MaaS applications which offer services to consumers in the EU, and impose more transparency obligations to platforms in relation to the access that business users may have to data (personal or not) when using the platform. The forthcoming Digital Markets Act and Data Governance Act, part of the EU's Digital Strategy may have synergies with the ITS Directive notably in the field of Business to Government (B2G) data sharing. Data made accessible under the Delegated Acts under the ITS Directive is also expected to be part of the future initiative on a common European mobility data space. This initiative aims to facilitate the access, pooling and sharing of data from existing mobility and transport databases.

1.3. Evaluation of the existing Directive

The evaluation[26] of the ITS Directive 2010/40/EU concluded that it had overall positive impacts on the deployment of ITS across the EU and Member States. Despite this, the evaluation identified shortcomings leading to 1) lack of coordination in ITS deployment across the EU and 2) slow, risky and not-cost-effective ITS deployment. In consequence, ITS deployment, despite improvements, still often remains restricted to a limited geographical scope. Thus, there remains a clear need for further action at EU level on interoperability, cooperation and data sharing to enable seamless, continuous ITS services across the EU, the evaluation concluded. Stakeholders responded strongly positive on the relevance of the delegated acts adopted under the Directive, however a few considered that some delegated acts

[24] https://eur-lex.europa.eu/eli/reg/2016/679/oj
[25] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32019R1150
[26] https://ec.europa.eu/transport/sites/default/files/legislation/swd20190368-its-ex-post-evaluation.pdf

could be extended to further increase their relevance. This has been reflected in the Directive's updated working programme adopted on 11 December 2018[27].

Member states reported progress in all priority areas, notably area IV, which was lagging behind, now witnesses the emergence of many pilot projects for C-ITS, following actions to establish a common legal and technical framework in order to ensure interoperability and continuity at EU level.[28] To make progress the EU level is still considered the most relevant for providing such a framework to foster deployment. The main conclusions from the ex-post evaluation, and their links with this impact assessment are presented in Table 2.

Table 2: Links between conclusions of the ex-post evaluation and the impact assessment

Main ex post evaluation conclusions	Impact Assessment
Conclusions on relevance	
The issues and challenges identified at the time of the adoption as well as the general and specific objectives of the Directive are still applicable.	The IA further develops the general and specific objectives of the directive
Conclusions on effectiveness	
The directive has had a positive but relatively limited contribution towards the uptake of ITS. NAPs have been established in many Member States since the adoption of the delegated regulations, but the usage of the data provided by NAPs is still relatively low, and only a limited number of interoperable ITS services have been deployed so far.	Policy measures are defined to enlarge the scope and further strengthen investments in ITS and ensure the deployment of essential services.
The ITS coordination mechanisms appear to have played a positive role. Engagement with national authorities (via the ITS Committee and the Expert Group) has worked well. Interaction with other stakeholders through the ITS Advisory Group has not been as successful.	Policy measures are defined to further strengthen the coordination mechanisms and involvement of all ITS stakeholders
Despite legislation in place, reluctance to share data continues to be a limiting factor. This is due to issues of trust, high expected costs and unclear benefits for those providing the data	Policy measures are defined to increase the availability of crucial data
Conclusions on efficiency	
Benefits of ITS cannot yet be quantified but stakeholders see costs as proportional and expect the benefits to outweigh the costs in the long term when services and their use are scaled up, if they should not do so already.	Policy measures are foreseen to increase the deployment of ITS and reach the scale needed to reap the (large) potential benefits
The cost-effectiveness of reporting obligations is hampered by the lack of comparability between Member State reports (differences in structure, level of detail and use of KPIs)	Policy measures are foreseen to harmonize all reporting obligations and increase the use of KPIs
Conclusions on coherence and coordination	
The ITS Directive and its delegated acts are internally coherent, but the frequency and timing of reporting obligations are currently not aligned. References between the ITS Directive and other relevant EU legislation are increasing, without introducing overlapping requirements. This interdependence is expected to increase moving forward to CCAM, on issues related to vehicles, telecommunications, cybersecurity, liability and the processing and availability of (personal) data	The IA includes measures to align reporting requirements and address synergies with other EU legislation, mainly linked to the use of in-vehicle data, bringing the GDPR into scope but also synergies with existing requirements for advanced driver assistance systems and road infrastructure
Conclusions on EU added Value	
EU level intervention brought benefits not possible with action at national or local level alone. The need for EU action	The IA concludes that EU action continues to be needed to deliver on the

[27] https://ec.europa.eu/transport/sites/transport/files/legislation/c20188264_en.pdf
[28] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=SWD%3A2019%3A373%3AFIN

Main ex post evaluation conclusions	Impact Assessment
to address the key problem of incoherent, inconsistent and fragmented development of ITS across the EU increased.	policy objectives.

2. Problem Definition

2.1. What is the problem?

Building on the evaluation of the ITS Directive, this IA further corroborated the problem analysis through desk research and stakeholders participating in exploratory interviews and workshops. The main problem is the "**slow and fragmented deployment of ITS services, hampering also the uptake of emerging ITS services**". Beyond TEN-T and including urban areas (*Member States are free to choose which sections of their road network they want to cover*) deployment remains slow and fragmented. ITS services cover many different aspects of (road) transport but they all aim at improving road safety or at improving transport efficiency. The latter includes linking all transport modes to foster a more sustainable and more inclusive multi-modal transport system, also for people with reduced mobility. In addition, market development in areas that are key for future transport competitiveness and growth is hampered, including CCAM and MaaS. These are expected to be key enablers in the transition to a mobility system that combines shared door-to-door mobility with public transport, using the most effective mode for each leg of the journey, and help break the paradigm of private car ownership.[29] An overview of the drivers and consequences of this problem is presented in Table 3.

Table 3: Overview of drivers, problems and implications

Drivers	Problems	Consequences
Lack of interoperability and continuity of applications, systems and services hinders the development of a common ITS market	Slow and fragmented deployment of ITS services, hampering also the uptake of emerging ITS services	Limited usage of ITS services with negative impacts on road safety, congestion and transport system efficiency, GHG and pollutant reduction
Lack of concertation and effective stakeholder coordination		Limited development of services such as MaaS and CCAM, leading to missed opportunities to build an inclusive multi-modal transport system
Limited data availability and access, lack of data quality and limited exchange and usage of data		Limited internal market development (for vehicles and infrastructure), limited competition and consumer choice

The Commission's evaluation of the ITS Directive indicated that many of the actions set out in the ITS action plan and the priority actions identified in the Directive have been completed. Table 4 outlines progress made across each priority area, as reported in the 2019 Commission

[29] https://english.kimnet.nl/publications/documents-research-publications/2019/08/15/promising-groups-for-mobility-as-a-service-in-the-netherlands

report to the Parliament and Council[30]. As of June 2021, all Member States have set up NAPs[31], enabling data sharing for the different specifications of the ITS Directive. The Member State reports on the implementation of the Directive paint a picture of incomplete deployment of ITS services and infrastructure and availability of relevant data along the different road types within Member States, with deployment taking up predominantly within the TEN-T network (core and comprehensive). Moreover, where Key Performance Indicators (KPI)[32] on deployment are reported[33], they highlight the uneven deployment of various ITS services. In the comprehensive TEN-T network, a relatively high coverage is identified – considering this is voluntary deployment – by ITS information-gathering infrastructure (57% for 14 Member States) and RTTI data (75% for 14 MSs) and to a lesser extent traffic management and control (18% for 11 MSs) and automatic incident identification (24% for 13 MSs).

Table 4: Summary of Member States progress on implementing the Directive

Priority Area	Member State Progress
I: Optimal use of road, traffic and travel data	Activities are ongoing across most MSs as 22 of the 24 EU MS that submitted a national report, identified projects relevant to this priority area including EU funded projects. MSs develop national journey planners and deploy data-collecting infrastructure. Some challenges persist with engaging private sector operators in access to road safety data.
II: Continuity of traffic and freight management ITS services	MSs are actively engaged, such as by improving their traffic management systems, improving road-rail transport linkages and developing multimodal smart/e-ticketing for public transport. 19 out of the 24 EU MS that submitted a report were actively involved in at least one project in this area (including EU-funded projects).
III: ITS road safety and security applications	Aside from eCall and S&S truck parking, few activities have been reported. Due to their focus on road safety, a few ITS projects along CEF corridors and the C-ITS deployment activities can also be considered partly related to this priority area. 18 out of the 24 EU MSs that submitted a report identified projects related to this priority area.
IV: Linking the vehicle with the transport infrastructure	Considerable effort has been reported in this priority area, largely in relation to C-ITS. 20 MSs have been involved in pilot projects under the C-Roads Platform, with a focus on building cross-border interoperability and harmonised standards. Most of these projects are receiving funding from the Connected Europe Facility (CEF).

Source: Member State Reports (2020-2021)

The availability and accessibility of quality ITS data is a prerequisite for the deployment of all ITS services and remains a serious issue. According to a JRC study[34], innovation deployment in the area of CCAM, as well as in the area of low-carbon and shared mobility is significantly lower as a consequence of the (slow) rate of investment in (ITS) infrastructure. The study identifies a time delay of 10 to 20 years from the technical emergence of new solutions to their

[30] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=SWD%3A2019%3A373%3AFIN

[31] https://ec.europa.eu/transport/themes/its/road/action_plan/nap_en 21 MSs have NAPs for S&S parking (priority action (e) – others have no S&S parking), 26 MS have one for MMTIS (priority action (a) – only Bulgaria is lacking) and all 27 EU MS have them for SRTI (priority action (c)) and RTTI (priority action (b))

[32] KPI should be reported separately by type of road network / priority zone / transport network and nodes. List of KPIs available on https://ec.europa.eu/transport/themes/its/road/action_plan/its_national_reports_en

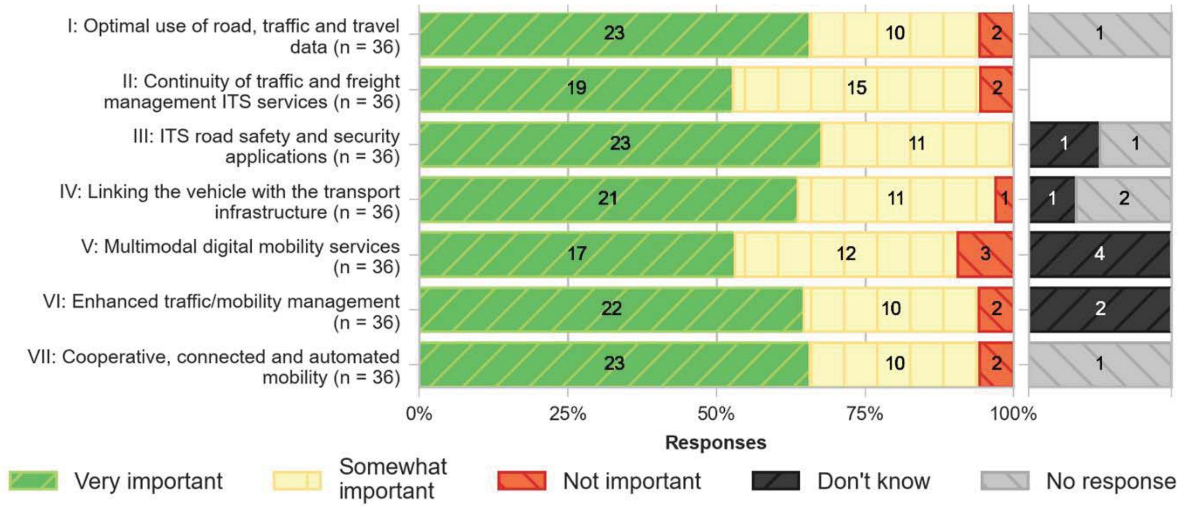
[33] Austria, Belgium, Denmark, Greece, Spain, Finland, Ireland, Italy, Latvia, the Netherlands, Poland, Romania, Sweden and Norway

[34] https://publications.jrc.ec.europa.eu/repository/handle/JRC116644

actual implementation and large-scale deployment. For instance, in 2016, a number of manufacturers announced that vehicles of higher automation levels (SAE level 4 or 5[35]) would be available as early as 2020-2021. This has not happened and release dates have been postponed[36]. Regardless, deployment is expected to vary significantly due to the availability of (roadside and other) ITS infrastructure and data necessary for CCAM.[37] As a result, even when automated vehicles would be available, until the supporting ITS infrastructure is too, CCAM services will not.

The deployment of MaaS is slow, some initiatives have been piloted across Europe but most had problems reaching a significant scale and stable business operation replicable at the EU level[38]. Shortcomings of the implementation of the ITS Directive contribute to this as MaaS requires relevant MMTIS data, currently available only to a limited extent.[39] Additionally, where MMTIS are developed, they are locally or regionally focused and not continuous across larger geographical areas. Furthermore, the extent to which these mobility platforms will integrate booking and payment services is uncertain. The deployment of (new) ITS services with no harmonised specifications (such as mobility management services) is expected to lag for a number of years and remain fragmented. Although such services are not explicitly excluded from the current scope of the ITS Directive, they are also not clearly defined and specifically targeted by existing priority actions and their deployment is slower and fragmented as a result. Figure 1 shows that a clear majority of the stakeholders indicated that current deployment levels of ITS services require further action in relation to the priority areas already identified in the ITS Directive (priority areas I to IV), but also for emerging ITS services (priority areas V to VII).

Figure 1: Stakeholder views on the need for EU action in existing and new priority areas



[35] https://www.sae.org/news/2019/01/sae-updates-j3016-automated-driving-graphic
[36] http://www.trt.it/wp/wp-content/uploads/2020/12/2021011_CAD_Employment_Impacts_Annexes.pdf
[37] https://home.kpmg/uk/en/home/campaigns/2019/09/mobility-2030-future-of-mobility.html
[38] https://cordis.europa.eu/project/id/723314
[39] Only 8 Member States have reported an average of 52% availability of such multimodal data

2.2. What are the problem drivers?

All ITS, mature and emerging, depend on the - often bi-directional - exchange of data between many stakeholders. That means that, despite the wide scope of services covered by the ITS Directive, the problem drivers are common for all priority areas, namely:

- Driver A: Lack of interoperability and continuity of applications, systems and services hinders the development of a common ITS market
- Driver B: Lack of concertation and effective stakeholder coordination
- Driver C: Limited data availability and access, lack of data quality and limited exchange and usage of data

These problems drivers and their underlying factors are described in more detail below.

2.2.1. Driver A: Lack of interoperability and continuity of applications, systems and services hinders the development of a common ITS market

A first contributing factor is ***financial and administrative capacity limitations***. This is highlighted in the KPIs for ITS deployment presented in the Member States country reports[40]. According to these, deployment of ITS services can vary significantly between countries, even when comparing only the TEN-T network or motorways and the disparity between Member States appears to be growing with some countries (e.g. Austria and Spain) having made significantly greater progress than other countries (e.g. Latvia and Greece). Lack of administrative and financial capacity is expected to continue delaying and fragmenting the deployment of ITS services across the EU transport network without further EU level intervention.[41] Although several Member States receive funding for the creation of NAPs via the Connecting Europe Facility (CEF)[42], this does not mean the full set of data types is available on all NAPs. Several stakeholders[43] pointed to the challenges with regard to collect, prepare and share data on all road networks, especially for smaller cities.

This will likely also be the case for the deployment of services unreported so far, such as MaaS applications. The mapping of such services reveals that deployment is highly localised and driven by the private sector, resulting in the deployment of services with relatively limited functional and geographic scope[44]. Achieving the appropriate balance between public and private components in a combined mobility scheme is a major issue, with actors needing to compromise on different business roles and objectives within the same transport ecosystem.[45]

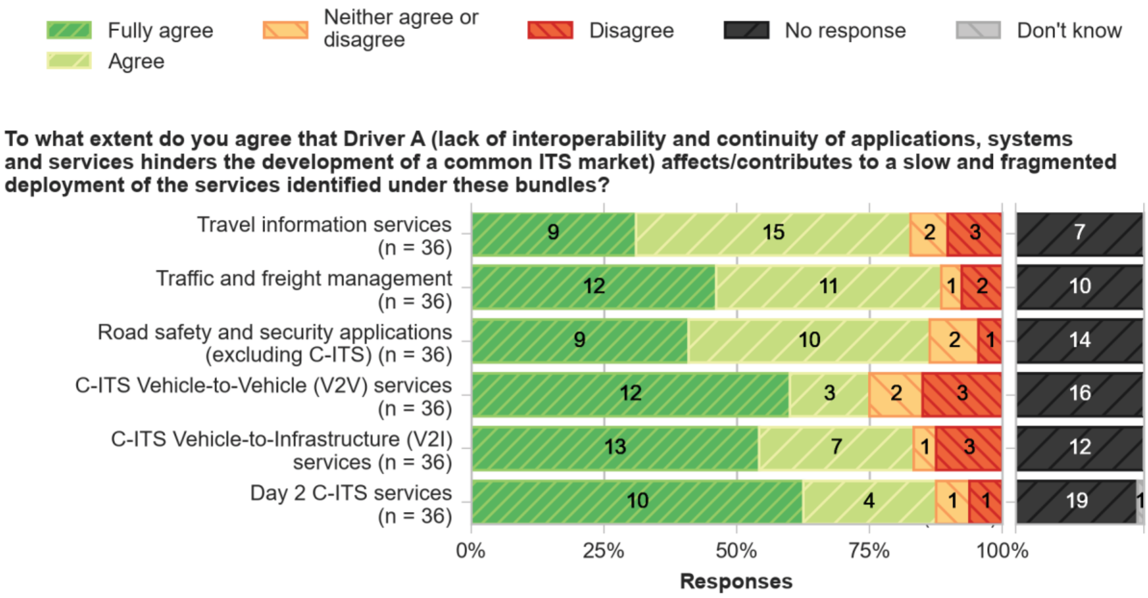
Barriers to interoperability and continuity of services also include ***lack of common standards, principles and quality requirements for emerging ITS services***. New service concepts such as

[40] This has also been reported in the evaluation of the Directive.
[41] https://ec.europa.eu/transport/sites/default/files/legislation/swd20190368-its-ex-post-evaluation.pdf
[42] For MMTIS 17 MS receive CEF funding to help them develop their NAPs
[43] UITP, POLIS, city of Hamburg
[44] https://maas-alliance.eu/maas-in-action/
[45] https://cordis.europa.eu/project/id/723314

MaaS and CCAM require the development of new common standards and priority actions if they are to develop at scale across the EU, including on sharing data between road operators and other stakeholders, speed limits, cycling networks, Urban Vehicle Access Restrictions (UVAR), historical traffic data, roadworks in cities and other road and traffic specific rules.[46]

The majority of stakeholders responding to the Inception Impact Assessment referred to the absence of interfaces that are able to link (all) essential vehicle data with (all) relevant ITS service providers as the most important missing piece to support interoperability, scalability and resilience of ITS services. The lack of interoperability and continuity of ITS services has also been acknowledged as a key issue amongst the Open Public Consultation (OPC) respondents as 42 out of 75 respondents participating to the survey indicated that they do not know which systems are available in a given situation.

Figure 2: Survey responses regarding the relevance of Problem Driver A



Respondents to the targeted survey agreed to a large extent with the existence of Problem Driver A for all types of ITS services as can be seen in Figure 2.

Finally, ***data generated by different transport modes also lacks interoperability***, which is especially relevant for services such as MMTIS and MaaS, as these integrate different transport modes and modes of operation (including not only traditional modes such as road and public transport, but also active modes and new mobility services such as shared and micro-mobility). The 2016 Study on ITS Directive, Priority Action A: The Provision of EU-wide MMTIS revealed that there is no single data exchange protocol for all transport modes, but rather one per mode. This was identified as the primary issue to enable a level playing field for intermodal services as the different data formats cannot be used by mobility platform providers and

[46] Mentioned by stakeholders such as ASECAP, POLIS, EUROCITIES, EPF, FIA, MaaS alliance, 5GAA, city of Lisbon, TomTom, Scania, Volkswagen Group

consumers.[47] The European Platform for SUMPs underlined the need for the legal framework to define interoperable architectures to ensure service availability to all users.[48]

2.2.2. Driver B: Lack of concertation and effective stakeholder coordination

A first contributing factor is the ***limited involvement and buy-in from external / industry stakeholders through the existing cooperation mechanisms in the ITS governance framework***. The governance structure of the ITS Directive includes the following three bodies:

- The European ITS Committee (EIC)[49], composed of Member State representatives was established through Article 15 of the Directive and is consulted on the working programme, the reporting Guidelines, standardisation requests and non-binding measures. It is also an important forum to facilitate the exchange of information with Member States and develop an overall vision on ITS deployment in Europe.

- The European ITS Advisory Group (EIAG) was established according to Article 16 of the Directive to advise the European Commission on business and technical aspects of the deployment and use of ITS in the Union. The group is composed of high-level representatives from a number of stakeholders, bringing together industry, users, social partners, local authorities and other relevant parties.

- The ITS Member States Expert Group[50] composed of national experts that are appointed by Member States to provide technical support in the development of the delegated acts and subsequent monitoring of implementation. The Expert Group is composed by different Member State experts depending on the topic of discussion.

This setting includes two higher level structures operating in parallel with the ITS Member State Expert Group(s), which supports the preparation of the delegated acts and subsequent monitoring. The ITS Advisory Group has convened three times formally, and another eight times informally (when these meetings took place outside Brussels, mostly in conjunction with ITS World or European Congresses). This included seven times with the members of the ITS Committee, in the so-called “Friends of ITS” format. In addition, the ITS Advisory Group has systematically been consulted in writing on the delegated acts, even if this was not formally required in the Directive.

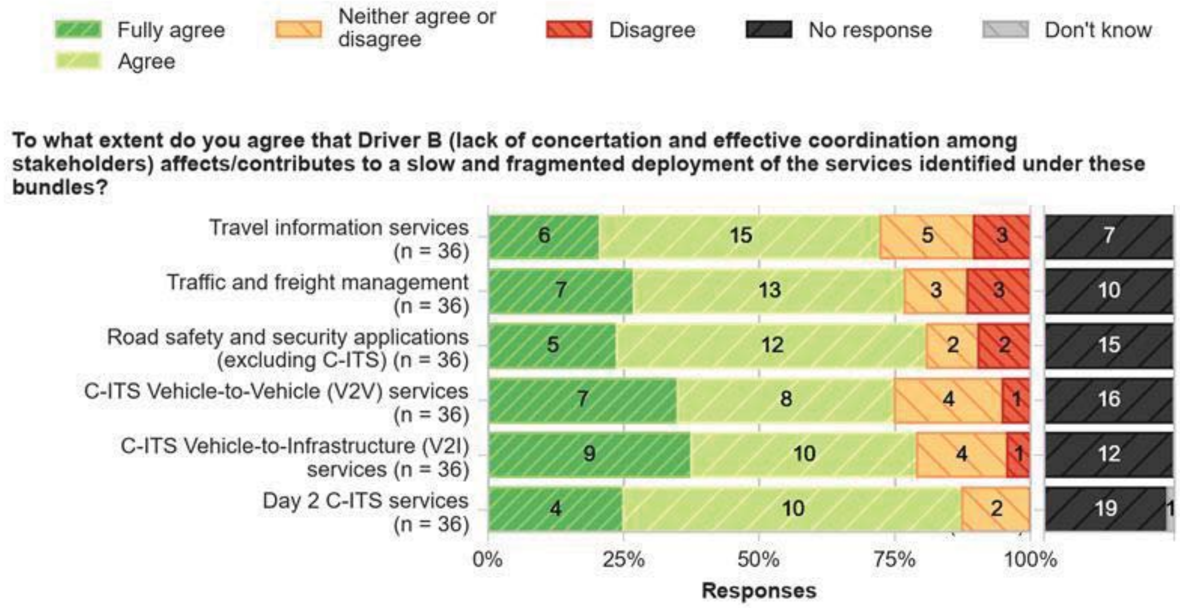
Whilst the format of the “Friends of ITS meeting” was generally well appreciated, as it allowed open discussions with and between public and private stakeholders, the structure has not proven to work effectively regarding the role of the ITS Advisory Group. Some members of the Advisory Group have criticised specifically the timing of the involvement they have had via this group as coming only at a very late stage of the regulatory preparation process, implying they are informed, but not consulted on more strategic discussions, e.g. on the definition of the work programmes and on the objectives of the new delegated acts. This may explain their

[47] https://fsr.eui.eu/publications/?handle=1814/40685
[48] https://www.eltis.org/sites/default/files/the_role_of_intelligent_transport_systems_its_in_sumps.pdf
[49] https://ec.europa.eu/transparency/comitology-register/screen/committees/C39400/consult?lang=en
[50] Register of Commission Expert Groups and Other Similar Entities, code number E01941

subsequently loss of interest in participating to the Advisory Group meetings. This has resulted in lack of formal industry involvement in the implementation of the ITS work programme. This is not due to lack of interest, as both public and private stakeholders increasingly recognise the importance of coordinating priorities and investments when dealing with ITS. This was demonstrated in the scope of the development of the Delegated acts, which included large consultations of stakeholders to which many actively contributed. Also, within other related Commission expert groups, such as those on eCall[51], C-ITS[52] or CCAM[53], coordination with industry stakeholders seemed to work better, which is related to the more upstream timing in the policy development process.[54]

In the absence of their inclusion in the scope of the ITS Directive and a clear coordination mechanism for the development of emerging services such as CCAM with all stakeholders, leading to concrete cooperation, for example to coordinate the deployment of ITS-relevant infrastructure, an uncoordinated deployment of ad hoc solutions is probable.[55] Respondents to the targeted survey agreed to a large extent with the existence of Problem Driver B as can be seen in Figure 3.

Figure 3: Survey responses regarding the relevance of Problem Driver B



The ***lack of comparable monitoring of ITS deployment across the EU*** is another issue, Member State reports do not help produce a comprehensive understanding of the current state of deployment of ITS infrastructure and services. The analysis of 24 reports received in 2020-2021 acknowledges that while most report on traffic management information, the majority provided less information on most other ITS services. The reports are also not consistent

[51] European eCall Implementation Platform - Register of Commission Expert Groups, code number E02481
[52] Platform for the Deployment of C-ITS in the EU - Register of Commission Expert Groups, code number E03188
[53] Expert group on CCAM - Register of Commission Expert Groups, code number E03657
[54] The CCAM platform deals with R&I topics and does not directly involve stakeholders in the regulatory process
[55] As mentioned by stakeholders such as ASECAP, ACEA and AustriaTech

regarding the level of detail used to monitor the deployment of ITS and the benefits produced thereof. Specifically, only 17 Member State reports follow the proposed structure in line with the four Priority Areas defined in the ITS Directive. The use of KPIs[56] is even less consistent as only 13 provide some sort of reporting on ITS deployment KPIs, 12 on benefit KPIs and 11 elaborate partially on financial KPIs. This leads to difficulties in mapping and supporting ITS deployment across Member States, particularly for cross-border comparisons.

2.2.3. Driver C: Limited data availability and access, lack of data quality and limited exchange and usage of data

A first contributing factor is ***long standing and emerging (trust) issues and issues related to data protection, privacy and liability, linked to technological and legislative developments***. These were also cited in the evaluation of the ITS Directive as hindering the further deployment of ITS services and are recurring issues as proven by the number of times the point has been raised in different meetings of the ITS expert group[57] over the last three years (see Figure 4).

Figure 4: Count of concerns raised in the ITS Expert Group meetings, 2017-2020

Source: produced by Ricardo E&E based on available meeting minutes. The red circles indicate topics that are especially relevant to the problem drivers.

The Open Public Consultation (OPC) respondents supported this finding as stakeholders participating to the survey (31 of 75), expressed concerns about the privacy and re-use of personal data. To a lesser extent, concerns have also been expressed regarding the security of ITS systems (18 of 75 participating stakeholders agreed with the issue). Concerns have also

[56] List of KPIs available on https://ec.europa.eu/transport/themes/its/road/action_plan/its_national_reports_en
[57] https://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupDetail&groupID=1941

been raised with regard to the security and privacy impacts of C-ITS which may slow down wide-spread deployment. In their responses to the IIA, a range of stakeholders, including the EPF, Move EU[58], the European Consumer Organisation (BEUC), ANEC[59] and Eurocities considered privacy and security concerns related to the sharing of static and dynamic transport user and providers data. FIA identified the capacity of drivers to retain ownership of their data as a key consideration for sharing. Other stakeholders also identified challenges to prove alignment of the ITS Directive with the GDPR and ePrivacy legislations.[60]

The 2016 Study on ITS Directive, "Priority Action A: The Provision of EU-wide Multimodal Travel Information Services" also revealed that the development of interoperable travel and traffic data and their sharing and reuse is currently hindered by commercial confidentiality issues. It highlighted again the need to increase trust in order to promote data sharing amongst mobility stakeholders. In this respect, a set of common principles on the conditions of data sharing and use of relevant data could increase stakeholder cooperation and the reuse of data.

The deployment of new types of services could pose new challenges in relation to existing policies laying down data sharing, data protection and privacy, and liability requirements. The development of the legal framework governing data protection[61] since the ITS Directive came into force might also lead to the need to align the provisions of the ITS Directive to clarify how ITS services need to comply with data-related regulations and identify the conditions under which data collection, sharing and reuse can be performed. The recent work of the European Data Protection Board provides guidance to vehicle and equipment manufacturers, service providers or any other data controller or processor to facilitate compliance with GDPR when processing personal data in the context of connected vehicles and mobility related applications. In addition to general recommendations, these Guidelines also analyse several examples of data processing such as usage-based insurance or eCall. [62]

Additionally, liability issues are still considered unresolved and can hinder the deployment of ITS services. For example, in a study from 2018[63] the European Parliament noted the need to revise the liability framework to address issues relevant to the deployment of automated vehicles. Also, a JRC study on "The future of road transport - Implications of automated, connected, low-carbon and shared mobility" identified Connected and Automated Vehicles (CAV) and other new mobility solutions as linked to raising issues in terms of privacy, and equity. As CAVs utilise multiple sources and sets of digitally stored personal data, keeping both personal and proprietary information safe is a key issue.[64] Finally, various stakeholders (AustriaTech, ASECAP and POLIS consulted through the exploratory interviews) identified the lack of a trust model for exchanging data between the involved stakeholders as the main

[58] representing the European ride-hailing sector
[59] representing consumers in the context of standardisation
[60] Mentioned by ACEA, Volvo Group and the Norwegian Public Road Authority in their IIA responses
[61] GDPR and ePrivacy Directive
[62] https://edpb.europa.eu/our-work-tools/our-documents/guidelines/guidelines-012020-processing-personal-data-context_en
[63] https://www.europarl.europa.eu/RegData/etudes/STUD/2018/615635/EPRS_STU(2018)615635_EN.pdf
[64] https://publications.jrc.ec.europa.eu/repository/handle/JRC116644

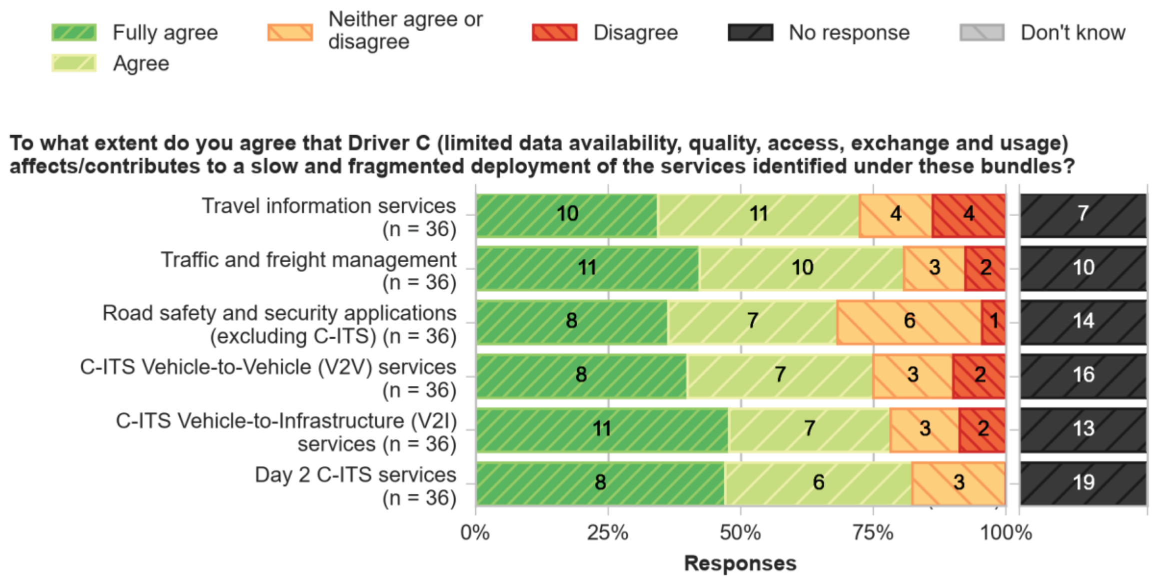
hurdle to enable the necessary data flow for the (quality) operation of ITS services. They highlighted that MaaS deployment requires a fair and non-discriminatory system outlining the rights and obligation of involved stakeholders, access and data sharing and reuse conditions.

Another factor elaborated in the evaluation of the Directive was that ***the actual sharing of data beyond static network information has been very limited***.[65] This is despite the fact that NAPs have been set up as a potential backbone for the digital transport infrastructure and an entry point for sharing data. An approach to develop a coordination mechanism to federate NAPs is currently in preparation and aims to stimulate and accelerate the coordinated provision of data (addressing also problem driver B).[66]

The current lack of data sharing can also be attributed to a ***lack of awareness of incentives and benefits to collect and share such data*** amongst the different stakeholders involved in the data value chain (e.g. data producers, intermediaries, users etc.). The support study on RTTI defines essential services and identifies the data types necessary for the operation of these services, which currently lacks availability. [67] The study concludes that there is a clear added value for making these data available in a phased manner, initially for a strategic road network and then expanding to the entire transport network.

Respondents to the targeted survey agreed with the contribution of Problem Driver C in hindering the deployment and use of ITS services across the EU as can be seen in Figure 5.

Figure 5: Survey responses regarding the relevance of Problem Driver C



There also seems to be a lack of policies and measures aiming to make fare information and service sharing possible, resulting in a barrier for the uptake of certain ITS services.[68] Some of the stakeholders responding to the IIA suggested that the lack of two-way sharing of data

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[65] KPI on the availability of dynamic data on NAPs used in Member State reporting
[66] https://ec.europa.eu/transport/content/2020-call-for-proposals-nap_en
[67] https://op.europa.eu/en/publication-detail/-/publication/043ee22b-643b-11eb-aeb5-01aa75ed71a1
[68] https://cordis.europa.eu/project/id/723314/results

between transport users, the public and private sectors may be a contributing factor. A number of stakeholders suggest that there is a minimum level of standardised data that would need to be shared to overcome this problem. However, differences in opinions persist as to how far the sharing of data also includes private sector data. A limited number of Member States have declared their intention to make also dynamic data available through their NAPs.[69]

2.3. How will the problem evolve?

In the absence of further EU level intervention to address the problem and its drivers, it is likely that the deployment of a number of ITS services that rely on EU-level standardised data streams will remain slow and fragmented, hampering innovation. In particular, ITS services will likely function primarily at a local, regional or national level as is currently the case, with limited cross-border interoperability and only at a later stage considering integrating EU-level services.

In the absence of additional EU level intervention, the problem drivers contributing to the problem would likely persist. Specifically, *Problem Driver A: Lack of interoperability and continuity of applications, systems and services (across different Member States and modes of transport)*, cannot be fully resolved by actions undertaken at a Member State or regional level alone. The Member State reports on the implementation of the Directive paint a picture of incomplete deployment of ITS services and infrastructure and availability of relevant data along the different road types within Member States, with deployment taking up predominantly within the TEN-T network. This points to the fact that deployment of continuous ITS services is unlikely until relevant infrastructure and data are delivered across the whole of the EU transport network. There is no indication that future Member State priorities will converge to the point of achieving full deployment of ITS services across the EU in the short- or mid-term.

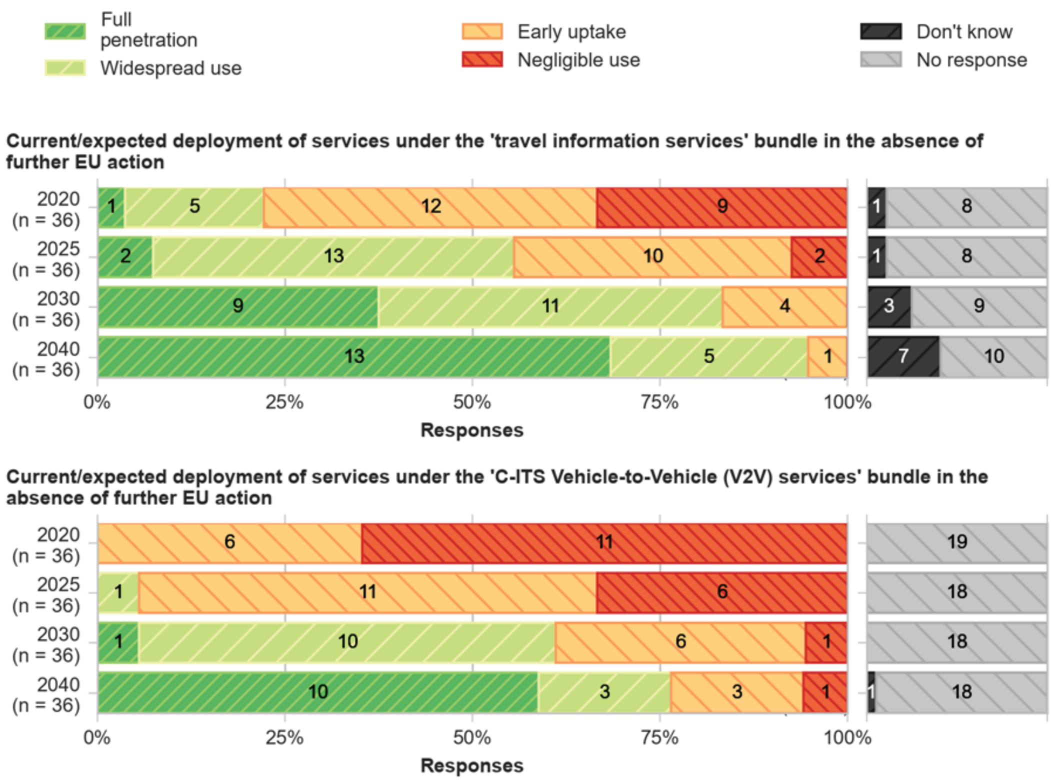
Beyond these continuity concerns, stakeholders also raised the high risk of fragmentation of (emerging) ITS services due to the use of different standards by different stakeholders[70]. Service interoperability will thus most probably develop on an ad hoc basis between service providers of different modes or regions but lacking a universal framework of application. The majority of respondents to the targeted survey, shared the view that most of the ITS service types identified, would only be fully available towards 2040 as illustrated by the examples presented in Figure 6 for "travel information" and "V2V C-ITS" services. As such, only partial availability of services is expected until then, with travel information services expected to be deployed earlier than C-ITS services.

Looking at the expected development of *Problem Driver B: Lack of concentration and effective coordination among stakeholders*, this also does not seem possible to be tackled in the absence of further EU-level action. Although stakeholder cooperation is already a fact for some ITS related topics (e.g. NAP coordination), this is largely a result of EU action. Therefore, in the absence of further EU-level action, public and private stakeholders could be expected to continue developing voluntary industry or Member State-led cooperation mechanisms to deal with specific ITS issues that would not contain the full selection of relevant stakeholders. Such

[69] https://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupMeetingDoc&docid=43371
[70] Indicated in the survey responses of Insurance Europe and Allianz

initiatives could be expected to develop a common approach or policies to deploy ITS, but would do so taking a more narrow geographical or modal view point and in relative isolation from other groups attempting similar initiatives.

Figure 6: Stakeholders' expectation of the state of deployment of ITS services



Source: Targeted stakeholder survey

Finally, with regard to the Problem *Driver C: Limited data availability and access, as well as lack of common data quality standards and limited exchange and usage of data,* no significant developments are expected without further EU-level intervention. A number of Member States are currently moving forward in making crucial data for the deployment of ITS services available (e.g. France has already mandated the availability of MMTIS data for persons with reduced mobility[71]). However, this is not expected to expand to the whole of the EU. As data sharing and reuse is currently often left at a voluntary basis, the sharing of data will likely remain limited to the level of individual business agreements. Also, current trust issues affecting the willingness of stakeholders to share and reuse data can be expected to continue in the absence of an EU level action, especially on addressing concerns regarding compliance of ITS deployment with EU data protection legislation.

The deployment of certain innovative services that rely on sharing specific data categories, is therefore expected to suffer from the lack of incentives to produce, share and reuse specific high quality, real-time data. Also, such data, where made available, would follow different quality standards introduced by different Member States or industry stakeholders in the absence

[71] Décret n° 2021-836 du 29 juin 2021 relatif à la collecte des données décrivant l'accessibilité des itinéraires pédestres https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000043714243

of an EU-level coordination on this topic intervention taking place. Thus, although it can be expected that more data will be made available in the future, these would come at different levels of availability and quality standards across the EU leading to the retention of the problem of essential data for ITS services being only partially available and used in the future.

3. WHY SHOULD THE EU ACT?

3.1. Legal basis

To ensure the correct functioning of the internal market the Treaty on the Functioning of the EU (TFEU) establishes the EU's prerogative to makes provisions for the Common Transport Policy, Title VI (Articles 90-91) and for the trans-European networks, Title XVI (Articles 170-171). With this legal framework in mind, EU action allows better coordination for even, continuous and widespread deployment of ITS, instead of relying on Member States only. This facilitates travel across the EU for consumers and transport operators. It also helps to avoid fragmentation of ITS deployment and encourages private service providers to commit to deployment, knowing the road infrastructure is in place.

3.2. Subsidiarity: Necessity of EU action

While ITS services can be (and are) introduced at regional or national level, the continuity of the EU transport system requires an EU-wide approach to deal with the problems at stake. Discrepancies between Member States and local authorities in support measures for the deployment of ITS could lead to a fragmented market leading to increased costs and reduced benefits for all stakeholders, including service providers, Member States, local authorities and transport system users. Different regional approaches may even lead to a complete inability to deploy specific services involving multi-modal or cross-border cooperation.

Industry-led standardisation through the European Standardisation Organisations contributes to interoperability, but it is voluntary by nature and allows non-interoperable implementations, and with many different actors and strong network effects, no actor can introduce an interoperable solution on its own. Similarly, setting rules at the national level would likely hinder the provision of continuous ITS services in the Single European Transport Area.

Compatibility between infrastructure and vehicle solutions will need to be assured across the EU in order to fully benefit from ITS. In addition, to ensure effective synergies with the deployment of new safety technologies and the roll-out of CCAM across the EU a more harmonised approach at EU level is needed. Only when reassurance is given that harmonisation is achieved at EU level, implying also, crucially, that vehicles will benefit from infrastructure services all across the Union, does deployment make sense. Similarly, though the business case is calculated differently for the public sector, it makes no sense to invest unless large portions of the fleet are expected to be equipped in the near future.

EU-level coordinated action is already introduced as an optimal approach for the deployment of the current version of the ITS Directive and EU action is foreseen to tackle the four priority areas identified in the Directive. A revision of the ITS Directive would aim to further yield results in these key priority areas as well as in new defined policy areas aiming to cover emerging ITS service. Stakeholder consultation also revealed support for action at EU level.

3.3. Subsidiarity: Added value of EU action

The main benefits of EU action lie in the continuous ITS services across the EU which the initiative aims to achieve. Travel throughout the EU should become safer and more efficient, whereby less advanced Member States will be able to benefit from the experience of more advanced Member States. This should in turn improve the functioning of the internal market, through a smoother and more coherent travel experience for passenger and freight transport, and support the EU's objective of economic, social and territorial cohesion.

A framework for continuous ITS services, supported by a broad group of stakeholders, would also help create a supportive ecosystem for the research and innovation in new ITS services and technologies such as MaaS. The development of highly automated road transport is part of a global race and competition, including stakeholders from outside the traditional automotive sector. As (cooperative) ITS is a key enabler for automation and deploying CCAM in the EU, its continuous, harmonized and EU-wide deployment would improve the EU’s international competitiveness in this field.

4. Objectives: What is to be achieved?

4.1. General objectives

This initiative aims to increase the deployment and operational use of ITS services across the EU, to improve road safety, increase the efficiency of the transport system as a whole and help linking all transport modes to foster a multimodal transport system and, and in doing so, to reduce the negative external effects of transport.

This contributes to the two key priorities for the transport system described in the Sustainable and Smart Mobility Strategy: the decarbonisation and digitalisation of the EU transport sector. In addition, this will contribute to reducing accidents and achieving Vision Zero.

4.2. Specific objectives

All ITS require the exchange of data. To make that happen the data needs to exist, be standardised, digitalised and available for sharing. In addition, there needs be trust between the parties sharing the data and coordination between multiple actors, particularly when effective delivery of the service depends on parallel investments. Furthermore, the very positive cost benefit ratio of ITS applies when deployment takes place at the scale of the Union. For example, it makes much less sense to equip vehicles when the public data needed to deliver the service is only available in a fragmented manner.

General objective	Specific objective	Indicator
Increase the deployment and	SO1:Increase interoperability and cross-border continuity of	• Increased financial and administrative capacity to accelerated ITS deployment

General objective	Specific objective	Indicator
operational use of ITS services across the EU, to improve road safety, increase the efficiency of the transport system as a whole and help linking all transport modes to foster a multimodal transport system and, and in doing so, to reduce the negative external effects of transport	applications, systems and services supporting a common ITS market	• Increased interoperability and continuity of services across Member States • Creation of common standards, principles and quality requirements for emerging ITS services • Increased interoperability of data generated by all modes
	SO2: Establish a clear and effective coordination and concertation process for all ITS stakeholders (including stake-holders relevant in the multimodal context of the Directive)	• Stronger cooperation in ITS governance, industry buy-in • Comparable monitoring of ITS deployment across MSs
	SO3: Ensure improved data availability, access and quality standards used and facilitate the exchange and usage of data supporting ITS services	• Solutions for (trust) issues with data protection, privacy and liability • Increased incentives / awareness to collect and share ITS data

From this, three specific objectives (matching the three problem drivers defined in chapter 2.2) were identified.

SO1: Interoperability is a necessary precondition for reaching cross-border continuity of ITS services. For existing services a lot of work has already happened but for emerging ITS services like multimodal services and when combining data from different modes, issues remain. Without this, deployment will by definition be fragmented and likely be delayed. As a result transport users cannot or will not benefit from such services when travelling in the Union, even when reaching regions that have invested in deployment. This will limit the potential of such services and fail to create the necessary scale required to unlock larger investments and support a European ITS market. Success will thus depend on addressing these issues and be measured by the financial and administrative capacity to develop innovative multi-modal mobility services that depend on this data and the deployment of all services.

SO2: ITS services are beneficial for individual transport users, as well as for transport network managers, road operators, vehicle manufacturers, mobility service providers, fleet managers etc. ITS services can also be offered by public authorities, road operators and industrial service providers. Moreover, some ITS services target multimodal travel services and require the collaboration of stakeholders from other modes. That implies that accelerated and harmonised deployment of ITS services can only happen when clear and effective coordination and concertation processes exist for all ITS stakeholders. Success will depend on aligning public and private interests, matching investments from both sides and the deployment of ITS that successfully builds on and combines data from public and private sources. In addition, comparable monitoring of ITS deployment helps understanding what already exists and works well, realising continuity of services and creating incentives to build on that.

SO3: in order to exchange data it first of all needs to be available. Next, the data also needs to be accessible, in a standardised format, and of high-quality, meaning not only the level of detail but also making sure that the data is not outdated. When personal data is involved, for example when C-ITS or in-vehicle data is used, issues on data protection, data ownership, privacy and liability need to be resolved. Trust amongst stakeholders is important, particularly when dealing with commercially sensitive data, and to be complemented by suitable business models, from both public and private perspective. Common solutions for all interested parties are needed as both vehicles and infrastructure would benefit greatly from increased data availability and sharing. In fact, for higher levels of automation many now consider this a necessary enabler. Success would be the timely availability of the necessary high quality data (such as traffic regulations) to support advanced vehicle features, whilst in-vehicle data is available for enriching traffic management and other infrastructure services. Success would also mean sharing of relevant data by all mobility providers to enable multi-modal mobility services. A by-product/additional manifestation of that success would be the continued presence of EU technology providers and automotive OEMs amongst the global leaders in the mobility sector.

5. WHAT ARE THE AVAILABLE POLICY OPTIONS?

5.1. What is the baseline from which options are assessed?

The EU Reference Scenario 2020 (REF2020) represents the starting point for assessing the options in this IA. The EU Reference scenario 2020 reflects the range of foreseen national policies and measures of the final National Energy and Climate Plans that Member States submitted in 2019 according to the Governance Regulation[72]. The EU Reference scenario 2020 also takes into account the impacts of the COVID-19 pandemic that had a significant impact on the transport sector. More detailed information about the preparation process, assumptions and results are included in the Reference scenario publication[73].

Building on the Reference scenario 2020, the Baseline scenario for this IA has been designed to include the initiatives of the 'Fit for 55' package and other measures of the MIX policy scenario[74]. The MIX scenario follows a balanced approach of carbon pricing instruments and regulatory-based measures to deliver on the ambition of at least 55% emissions reductions by

[72] Regulation (EU) 2018/1999
[73] EU Reference Scenario 2020 | Energy (europa.eu)
[74] The representation of the CO2 standards for light duty vehicles and the revision of the Renewable Energy Directive in the MIX scenario is not fully consistent with the proposals adopted on 14 July. These however are not expected to have any impact on the deployment of ITS services relevant for the Baseline scenario of this impact assessment. In addition, as the road transport and buildings are subject to a separate Emission Trading Scheme, the emissions from these sectors are capped. This means that if the contribution of renewable and low carbon fuels is higher than in the MIX scenario this would result in a somewhat lower ETS price but without a significant impact on transport activity and emissions.

2030 and climate neutrality by 2050[75]. The Baseline scenario is commonly used by this IA and the one underpinning the review of the TEN-T Regulation (both planned to be adopted in autumn), to ensure consistency.

The Baseline scenario assumes no further EU level intervention beyond the current ITS Directive. It assumes the continuation of the application of the ITS Directive provisions and the preparation of standards for the already defined priority areas. It also covers:

- National ITS deployment projects (e.g. C-Roads and ITS corridors) are expected to result in important ITS deployment at regional level, but not widespread adoption.

- Industry announcements and identified trends around ITS deployment.

Without further EU level intervention ITS service usage is projected to progress slowly.

In this IA the existing priority areas and services as described in chapter 1.2 (many of which are already covered by Delegated Regulations) are complemented by emerging ITS services. The multi-modal area is strengthened by including booking services and intermodal interfaces for drivers, whilst traffic management is complemented by mobility management and support for automated vehicles is also included. The various types of services have been bundled, taking into account mainly the targeted transport users and the underlying deployment drivers (see Table 5). The 3 C-ITS bundles (4, 5 and 6) are separate because they rely on communication between dedicated C-ITS devices (typically installed in vehicles or in the infrastructure) whilst the information services in the other bundles can generally be delivered through various non-dedicated means, such as navigation devices and smartphones (e.g. planning a multimodal trip). This forward-looking extension, and some regrouping, was subsequently tested in the first open stakeholder workshop. This led to splitting the first bundle, making a clear distinction between drivers and travellers, again strengthening the multi-modal angle. The bundles were presented in several workshops afterwards, in which stakeholders recognised the logic not only in terms of functionality and target users, but also of the required investments.

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[75] It should be noted that the MIX scenario underpinning the impact assessments accompanying the ‘Fit for 55’ package covers the initiatives adopted in July 2021 but also some other initiatives of this year and of the following year (e.g. for transport, CO_2 standards for heavy duty vehicles, the revision of the TEN-T Regulation, the revision of the ITS Directive, the revision of the Rail Freight Corridors Regulation and of the Combined Transport Directive, etc.). For this reason, only a few adjustments had to be made in order to provide a suitable Baseline scenario for this impact assessment. This however does not mean that the Baseline scenario deviates from the balanced approach of the MIX scenario, combining carbon pricing instruments and regulatory-based measures. These two initiatives were represented in a stylised way in the MIX scenario, ahead of the respective legislative proposals. In order to provide a meaningful Baseline for the two impact assessments, showing how the problem would evolve without further EU level intervention, it has been assumed that only the current EU level legislation (i.e. the current TEN-T Regulation and the current ITS Directive) is in place for these two initiatives. In addition, for the Rail Freight Corridors Regulation and for the Combined Transport Directive it has been assumed that only the current EU legislation is in place. This is because of the important synergies between the revision of the TEN-T Regulation and the forthcoming revisions of the Rail Freight Corridors Regulation and of the Combined Transport Directive, that need to be enabled by the availability of high quality infrastructure for their success. All other assumptions were kept unchanged.

Table 5: ITS service bundles

No.	Service bundle	ITS service type	Intended impacts on transport
1a	Information & booking services for travellers	• Multimodal travel information service • Multimodal booking / re-selling service (including mobility as a service)	Improved trip planning choices (time/route/modal)[76] leading to: • Congestion reduction / trip time • Reduction in fuel consumption / emissions • Modal shift • Reduction of transport costs (incl. external cost of transport to society) • Improvement in resilience and quality of service
1b	Information and booking services for drivers	• Road traffic & navigation service • Real-time traffic information service • Parking (and pricing) information • Re-charging/re-fuelling information • Intermodal interfaces	
2	Travel management services	• Traffic incident management systems • Mobility management services	
3	Road safety and security applications	• Road safety-related traffic information • S&S truck parking • eCall	Improved transport safety • Reduction of accidents (fatalities and injuries) • Reduction of external costs (caused by accidents)
4	Vehicle-to-vehicle (V2V)	• C-ITS services such as electronic brake light & hazardous location	
5	Vehicle-to-Infrastructure (V2I)	• C-ITS services such as shockwave damping, in-vehicle speed limits, green light optimal speed advice and Signal violation	• Congestion reduction / trip time • Reduction in fuel consumption / emissions
6	Future C-ITS services	• C-ITS cooperative perception services (day 2) and automation support services (day 3) – e.g. platooning	• Significant (longer term) impacts in transport safety and mobility

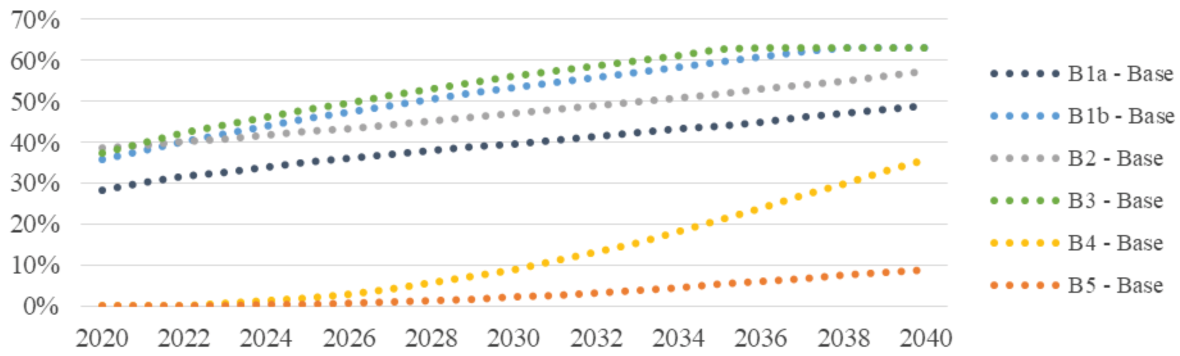
Stakeholders contributed to the establishment of the list of ITS services and its bundling during the targeted interview programme and the series of workshops held (see annex II). Electronic tolling and payment services were considered at some point but discarded as they are already regulated outside the scope of the ITS Directive[77]. Stakeholder feedback also led to the splitting of bundles 1a and 1b to clearly identify services having primarily a multi-modal focus targeting travellers rather than drivers. Some stakeholders questioned whether the bundling reflected any choices in technology to deliver the services (particularly related to the C-ITS bundles) but that is not the case. The ITS service bundles do not aim to develop any formal classification but serve a functional purpose for this IA. Specifically, by grouping together services with similar/overlapping functionalities, the deployment rates and their impacts can be assessed in a systematic way, without going into details for the numerous ITS services while at the same time capturing all the costs and benefits associated to them.

The usage of the ITS services in these seven bundles is what drives impact on the transport system so the IA estimates the expected increase in ITS service usage in the baseline for all service bundles until 2040. Services in Bundles 1-3 start from a higher level of usage in 2021 compared to Bundles 4-5 that are reliant on the continued roll out of dedicated infrastructure

[76] Provided alternatives to car / truck transport are available.
[77] https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX:32019L0520

and deployment of equipped vehicles, which take time to penetrate the total fleet. The more mature ITS services (i.e. travel management services (bundle 1b) and road safety and security applications (bundle 3)) are projected to reach 70% coverage on TEN-T roads in front runner countries by 2040, see Figure 7.[78] For Bundle 6, which includes services leading to higher levels of automation, no service usage is projected in the IA. [79]

Figure 7: service usage in front runner countries in the baseline



Source: Ricardo et al. (2021), Impact assessment support study

In the Baseline scenario, EU transport activity is projected to grow post-2020, following the recovery from the COVID pandemic. Road transport would maintain its dominant role within the EU in 2040, despite the fact that rail transport activity would grow significantly faster. Congestion costs would increase by about 14% by 2030 and 23% by 2040, relative to 2015. Congestion on the inter-urban network result from growing freight transport activity along specific corridors, in particular where these corridors cross urban areas with heavy local traffic.

CO2 emissions from transport including international aviation but excluding international maritime transport, are projected to be 19% lower by 2030 compared to 2015, and 70% lower by 2040. The reduction in road transport emissions would be higher, at around 24% by 2030 relative to 2015 (78% decrease by 2040) driven in particular by the proposed CO2 standards for light duty vehicles, supported by the roll-out of recharging/refuelling infrastructure, but also by other measures like carbon pricing and energy taxation.

NOx emissions are projected to go down by 56% between 2015 and 2030 (77% by 2040), mainly driven by the electrification of the road transport. The decline in particulate matter (PM2.5) would be slightly lower by 2030 at 52% relative to 2015 (79% by 2040).The number of fatalities is projected to be 22% lower in 2030 relative to 2015 and 28% lower by 2040,

[78] Bundle 1a is shown for urban roads and not TEN-T as this is where usage of MaaS and MMTIS services is expected to be highest. The model also distinguishes between service delivery methods (generic devices such as smartphones and in-vehicle systems) but the chart does not make this distinction and shows all service usage. Finally, the model also distinguishes between vehicle types (cars, light trucks, heavy trucks and busses), in the chart cars are shown as they represent the largest fleet, with the exception again of bundle 1a, which is associated with travellers and not with drivers or vehicles.

[79] Due to their early level of development, there are no concrete studies that have investigated the impacts considered in this impact assessment, and it is therefore not possible to accurately represent them in the model. This was confirmed during discussions with stakeholders during the workshops, who agreed that there were no reliable sources, and stated that the focus of the ITS Directive should be on increasing the deployment of services with a higher level of maturity, rather than Bundle 6, which is more forward looking.

being however far from the milestone of the Sustainable and Smart Mobility Strategy of close to zero death toll for all modes of transport in the EU by 2050. The number of serious and slight injuries would go down at lower speed (18% for 2015-2030 and 22% for 2015-2040). More details on the baseline scenario are provided in Annex 4.

5.2. Description of retained policy measures

As a first step, a comprehensive list of possible policy measures was established after extensive consultations with stakeholders, expert meetings, independent research and the Commission's own analysis. This list was subsequently screened based on the likely effectiveness, efficiency and proportionality of the proposed measures in relation to the given objectives, as well as their legal, political and technical feasibility. The retained policy measures are presented in Table 6 and linked to the service bundles (SB) that are expected to most benefit from them. Measures 11, 12, 13, 14 and 15 are implemented, for most in a phased approach, between 2025 and 2030. All other measures are assumed to be implemented starting in 2025.

Table 6: list of policy measures and service bundles expected to benefit from them

#	Type of measure	Policy measure	Policy measure description	Aim of the policy measure	SB
1	Extension of scope	Adjust the scope of the Directive to explicitly include MDM services	The scope of the Directive would be broadened to explicitly cover ITS services that support multimodal mobility.	Improve the deployment of the relevant ITS infrastructure, continuity of services, address the lack of common standards and improve the interoperability of data generated across modes.	1a
2	Update priority areas	MDM services	The definition of the priority area would be broadened to ensure that it clearly covers services in support of multimodality.	Improve the deployment of the relevant ITS infrastructure, continuity of services, address the lack of common standards and improve the interoperability of data generated across modes.	1a
3		Enhanced traffic/mobility management	The priority area would be updated by bringing together 'mobility services' and 'traffic management' under 'mobility management'.	Better reflect actions of transport authorities and prioritise the deployment of ITS infrastructure that supports mobility management more generally.	2
4		CCAM	A new priority area would be established focusing on CCAM to be updated to reflect current needs.	Ensure that the subsequent actions relating to CCAM will be developed appropriately, accelerating deployment	4-6
5		Include (mandatory) deployment in scope of application	The scope of the application of the priority areas will be expanded from "standards and specifications" to also include 'mandating data and services'.	This will facilitate some of the policy measures below, which would help to ensure the deployment of ITS.	All
6	New standards/ specifications	New standardisation mandate(s) under Article 8	An extension of the validity of Article 8 will be needed to reflect the new standardisation requirements.	This will enable the development of standards for new specifications, supporting the interoperability between different modes and for new services.	All
7		Revision of specification for RTTI	Develop specifications for data types relevant for the delivery of essential RTTI services, including (1) UVAR;	Common specifications enable the development of interoperable datasets, support data exchange with	1b

#	Type of measure	Policy measure	Policy measure description	Aim of the policy measure	SB
			(2) Recharging/Refuelling points and stations; (3) Historical traffic data; (4) Other road and traffic specific rules. The specifications will also define an extended geographical scope for both current and new data types.	little transaction effort, foster service continuity and the faster/cheaper deployment of more comprehensive services.	
8		Requirements for the access to in-vehicle generated data for road operation (asset and traffic management) services	Define, through a separate Delegated Act, a set of requirements for providing B2G access to in-vehicle data. OEMs or service providers that provide road operation services based on in-vehicle generated data must: • List themselves on NAPs, addressing discoverability of data • Allow non-discriminatory B2G access to their services (i.e. same T&Cs across EU).	A common set of requirements gives service providers and authorities knowledge of existing datasets and improves access to these through NAPs. Knowledge of existing datasets as well as non-discriminatory access may lead to an improved B2G sharing and usage of available data and lead to the deployment of more advanced services that account for these data.	1b
9		Standards for in-vehicle generated data for road operation (asset and traffic management) services	Define, through subsequent Delegated Acts, a standard for in-vehicle generated data. This will target data relevant for asset and traffic management. OEMs or service providers that provide (aggregated) in-vehicle generated data for road operation purposes must do so following the defined standards	Common standard allow interoperability of data for road operation services, facilitating its exchange between OEMs, service providers and road management authorities, reducing transaction costs and leading to development of advanced services related to road and traffic management.	1b
10		Specifications for C-ITS (Day 1, Day 1,5 and Day 2 services)	Define, through a specific Delegated Act, EU specifications to ensure EU-wide compatibility, interoperability and continuity for the deployment and operational use of C-ITS, including: • Service definitions and relevant communication specifications; • compliance assessment, putting on the market, and operating ITS; • Security requirements.	This measure will ensure the interoperability of relevant C-ITS services and equipment, fostering deployment of C-ITS and single market for ITS components. Improved security through the use of a common communication standard is also expected to improve perception and trust in C-ITS services, supporting usage of relevant services.	4-6
11	Mandating data availability	Mandate availability of crucial RTTI data	This mandate will oblige local and national authorities and road operators to generate (following quality standards) and make accessible via the NAPs, in a phased manner, data on: • Restricted Vehicle Access Zones • Traffic regulations and circulation plans • Road and lane closures, direction of travel on reversible lanes, roadworks and temporary traffic management measures	Mandating the availability of these data will lead to improved access, availability and eventually usage of data. It will also enable the faster deployment of RTTI services using these data. The measure will implement data updates on TEN-T first and later move to full date sets, as well as a similar, but even later, phased approach on the entire network	1b
12		Mandate availability of MMTIS crucial data	This mandate will oblige transport service providers to generate (following quality standards) and make accessible via the NAPs data	Mandating the availability of these data will lead to improved access, availability and eventually usage of data. It will also enable the faster	1a

#	Type of measure	Policy measure	Policy measure description	Aim of the policy measure	SB
			types related to the provision of MMTIS: • data for PRM users e.g. accessibility of vehicles and access nodes (static), status of an access node feature: operational lifts / escalators (dynamic) • Connection points/ access nodes	deployment of travel information services using these data. The measure applies to the entire transport network as of 2028	
13		Mandate availability of Safe & Secure truck parking data	This mandate will oblige transport service providers to generate (following quality standards) and make accessible via the NAPs specific data related to S&S truck parking location services for the entire transport network as of 2028.	Mandating the availability of such data is expected to lead to improved access, availability and eventually usage of data. It will also enable the faster deployment of S&S truck parking information services using these data.	3
14	Mandating services	Mandate availability of (SRTI) services	This mandate will oblige authorities and organisations responsible for the operation of the TEN-T comprehensive road network to deliver SRTI.	Guaranteed deployment of SRTI services on TEN-T, possibly leading to spill-over effects on other parts of the network.	3
15		Mandate availability of Day 1 C-ITS services	This measure introduces a mandate for the delivery of C-ITS services in all new vehicle models after 2028.	The measure will accelerate the deployment of Day 1 C-ITS services.	4
16	ITS deployment principles	Update the principles for specifications and deployment of ITS	Update Annex II of the Directive, focusing on transparency of data availability and equality of access of the information, data privacy and transparency of the ranking of services, in addition to provisions established in the context of the P2B Regulation.	Applying a harmonised set of principles can be expected to increase trust in the deployed ITS services regarding their compliance with critical elements and thus lead to an improved usage and deployment of ITS services.	All
17	Governance framework	Setting-up of governance and the facilitation of national & EU wide operational co-ordination of NAPs	Develop a governance framework for the coordination of NAPs in a CEF-funded PSA, including on monitoring the availability and accessibility of data, harmonised levels of service of the NAPs, harmonised compliance assessment processes and the coordinated creation and collection of data.	A common approach across the NAPs, including in relation to creating, collecting and monitoring data, will improve coordination and help to support the availability, access to, and the more efficient and consistent use of data	All
18		Introduce legal provisions on governance of national & EU wide operational coordination of NAPs	Ensure the operation of a governance structure and the continued monitoring of the availability and accessibility of data in all Member States, including harmonised levels of service of the NAPs, harmonised compliance assessment processes and the coordinated creation and collection of data.	This will ensure a common approach across all NAPs, including in relation to creating, collecting and monitoring data, supporting the more efficient and consistent use of these data throughout the EU.	All
19	Governance framework - C-ITS	Implement the European C-ITS Trust model	In a new CEF project, continue implementation of the EU CCMS. This certificate policy defines requirements for the management of public key certificates for C-ITS	The C-ITS trust model is a defining feature of C-ITS and a necessary condition to enable trust between all C-ITS users. It supports the deployment of C-ITS services.	4-6

#	Type of measure	Policy measure	Policy measure description	Aim of the policy measure	SB
			applications.		
20		Introduce legal provisions on the EU C-ITS Trust model	Give the EU CCMS legal status. This certificate policy defines requirements for the management of public key certificates for C-ITS applications.	Providing legal and technical certainty to the C-ITS trust model will accelerate the development and deployment of C-ITS services.	4-6
21	Governance framework	Further improve and streamline the interaction with ITS stakeholders	The way stakeholders will be consulted in the implementation of the Directive and in the development of the delegated acts will be made more efficient (e.g. by including stakeholders other than Member States on implementation objectives)	This will ensure that the relevant expertise is involved at the most appropriate points in the process, as well as ensuring that the concerns of particularly stakeholders are sufficiently addressed. In this way, the measure would help to improve coordination.	All
22	Improve reporting	Update and streamline reporting obligations	Streamline reporting requirements, with reporting for all delegated acts integrated into Member States' overall reporting on the Directive.	This will reduce administrative burden, particularly for Member States.	All
23		Mandate reporting based on common format & KPIs	A mandatory common format for the MS reports, requiring a minimum level and quality of data, for the assessment of progress with the implementation of the Directive and its Delegated Acts, supported by methodological guidance to ensure that KPIs are measured consistently.	This will make comparisons between Member States easier and paint a clearer picture of the state of play across the EU (e.g. on the performance of NAPs and on the level of deployment and use of ITS services). This could help to facilitate better coordination between Member States.	All
24	Enhance coherence	Improve the coherence of the ITS Directive with the existing legal framework	The approach taken in relation to ITS services will be aligned with: • GDPR • ePrivacy legislation • Passenger rights legislation	Capitalising upon synergies and addressing overlaps and conflicts, increased availability of more consistent data, improved confidence in the use of data, helping the deployment of services and reducing the administrative burden of data providers.	All
25		Improve the coherence of the ITS Directive with expected initiatives	The ITS Directive will be aligned with initiatives expected to be in place as of September 2021: • The Mobility Data Space • Upcoming EU framework for in-vehicle data architecture. • TEN-T and Rail Freight Corridors Regulation	Capitalising upon synergies and addressing overlaps and conflicts, including mobility data and access to in-vehicle data. More consistent data are expected to help with the deployment and use of services, reduce the cost related to identifying, sharing, accessing and using the data needed to deploy ITS services.	All

Stakeholders were involved in all steps of the process, from the definition of the problem, to the identification of the policy measures. As such, there is general agreement on the scope of action needed and the options proposed. The detailed figures below show, for each specific objective defined in chapter 4.2 a combination of interview and survey responses presenting stakeholder general agreement with the measures put forward (please note that some measures address multiple specific objectives, for more details on the links between policy measures and specific objectives see chapter 5.2.2).

Figure 8: stakeholder support for measures addressing SO1

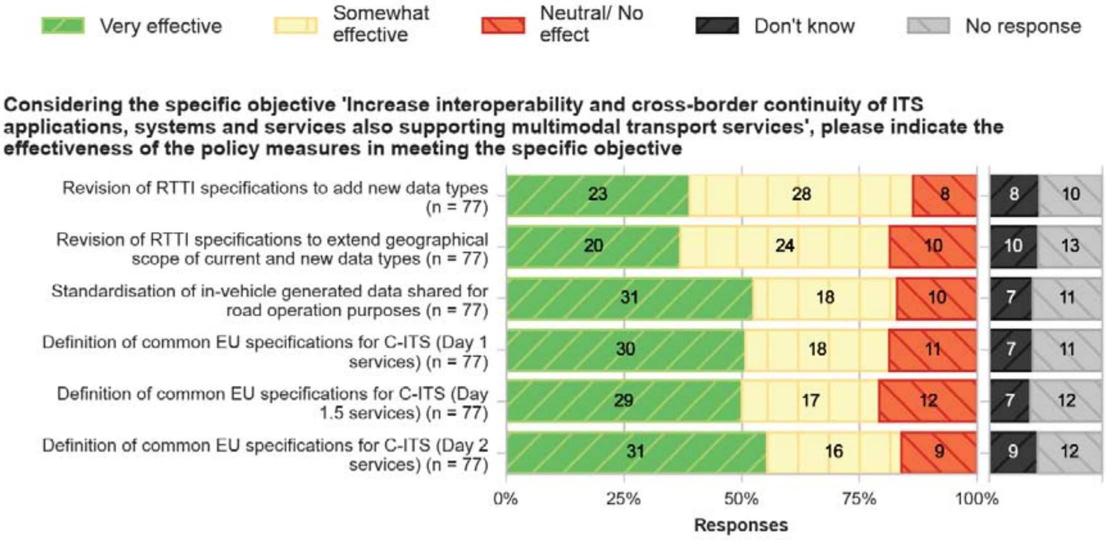


Figure 9: stakeholder support for measures addressing SO2

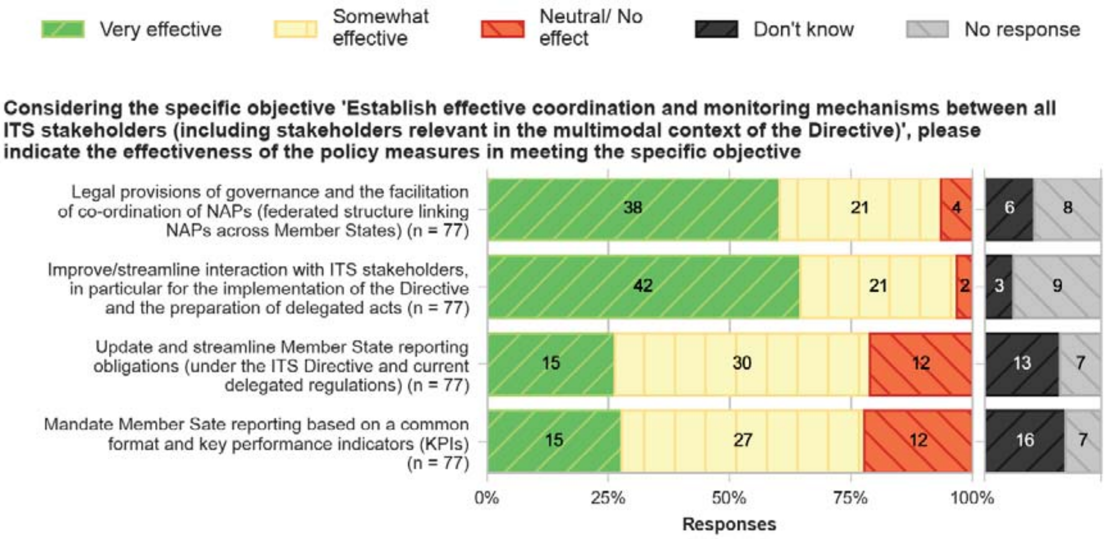
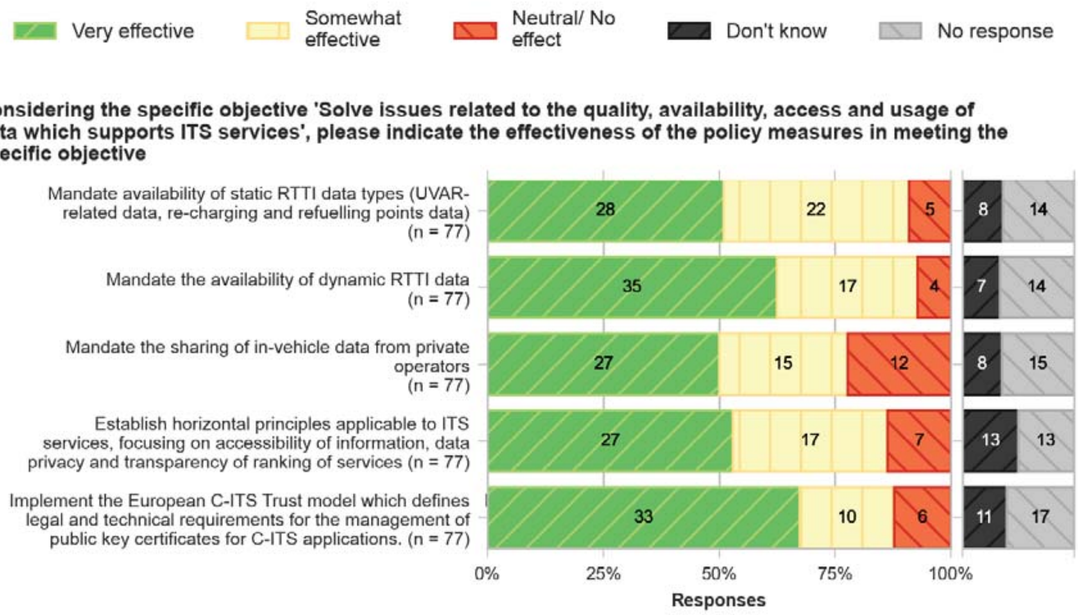


Figure 10: stakeholder support for measures addressing SO3



5.2.1. Measures discarded at an early stage

The collection of real consumption data of vehicles was briefly considered but discarded as possible updated legislation on this topic is currently being investigated in an IA by DG CLIMA. Requirements on data types regarding availability of relevant recharging and refuelling-related data were also considered but are now part of AFIR.[80]

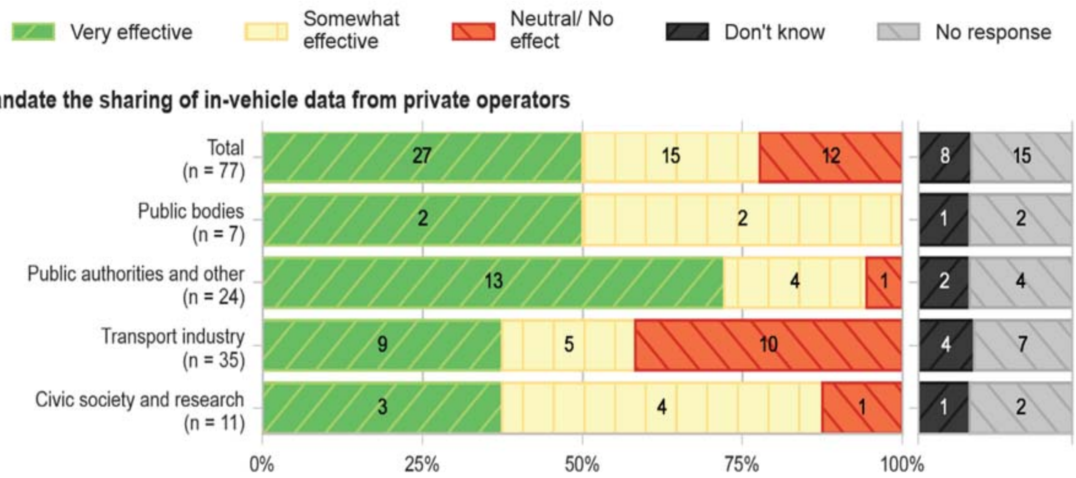
Regarding access to in-vehicle generated data, in the scope of this initiative, the purpose is to facilitate the reuse of in-vehicle generated data relevant for road maintenance and traffic management, not at the level of the vehicle itself, but at the level of aggregation and interpretation of data for that aim. There are existing standards for the re-use of in-vehicle generated data under development, but not all stakeholders have yet subscribed to use them. The adoption of a single standard / single specifications would represent a strong improvement. A complementary mandate on the sharing of in-vehicle data was briefly considered and well supported by stakeholders (see Figure 11)[81]. Nevertheless, this is an emerging service at this stage and a mandate was not considered feasible until it is clearer which data is precisely useful

[80] As emphasized in recitals 45 and 46 of the proposal for a Regulation of the European Parliament and of the Council on the deployment of alternative fuels infrastructure, and repealing Directive 2014/94/EU of the European Parliament and of the Council (COM(2021) 559 final), it is necessary to provide consumers with sufficient information regarding the geographic location, characteristics and services offered at the publicly accessible recharging and refuelling points of alternative fuels. Requirements on data types regarding availability of relevant recharging and refuelling-related data should be laid down in that framework, rather than under the ITS Directive, following the outcomes of ongoing the Programme Support Action on “Data collection related to recharging/refuelling points for alternative fuels and the unique identification codes related to e-mobility actors” (‘IDACS’). The accessibility requirements, meaning the data is accessible on NAP in a standardised format (i.e. Datex II), are laid down in the ITS Directive framework in Delegated Regulation 2015/962 and cross-referenced with the regulation on alternative fuels infrastructure.

[81] The transport industry is somewhat divided on this but this seems mainly related to an ongoing debate on the possibility for independent service providers to get fair and non-discriminatory access to in-vehicle data and resources. However, this is the subject of a specific initiative under the type-approval framework (lead DG GROW) with a new proposal expected by Q2 2022.

for such business-to-government services, and how it can best be collected and shared with infrastructure and road managers.

Figure 11: stakeholder support for a mandate on in-vehicle data (interview and survey responses)



Overall, very few measures were discarded because either stakeholders clearly agreed with the proposed measure or the measure builds on an existing or already planned initiative (see also chapter 5.2). Looking into some more detail by type of measure (as used in Table 6):

- **Measures on scoping**: stakeholder views during the first workshop confirmed the continued relevance of existing priority areas as well as the update of the scoping of the Directive with new priority areas. Subsequent stakeholder consultations agreed and hence none of the proposed measures was discarded.

- **Measures on specifications, standards and mandates**: these are essentially on/off options (e.g. you develop a standard or not). For the mandates, proportionality is particularly important however and only the most crucial data types were included. Identification of crucial datatypes started with the preparation for the revision of the Delegated Regulation on real-time traffic information, where alternatives were already tested and discarded. These were subsequently confirmed during the various workshops organised in the scope of this IA. The other mandates cover significantly smaller datasets (e.g. the 8 events considered in the safety related traffic information service). Regarding services, the mandates are relatively limited, with the deployment of the safety-related information service on the TEN-T network, and for C-ITS the final selection of services is open and conditional to a dedicated impact assessment.

- **Measures on stakeholder cooperation and governance**: these are either high-level or build on pre-existing actions e.g. NAP cooperation, mandating the KPIs reporting, C-ITS governance etc. They are widely supported in the stakeholder community and considered essential for continuation.

- **Measures on coherence**: Measures were developed specifically to tackle the issues identified in the legal coherence analysis.

5.2.2. Retained policy measures and policy options overview

In Table 7 the policy measures from Table 6 are linked to the specific objectives described in chapter 4.2. The strong interventions (shown as ✓✓✓ below) related to the mandatory collection of crucial data (PO2) and mandatory provision of essential services (PO3) contribute to both SO1 and SO3. The retained policy measures were also combined into three policy options (PO), each building on the previous, i.e. PO2 includes all measures of PO1 and PO3 includes all measures from PO2 (the policy measures are re-ordered to illustrate this).

Table 7: Policy measures, their contributions to the specific objectives and inclusion in policy options

No	Policy measure	SO1	SO2	SO3	PO1	PO2	PO3	
1	Adjust the scope of the Directive to explicitly include MDM services	✓			✓	✓	✓	
2	Update the priority areas – MDM services	✓			✓	✓	✓	
3	Update the priority areas - enhanced traffic/mobility management	✓			✓	✓	✓	
4	Update the priority areas - CCAM	✓			✓	✓	✓	
6	New standardisation mandate(s) under Article 8	✓			✓	✓	✓	
7	Revision of specification for RTTI	✓			✓	✓	✓	
8	Requirements for the access to in-vehicle generated data for road operation (asset and traffic management) services	✓			✓	✓	✓	
10	Specifications for C-ITS (Day 1, Day 1,5 and Day 2 services)	✓			✓	✓	✓	
16	Update the principles for specifications and deployment of ITS			✓	✓	✓	✓	
17	Setting-up of governance and the facilitation of national & EU wide operational co-ordination of NAPs		✓		✓	✓	✓	PO1
19	Implement the European C-ITS Trust model			✓	✓	✓	✓	
20	Introduce legal provisions on the European C-ITS Trust model			✓	✓	✓	✓	
21	Further improve and streamline the interaction with ITS stakeholders		✓		✓	✓	✓	
22	Reporting: update and streamline reporting obligations		✓		✓	✓	✓	
23	Reporting: mandate reporting based on common format & KPIs		✓		✓	✓	✓	
24	Various measures to improve the coherence of the ITS Directive with the existing legal framework (i.e. GDPR, ePrivacy, passenger rights)	✓		✓	✓	✓	✓	
25	Various measures to improve the coherence of the ITS Directive with expected initiatives (i.e. Mobility Data Space, in-vehicle data architecture, TEN-T and Rail Freight Corridors Regulation)	✓		✓	✓	✓	✓	
5	Expand the scope of application of the priority areas from "standards and specifications" to include deployment (mandating data & services)	✓✓✓		✓✓✓		✓	✓	
11	Mandate availability of RTTI crucial data	✓✓✓		✓✓✓		✓	✓	
12	Mandate availability of MMTIS crucial data	✓✓✓		✓✓✓		✓	✓	PO2
13	Mandate availability of S&S truck parking data	✓✓✓		✓✓✓		✓	✓	
18	Introduce legal provisions on relation to governance and the facilitation of national & EU wide operational co-ordination of NAPs		✓			✓	✓	
9	Standards for in-vehicle generated data for road operation (asset and traffic management) services	✓					✓	
14	Mandate availability of SRTI services	✓✓✓		✓✓✓			✓	PO3
15	Mandate availability of Day 1 C-ITS services	✓✓✓		✓✓✓			✓	

As a result, despite all policy options addressing all specific objectives, the majority of measures addressing SO2 are already included in PO1 and the higher level of ambition from PO2 and PO3 comes primarily from a stronger intervention to tackle SO1 and SO3.

Table 8: Overview of policy options in terms of ambition and level of intervention

No	Policy option description	Degree of ambition	Level of intervention
PO1	Strengthened coordination and deployment principles	+	+
PO2	Mandate collection and availability of crucial data	+++	+++
PO3	Mandate provision of essential services	++++	++++

5.3. Description of the policy options

As illustrated in Table 7 policy options are built incrementally, with the majority of measures already included in the first policy option. This is because the critical policy choices revolve around the scope and level of ambition of the mandates, as these are the most intervening measures and represent significant investments. The policy options need to provide a good understanding of how these mandates help reaching the overall goal of deploying ITS, as their usage is ultimately responsible for the generation of impacts. To bring this out in the clearest manner possible one policy option introduces the data mandates whilst another introduces the service mandates. A policy option including service mandates but without the data mandates was not considered as all services rely on data. Indeed, though the overall objective is to accelerate the deployment of ITS services, the Directive is an enabling framework and many actions take place at an upstream level, such as working on the standardisation and availability of data.

5.3.1. PO1: Strengthened coordination and deployment principles

This first policy option introduces the largest amount of policy measures but nevertheless mostly takes a light touch approach, including those related to amendments to the Directive to allow for the expansion of its operation in emerging ITS service areas, addressing shortcomings in stakeholder cooperation with measures improving coordination and finally, ensuring coherence of Directive provisions with those of other existing legal instruments. It also includes measures that aim to institutionalise parts of the governance framework, and aims to future-proof the Directive to function in the advent of known upcoming EU policy initiatives. Policy option 1 includes the following measures addressing each of the problem drivers:

- **Problem Driver A** (measures number 1, 2, 3, 4, 6, 7, 8 and 10): improvements and updates to the functioning of the ITS Directive to enable it to account for new developments in the mobility eco-system and the evolving policy priorities in the field of transport as well as to cover emerging ITS services and to ensure coherence with existing EU legislation. These include the renewal of the standardisation mandate to allow the development of standards covering an updated set of priority areas such as standards for in-vehicle generated data for road operation, the revision of the RTTI specifications and new specifications for mature and upcoming C-ITS services. These new priority areas include the areas of MDM services, enhanced traffic/mobility management and CCAM services.

- **Problem driver B** (measures number 17, 21, 22 and 23): improve stakeholder coordination through the continuation of NAP coordination in a non-binding legal format and set up a more formal format for stakeholder involvement in the implementation of the Directive and the preparation of Delegated Acts. Streamline requirements for Member State reporting on the implementation of the Directive and Delegated Acts (currently each Delegated Act introduces separate reporting requirements) including the use of a set of common KPIs.

- **Problem driver C** (measures number 16, 19, 20, 24 and 25): facilitate data sharing and reuse between stakeholders by introducing a set of common principles for the deployment of ITS services (e.g. on accessibility of the information, data privacy and transparency of the ranking of services) as well as for the non-discriminatory sharing of in-vehicle data for purposes of asset and traffic management. The application of the C-ITS Trust model[82] becomes embedded in legislation to increase trust in C-ITS services. Finally, in addition to ensuring coherence with existing legislation (e.g. GDPR and ePrivacy), this Policy Option aims to further future-proof the ITS Directive ensuring coherence with known upcoming EU initiatives such as the ones related to the revision of the TEN-T and Rail Freight Corridors Regulations, in-vehicle architecture and the European Mobility Data Space.

5.3.2. PO2: Mandate collection and availability of crucial data

This strong intervention makes the collection and sharing of data crucial for the operation of essential services mandatory as a means to boost the deployment of such services. These measures aim predominantly to improve data availability, quality, access exchange and usage while all other aspects of Policy Option 1 are retained. More specifically, it will include the following measures for each problem driver:

- **Problem drivers A and C** (measures number 5, 11, 12 and 13): this policy option will expand the scope of application of the priority areas from “standards and specifications” and introduce the possibility to develop mandates for collecting and making available all data considered crucial for the deployment of essential services in the priority areas of RTTI, MMTIS and S&S truck parking. In doing so, this policy option also enables the development of data quality standards applicable for the mandatory sharing of the crucial data types required for the delivery of these essential services. In that respect, specific Delegated Acts for each priority action are to be included to develop the definition of essential services, the definition of crucial data needed to deliver these services, the definition of the geographical scope and time-horizon for the data mandate as well as the development of the required data quality standards.

- **Problem driver B** (measure number 18): support the data sharing mandate by embedding the NAP coordination platform in legislation.

[82] C-ITS connects all road users with each other and with infrastructure elements. Exchanging messages requires trust (think for example about safety messages that trigger automated reactions from vehicles). This trust comes from digitally signing all messages, but for that to be possible all C-ITS stakeholders need to be part of the same trust model, i.e. agree to a common set of security requirements. Other than ensuring (cyber)security the trust models also helps addressing data protection issues by pseudo-anonymising all messages

5.3.3. PO3: Mandate provision of essential services

This strong intervention foresees the possibility to introduce mandates for the deployment of essential services through Delegated Acts. It especially capitalises on the increased data availability, quality, exchange and usage promoted by Policy Option 2 (Driver C) and aims to further support the deployment of interoperable and continuous services (Driver A). More specifically, in addition to the measures under PO2 and PO1 it includes:

- **Problem driver A** (measure number 9): Development of a mandatory standard for in-vehicle generated data facilitating their sharing and integration in ITS services.
- **Problem driver A and C** (measure numbers 14 and 15): Expansion of the scope of application of the priority areas and mandating the availability of data required for essential services and for the deployment of such services. Specific Delegated Acts for each priority area will develop the definition of essential services, the appropriate quality standards, as well as the definition of the geographical scope and time-horizon for mandatory deployment of those services. This mandate focuses on road safety services and will cover the areas of SRTI and Day 1 C-ITS deployment. To support this deployment mandatory equipment of new vehicles with dedicated C-ITS stations from 2028 onwards is included.
- **Problem driver B**: no additional measures

6. WHAT ARE THE IMPACTS OF THE POLICY OPTIONS?

This section summarizes the main expected economic, social and environmental impacts of each policy option. In terms of time horizon, the assessment has been undertaken for the 2021-2040 period. The measures that are part of the POs will not all be implemented at the same time, notably, the data availability mandates in PO2 (measures 11, 12 and 13) and the service availability mandates in PO3 (measures 14 and 15) are modelled from 2028 and 2030 onwards. All other measures are assumed to be implemented starting in 2025. The analysis presented in this section covers the EU27 scope. Costs and benefits are expressed as present value using a 4% discount rate. The assumptions on the take-up rate of the specific services - as well as their impacts - feeding the ASTRA-TRUST model are based on the best, and most relevant, data identified in literature. Stakeholders were consulted in several workshops on these assumptions, including primary cost and impact estimates for all service bundles. The usual assumptions in monetising externalities are also relevant, for example we cannot model every individual trip but use units representing averages of all types of trips. Additionally, assumptions were introduced to extrapolate and cover possible data gaps in different Member States and road-types, as well as to address potential overlapping effects of services. As a result, we obtain a reliable estimate of the scale of magnitude of the expected impacts. More details on modelling are provided in Annex 4 "Analytical methods".

6.1. Economic impacts

Deployment, investment and operating costs

The deployment of ITS infrastructure over the 2021-2040 period is presented in Table 9 for the baseline and policy options. The deployment assumptions, linked to the policy measures included in each option, build on significant expert input and stakeholder consultation.

Table 9: Cumulative deployment over the 2021-2040 period supporting ITS services

Deployment of ITS	Baseline	PO 1	PO 2	PO 3
New vehicles equipped	106,289,623	145,054,914	145,054,914	199,744,597
Smartphone used for in-vehicle ITS services	90,443,469	111,093,635	196,424,764	193,092,502
Total ITS users	**196,733,092**	**256,148,549**	**341,479,678**	**392,837,099**
New infrastructure (RSU)	20,250	45,599	45,599	155,552
New infrastructure (RSI)	22,117	32,940	186,247	196,344
New infrastructure (TMC)	115	159	402	425

Source: Ricardo et al. (2021)

To deploy ITS services costs are incurred by both the public and private sector, notably by the road authorities and ITS service providers, including vehicle manufacturers. An overview per policy option for various types of costs is presented in Table 10. Roadside units are required to support C-ITS services, and costs are highest in PO3 as the mandatory equipment of vehicles is expected to trigger significant voluntary investments on the infrastructure side. New and upgraded roadside infrastructure supports data collection and information sharing across all ITS services. While most NAPs have been set up, they are in various stages of operation and ongoing costs will scale according to the number and quantity of data sets that are supported.[83] Central ITS subsystems include traffic management centres and systems that support overall administration and management of road systems. The mandatory data collection proposed in PO2 is responsible for the cost increase in these categories. Mobile systems connect the users to the infrastructure and costs are dominated by in-vehicle systems, which are required for the delivery of C-ITS services whilst smartphone costs only include application development as ownership and data costs are assumed to be covered and will not be affected by the policy options. While costs in PO1 and PO2 have a similar increase, related to policy measures that align GDPR, ePrivacy and passenger rights and the C-ITS trust model provisions, all increasing trust in the system, the costs increase significantly in PO3 as this includes mandatory equipment of new vehicle types from 2028 onwards.

Table 10: Cost for each PO compared to the baseline (EUR bn), expressed as present value over 2021-2040

Sector	Cost component	Baseline	PO1		PO2		PO3	
			Total	Net	Total	Net	Total	Net
Public	Roadside units	0.2	0.4	0.2	0.4	0.2	1.3	1.1
	Roadside infrastructure	6.0	6.9	0.9	9.2	3.2	9.3	3.3
	National access points	0.7	0.8	0.1	1.1	0.4	1.1	0.4
	Central ITS sub-systems	1.0	1.1	0.1	1.6	0.6	1.6	0.6

[83] https://op.europa.eu/en/publication-detail/-/publication/043ee22b-643b-11eb-aeb5-01aa75ed71a1

Sector	Cost component	Baseline	PO1		PO2		PO3	
			Total	Net	Total	Net	Total	Net
Total infrastructure		**7.8**	**9.2**	**1.3**	**12.3**	**4.4**	**13.2**	**5.3**
Private	In-vehicle systems	16.3	22.5	6.2	22.5	6.2	31.8	15.4
	Smartphone and applications	0.0	0.01	0.01	0.02	0.02	0.02	0.02
Total mobile equipment		**16.4**	**22.5**	**6.2**	**22.5**	**6.2**	**31.8**	**15.4**

Source: Ricardo et al. (2021), impact assessment support study

These costs are of course expected to boost service usage, which is presented for all service bundles across all policy options in Figure 7, Figure 12 and Figure 13. PO1 is expected to result in smaller improvements, whilst step-change improvements are expected from PO2 and PO3.

For information services (B1a and B1b) the mandatory provision of data in PO2 is the main driver for accelerated usage (these services are not covered by PO3 and do not require dedicated in-vehicle equipment, in the chart lines of PO2 and PO3 overlap). The same is true for travel management services (B2), the only bundle not targeted by dedicated measures at this stage. Road safety service usage (B3) is expected to increase markedly thanks to mandates from both PO2 and PO3, whilst C-ITS services (B4 and B5) benefit from the mandatory equipment of vehicles in PO3 (PO2 does not cover C-ITS, in the chart lines of PO1 and PO2 overlap).

Figure 12: Service usage of information and booking bundles in front runner countries across policy options

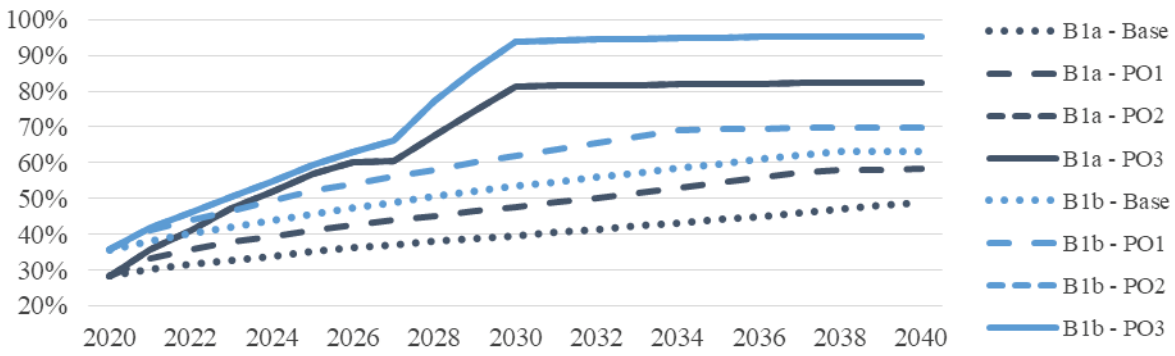


Figure 13: Service usage of travel management and road safety bundles in front runner countries across policy options

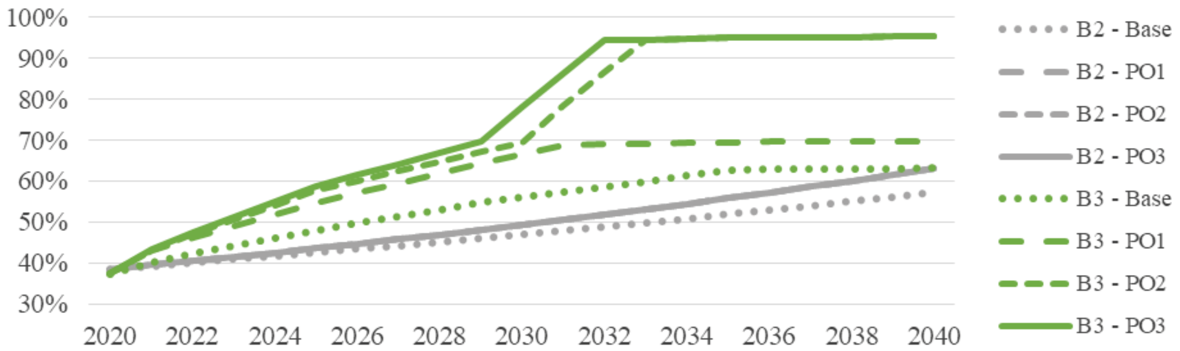
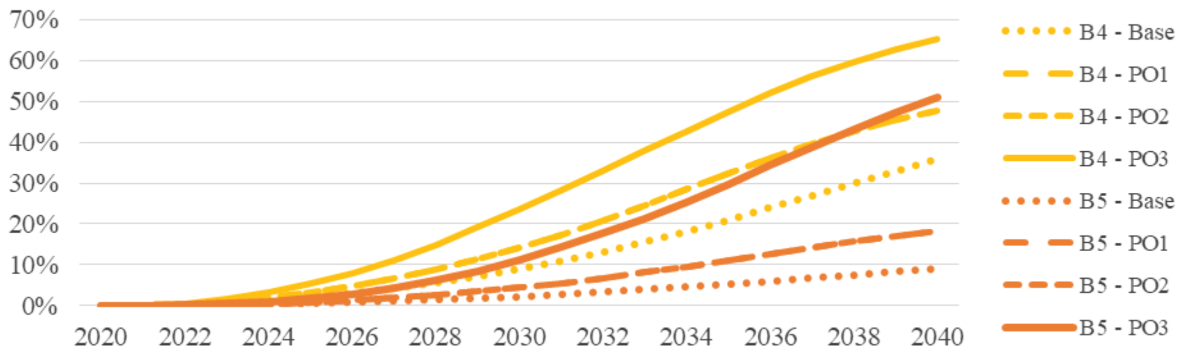


Figure 14: Service usage of C-ITS bundles in front runner countries across policy options



Administrative costs

The costs to public authorities from the requirements to review and update the national policy frameworks (NPFs) and report on the implementation are similar as in the baseline. Monitoring costs may increase to some extent to report on compliance with the mandatory provision of crucial data and essential services. Stakeholders highlighted that hundreds of authorities across Europe would be involved, which is challenging for smaller municipalities as they might lack the know-how and resources, leading to increased coordination costs. The RTTI support study estimates the administrative burden resulting from a data collection mandate covered under PO2 and PO3 in this IA at just over €18 million (present value) for the period 2021-2030.[84] The estimated cost includes personnel cost for data collection, processing and maintenance, coordination, standardisation and training, but focusses on the actual collection of data, going beyond the administrative costs resulting from it, which can reasonably be assumed to be lower.

On the other hand, the provision of standardised data formats, a common reporting format and KPIs, and alignment of reporting requirements (from Delegated Regulations and Directive) will simplify overall reporting under the Directive and reduce administrative costs. The digitisation of processes leading to the creation of digital information should also reduce the burden of transmission of information to third parties (e.g. transmission of traffic regulations updates to service providers, which would be done only once through the National Access Points). Whether the expected increases and decreases compensate or whether one is higher than the other is however very difficult to quantify. Sources that have been used to try to estimate these costs include interviews carried out as part of the IA, the RTTI support study, the 2020 ITS Member State reports, and feedback from some cities and road authorities. None of the reported costs were, however, sufficiently granular for this purpose, nor could they be compared.

[84] https://op.europa.eu/en/publication-detail/-/publication/043ee22b-643b-11eb-aeb5-01aa75ed71a1 the timeline is not the same as the period considered in this IA but the period would cover all the initial investments to create the data and its supporting infrastructure. Maintenance and operational costs, including coordination costs, for the period 2031-2040 are expected to be significantly lower

Urban travel time costs

Several ITS services target reductions of (urban) travel time, for example through increased ease of use of multimodal solutions or RTTI. These services types are strongly stimulated by the data mandates in PO2, leading to very large time savings.

Table 11: Monetised urban travel time saving for EU27 (EUR bn), expressed as present value over 2021-2040

		PV 2021-2040 relative to baseline		
Cost category	Baseline	PO1	PO2	PO3
Travel time	6,164.0	-43.0	-138.8	-144.5

Source: ASTRA / TRUST model

The mandatory equipment of vehicles in PO3 enables services such as green light optimal speed assistance, which bring additional time savings. These present reductions in overall annual urban travel time (0.7%, 2.3% and 2.3% in 2040 compared to the baseline for PO1, PO2 and PO3 respectively). Given the high number of hours lost in traffic, the monetary value of these savings is significant.[85]

Fuel consumption costs

A range of ITS services have a positive impact on fuel consumption. RRTI will help to improve journey efficiency by influencing vehicles to take optimal routes from a time or even fuel efficiency perspective, which drives the reduction in PO2. The effect of mandatory equipment of new vehicles with C-ITS stations in 2028, enabling services that support smoother traffic flows, becomes noticeable after 2030 and drives the even larger savings in 2040 of PO3.

Table 12: Fuel consumption (in million toe) in 2030 and 2040 for the baseline and policy options

Year	Mode	Baseline	PO1	PO2	PO3
2030	Annual fuel consumption in 2030	202	201.8	201.1	201
	Saving relative to the baseline in 2030	-	0.19	0.85	0.92
	% savings relative to the baseline	-	-0.10%	-0.42%	-0.46%
2040	Annual fuel consumption in 2040	123.6	123.4	123.2	122.8
	Saving relative to the baseline in 2040	-	0.2	0.42	0.77
	% savings relative to the baseline		-0.16%	-0.34%	-0.62%

These represent significant reductions in overall fuel consumption as can be seen in Table 13.

Table 13: Monetized fuel costs saving for EU27 (EUR bn), expressed as present value over 2021-2040

		PV relative to baseline		
Cost category	Baseline	PO1	PO2	PO3
Fuel consumption	790.0	-0.6	-2.1	-2.4

Source: ASTRA / TRUST model

[85] The monetary value was calculated based on the cost of time values from the 2019 Handbook of External Costs of Transport

Impacts on transport activity and modal shift

The model shows no discernible impact on total passenger transport activity but Table 14 does show a (very) small increase of freight transport activity (which is more price-sensitive). Road transport benefits most from the deployment of ITS services and more efficient road transport leads to a modal shift towards road. MaaS and mobility management services are an exception and these are not yet included in this analysis as desk research identified very little evidence on the impact of these services. To account for this, two additional sensitivity model runs were performed (see chapter 7.5) to evaluate the potential of MaaS and mobility management services to compensate for the small modal shift observed in Table 15 for the more ambitious Policy Options.

Table 14: Freight transport activity (total of all modes) for EU27

Year	Freight transport (billion tkm/year)	Baseline	PO1	PO2	PO3
2030	Transport activity	2,898	2,898	2,899	2,899
	% difference	-	0.00%	0.03%	0.03%
2040	Transport activity	3,149	3,149	3,152	3,152
	% difference	-	0.02%	0.09%	0.09%

Source: ASTRA / TRUST model

Table 15: Modal split for passengers

Year	Mode	Baseline	PO1	PO2	PO3
2030	Car	80.2%	0.1%	0.3%	0.3%
	Bus	9.4%	0.0%	-0.2%	-0.2%
	Train	10.5%	0.0%	-0.1%	-0.1%
2040	Car	79.9%	0.1%	0.4%	0.3%
	Bus	9.0%	0.0%	-0.2%	-0.1%
	Train	11.1%	-0.1%	-0.2%	-0.2%

Source: ASTRA / TRUST model

Impact on GDP

The ASTRA model also makes an assessment of the impact of each policy option on GDP. These are mainly driven by investments in support of ITS. The 2030 and 2040 annual impacts relative to the baseline are shown in Table 16, which shows modest impacts in PO1 and marginally higher impacts in PO2 (driven by infrastructure investments needed for mandatory data collection) and PO3 (driven by vehicle investments in mandatory C-ITS equipment), with a maximum of increase of 0.12% relative to the baseline in 2040 for PO3.

Table 16: Impacts on GDP for EU27

Year		PO1	PO2	PO3
2030	Increase (EUR bn)	1.5	8.6	8.9
	% difference to the baseline	0.01%	0.07%	0.07%
2040	Increase (EUR bn)	4.3	16.2	17.3
	% difference to the baseline	0.03%	0.11%	0.12%

Source: ASTRA / TRUST model

Impact on internal market and competition

All policy options are expected to improve the functioning of the internal market, albeit at different levels. In particular, new specifications foreseen to be developed under PO1 will support the development of a common EU market for ITS services. These measures will especially prevent the fragmentation of the market that would take place should different data standards be developed at a national, local or operator level, which is already an issue today for e.g. UVAR regulations. It will also create a level playing field, as it guarantees that all companies will have equal access to the data shared by public authorities, whilst provisions for the implementation of the C-ITS Trust model will strengthen the internal market for C-ITS equipment. The mandate to collect and share data for MMTIS, RTTI and S&S truck parking in PO2 can be expected to further strengthen the internal market. Guaranteeing the availability of crucial data of uniform quality fosters the development of EU-wide ITS services for the transport sector and a level playing field for transport operators. The essential service mandate in PO3 further supports the development of the EU level playing field.

Impact on Innovation

Impacts on innovation can be expected to be delivered through two mechanisms, first, common data specifications and ITS standards preventing market fragmentation and allowing for the accumulation of a critical mass for the development of innovation. All policy options deliver on this however the introduction of mandatory standards for in-vehicle generated data in PO3 is expected to be a game changer, as it would allow the development of innovative services integrating data from sources currently unavailable. Second, improved data availability and quality allowing for the development of innovative ITS services making use of the increased data provision. This is predominantly related to the data mandates in PO2. The mandatory introduction of C-ITS systems in new vehicles post 2028 will assist in reaching a critical market mass, promoting the development of innovative services for these systems.

Impact on SMEs

SMEs are not a specific target of the policy measures and there is no indication that a differentiated impact can be expected to companies of different sizes. However, a fragmented market, as would have been the case without the introduction of new data specifications and standard requirements and the widespread use of NAPs, may produce a comparative advantage for larger companies compared to SMEs. In a harmonised market, as far as standards are concerned, SMEs will benefit from lower entry barrier to expand their operations and compete on an equal basis with larger enterprises. In that respect, the measures included in PO1 are expected to generate the most impact on SMEs, with no additional impacts from PO2 and PO3.

6.2. Social impacts

Impact on road safety

Several of the ITS services considered in this IA specifically aim to improve road safety and to decrease both the number and severity of accidents. The numbers presented here do not include the improvement in road safety, resulting from a modal shift from passenger car travel to safer modes such as bus and train, related to the deployment of MaaS and mobility management services, which as discussed in chapter 6.1 are difficult to quantify at this moment. All policy options show a reduction in the number of accidents relative to the baseline for both 2030 and 2040, albeit a moderate difference in 2030 (see Table 17) as the uptake of C-ITS equipment is still low then. All accident types (fatalities, serious injuries and minor injuries) are projected to decrease under each of the policy options. Minor injuries are most common and are thus predicted to see the greatest reductions in absolute terms compared to the baseline in all policy options.

Table 17: Annual accidents and accidents avoided relative to the baseline

	2030			2040		
	Annual accidents	Relative to the baseline	% reduction relative to the baseline	Annual accidents	Relative to the baseline	% reduction relative to the baseline
Baseline						
Fatalities	18,347	-	-	16,655	-	-
Serious injuries	247,699	-	-	224,654	-	-
Minor injuries	863,934	-	-	799,892	-	-
PO1						
Fatalities	18,315	32	0.2%	16,496	159	1.0%
Serious injuries	247,291	407	0.2%	222,475	2,179	1.0%
Minor injuries	862,752	1,182	0.1%	792,729	7,163	0.9%
PO2						
Fatalities	18,244	104	0.6%	16,400	255	1.5%
Serious injuries	246,709	990	0.4%	221,611	3,043	1.4%
Minor injuries	861,624	2,310	0.3%	791,002	8,890	1.1%
PO3						
Fatalities	18,195	152	0.8%	15,898	757	4.5%
Serious injuries	246,069	1,629	0.7%	214,735	9,919	4.4%
Minor injuries	859,477	4,457	0.5%	767,363	32,529	4.1%

Source: Ricardo et al. (2021)

However, the reduction in fatalities is where the greatest relative benefits are realised, reaching a maximum 4.5% reduction in 2040 in the case of PO3, which is three times that of PO2 in the same year (1.5%). PO3 is also expected to have the greatest reduction in total accidents (43,206 in 2040) by considerable margin, which can be explained by the marked increase in road safety services deployment and uptake due to the introduction of a mandate covering SRTI and C-ITS services. The relatively low impact in 2030 is because the mandatory equipment, for new vehicles only, is from 2028 onwards. Looking at the external costs of accidents, expressed as present value over the 2021-2040 period, as shown in Table 18, PO3 shows the largest savings relative to the baseline.

Table 18: External costs of accidents expressed as present value over (2021-2040) for EU27 (EUR bn)

	PO1		PO2		PO3	
	Difference to baseline	% difference to baseline	Difference to baseline	% difference to baseline	Difference to baseline	% difference to baseline
Fatalities	1.8	0.25%	4.0	0.55%	8.5	1.16%

	PO1		PO2		PO3	
	Difference to baseline	% difference to baseline	Difference to baseline	% difference to baseline	Difference to baseline	% difference to baseline
Serious injuries	3.9	0.25%	7.0	0.44%	17.0	1.06%
Minor injuries	1.0	0.22%	1.4	0.32%	4.1	0.93%
Total	**6.7**	**0.24%**	**12.3**	**0.45%**	**29.5**	**1.07%**

Source: Ricardo et al. (2021)

Affordability of transport services

Table 19 presents the impacts of each policy option on average transport expenditures per person. These transport expenses are reported by the ASTRA-TRUST model and include transport costs for road bus and rail[86]. Each policy option results in average savings per person due to the increased deployment of ITS services that reduce transport costs. PO1 generates a 0.3% saving in 2040 relative to the baseline as a result of the somewhat increased ITS service deployment it brings. This saving increases to up to 0.8% for PO2 and PO3 which through the mandates for data and services lead to a considerably increased usage of services that have an impact on reducing transport expenditure (through the reduction of fuel costs).

Table 19: Average expenditure for mobility per person (Euro/person-year)

Year		Baseline	PO1	PO2	PO3
2030	Annual transport expenditure per person	€ 801	€ 800	€ 796	€ 796
	% difference to the baseline	-	0.2%	0.7%	0.7%
2040	Annual transport expenditure per person	€ 715	€ 713	€ 709	€ 709
	% difference to the baseline	-	0.3%	0.9%	0.9%

Source: ASTRA / TRUST model

Impact on health

Impacts on health are expected to occur primarily as a result of changes in air pollution achieved by the various Policy Options. These impacts are quantified and monetised in chapter 6.3. Further positive impacts on health can be expected from the increased use of active modes in the context of multimodality as promoted by the deployment of MaaS and mobility management services. Such effects would be present in all policy options but can be expected to be higher in PO2 (and PO3) where their deployment is supported by a MMTIS data mandate.

Impact on persons with reduced mobility

MMTIS for people with disabilities and reduced mobility is seen by the relevant representative organisation - European Disability Forum - as being at risk of continued market fragmentation. In that respect, under PO1, the continued deployment of common data standards could help mitigate this risk for new services. However, the introduction of the mandatory sharing of MMTIS data under PO2 and PO3 can be expected to produce the largest effect on people with disabilities or reduced mobility. The mandatory availability of accessibility-related data for the functioning of essential services under these POs, supports the potential development of

[86] Thus, the difference with the figures reported in the EU Statistical Pocketbook for transport that includes also aviation, IWT and maritime transport as well as costs of courier services and warehousing activities.

relevant multi-modal travel information services for this passenger group that can contain real-time updates of accessibility-critical information.

Impact on employment

The increase in deployment of ITS services under the different policy options can be expected to lead to second order employment effects as a result of the increased production of ITS-relevant central systems and vehicle equipment needed for their deployment leading to an increased turnover for the ITS sector in the EU. Additionally, the increased need for collecting and making data available can lead to additional employment due to the need to install the necessary equipment to facilitate this data collection and to operate the systems required to distribute them. It may also lead to the need to deploy human resource to perform these actions. The impact on employment generated can be expected to be larger as ITS service deployment levels increase with the more intervening policy options. This analysis considers two employment impacts calculated through different approaches:

- Direct employment impacts, that is, changes in employment in the sector that would need to produce additional goods and services.
- Total employment impacts, including direct, indirect and induced impacts, which reflect the economy-wide effects of changes in investment.[87]

The figures presented in Table 20 represent the average employment ranges (in FTEs) generated from investments in ITS equipment and services, either directly or indirectly. This is presented in average values for five-year periods. As seen in the table, the impacts of all POs reaches its peak by 2035 as ITS deployment levels increase till that moment, in the years after less investments in deployment are needed and costs are increasingly related to maintenance.

PO1 produces the least additional employment due to the lower investments induced by only indirectly incentivising the deployment of ITS services, with the most important contributor being the increased deployment of equipment in vehicles. These peak in the years between 2031-2035 at between 7,800 and 10,800 total FTEs out of which between 2,000 and 2,800 are direct employment generated in the EU ITS sector. The employment generated by PO2 are higher and total employment generated is estimated between 12,000 – 16,600 FTEs in the period between 2031-2035. Out of these 3,000 - 4,100 FTEs are estimated to be the direct employment generation in the ITS sector. This is boosted by the increased deployment of road-side equipment necessary to facilitate the data availability mandates.

Table 20: Impacts on employment

Period	PO1	PO2	PO3
Direct average employment (FTEs)			
2025-2030	1,800 – 2,400	2,500 – 3,500	5,400 – 7,500
2031-2035	2,000 – 2,800	3,000 – 4,100	3,800 – 5,400

[87] Total impacts include the changes in employment in the sectors that change their production, their suppliers, suppliers of the suppliers, and the economy-wide employment effects caused by the additional employees spending their wages on goods and services.

Period	PO1	PO2	PO3
2036-2040	1,300 – 1,800	1,800 – 2,500	2,300 – 3,200
Total average employment (FTEs)			
2025-2030	6,800 – 9,500	10,190 – 14,200	21,200 – 29,500
2031-2035	7,800 – 10,800	12,000 – 16,600	15,300 – 21,300
2036-2040	5,000 – 7,000	7,400 – 10,200	9,100 – 12,700

Source: Ricardo et al. (2021)

PO3 leads to the largest employment impacts, predominantly as a consequence of the C-ITS equipment mandate for all new vehicles introduced. As the mandate is expected to come into effect at 2028 for new vehicle models and 2030 for all new vehicles, the majority of additional equipment costs incurred are expected to take place in the period leading up to its introduction. This means that employment impacts can be expected to maximise in 2026-2030 and produce a total employment impact of between 21.200 – 29,500 FTEs. The direct employment generated in the ITS sector is expected to be at the level of 5,400 – 7,500 FTEs for the same period. In all cases, as the vast majority of additional costs are expected to be in the area of additional equipment deployed either in vehicles or in the form of RSIs, these ITS sectors can be expected to see the lion's share of the direct generated employment.

6.3. Environmental impacts

Impact on greenhouse gas emissions

Several of the services considered in this IA, such as green light optimal speed advisory, real time information on congestion, roadworks or incidents, will contribute towards a reduced fuel consumption and, in turn, lower CO2 emissions by improving traffic flow, reducing travel time and increasing modal shift towards public transport and active modes. As shown in Table 21, the model outputs give a reduction of CO2 emissions relative to the baseline for all three policy options, with PO2 and PO3 have significantly greater benefits than PO1, particularly by 2040 when PO3 becomes fully effective.

The CO2 emission values have been monetised using the CO2 price from the 2019 Handbook on external costs. When the present value of the cost of CO2 emissions savings are considered, total benefits are also highest in PO3 with a saving of €2.4 billion between 2021 and 2040, relative to the baseline. PO2 (€2.1 billion) has similar costs savings to that of PO3, while PO1 (€0.6 billion) is significantly lower. As with other impacts described in previous sections, the more significant savings in PO2 and PO3 are driven by increased deployment which is a result of the critical data and service mandates that are introduced. The costs savings associated with each policy option are limited when put into the context of the baseline external costs.

Table 21: Annual CO2 emissions from road transport (million tonnes) – EU27

Year	Mode	Baseline	PO1	PO2	PO3
2030	Annual CO2 emissions in 2030	522.6	522.1	520.2	520.0
	Saving relative to the baseline in 2030	-	0.6	2.5	2.7
	% savings relative to the baseline	-	0.10%	0.50%	0.50%
2040	Annual CO2 emissions in 2040	168.9	168.4	167.7	167.0
	Saving relative to the baseline in 2040	-	0.5	1.2	1.9

	% savings relative to the baseline	-	0.30%	0.70%	1.10%

Source: Ricardo et al. (2021)

Impact on air pollutant emissions

Other emissions modelled include nitrous oxides (NOx), volatile organic compounds (VOC) and particulate matter (PM) for all road transport. NOx emissions benefit from the same ITS services and follow a similar trend to CO2 emissions, however Table 22 does not show as clear a picture for VOC and PM. The annual VOC emissions increase in all policy options in 2030 and PM increases with increasingly intervening policy options.

Table 22: Annual pollutant emission savings for EU27 (tonnes)

	2030			2040		
	Annual emissions	Saving relative to the baseline	% difference to the baseline	Annual emissions	Saving relative to the baseline	% difference to the baseline
Baseline						
PM	50,447	-	-	15,050	-	-
NOx	885,687	-	-	308,373	-	-
VOC	67,457	-	-	37,059	-	-
PO1						
PM	50,384	63	0.13%	14,998	53	0.35%
NOx	884,940	747	0.08%	307,733	640	0.21%
VOC	67,475	-18	-0.03%	37,048	11	0.03%
PO2						
PM	50,425	23	0.05%	15,007	43	0.29%
NOx	884,136	1,550	0.18%	307,349	1,024	0.33%
VOC	67,568	-111	-0.16%	37,070	-11	-0.03%
PO3						
PM	50,429	18	0.04%	15,027	24	0.16%
NOx	884,018	1,669	0.19%	307,108	1,265	0.41%
VOC	67,558	-101	-0.15%	37,051	8	0.02%

Source: Ricardo et al. (2021)

NOTE: negative values reflect an increase of emissions

The estimated impacts on PM and VOC emissions across the policy options are based on the findings of the DRIVE C2X study concerning the impact of ‘in-vehicle speed limits’ (VSPD) service under C-ITS V2I applications, showing an increase in PM and VOC emissions.[88] They found that the service would result in a smoother driving style on motorways, while on inter-urban roads the increased braking or speed changes when approaching new speed limits would result in increased PM and VOC emissions. The same study reported on the impact on NOx emissions described above, but does not explain why the impacts differ between pollutants.

88 https://www.eict.de/fileadmin/redakteure/Projekte/DriveC2X/Deliverables/DRIVE_C2X_D11.4_Impact_Assessment_v1.0_full_version-1.pdf

At the same time, no evidence was found that confirms this finding and green light optimal speed advisory (GLOSA) – a similar type of service – has been reported to result in emission reductions of these pollutants. Furthermore, it should be expected that a similar impact should be expected in relation to NOx, but the study does not report on the reduction in NOx emissions. Concluding, ITS services and particularly C-ITS services aim at smoother driving, which has a positive effect on all emissions. Implementations that would not pre-empt speed changes (e.g. only warning on the spot that the speed limit has changed) could however lead to increased braking as one study has found, with a negative impact on some emissions. This highlights how certain services, such as those that require speed reductions, can have different impacts depending on the smartness of implementation (i.e. a heads-up on oncoming speed changes should lead to smoother driving).

Despite the potential uncertainty around this impact on PM and VOC, the modelled impact is very small, representing less than 0.35% for PM and less than 0.1% for VOC across the policy options. Nevertheless, in 2040 all policy options are expected to bring emission savings, with PO3 having the most significant impact. Cumulatively, the total air pollutant emissions expected to be saved between 2021-2040 and the reduction in external costs of air pollution (expressed as present value over 2021-2040) is greatest in PO3 with the PV benefits in PO2 also much greater than PO1 (see Table 23), although these improvements are dominated by NOx and small overall, compared to the total emissions from road transport.

Table 23: Cumulative air pollutant emissions avoided (tonnes) relative to the baseline and the reduction in external costs of air pollution, expressed as present value (EUR mn) for 2021-2040

	PO1		PO2		PO3	
	Cumulative emissions avoided	Reduction in external costs of air pollution	Cumulative emissions avoided	Reduction in external costs of air pollution	Cumulative emissions avoided	Reduction in external costs of air pollution
PM	1,000	11.0	485	4.4	314	2.8
NOx	13,140	158.2	22,038	223.3	25,005	253.1
VOC	-69	-0.1	-1,301	-1.3	-1,001	-1.1
Total	**14,070**	**169.1**	**21,222**	**226.4**	**24,319**	**254.8**

Source: Ricardo et al. (2021)

Impact on noise

Impacts on noise are a result of total transport activity. As the impacts of the policy options on transport activity and modal shift are expected to be relatively limited, it is also expected that any impacts on noise production will also be minimal. For more details see chapter 6.1. In addition, smoother driving could also result in less noise but as described in the paragraphs above such impacts face some uncertainty today and are expected to be smaller still.

7. HOW DO THE OPTIONS COMPARE?

7.1. Effectiveness

The effectiveness of the intervention is measured by the extent to which the specific and general objectives of the policy intervention are addressed, or, as described in section 4.2, to what extent the indicators of success are met. Table 24 gives a detailed analysis of the effectiveness of each policy option, measured against those indicators. All in all, moving through the policy options from PO1 towards PO3, a progressively improved achievement of the specific objectives set for the ITS Directive can be observed.

Table 24: detailed comparison of policy options measured against assessment criteria linked to problem drivers

Indicator	PO1	PO2	PO3
General Objective: Increase the deployment and (inter-)operational use of ITS services across the EU to improve the functioning of a multimodal transport system and enhance interfaces between all modes			
Deployment levels	In 2040, 145mn equipped vehicles, 111mn smart-phone users of ITS services, 45k RSUs + 33k RSI + 159 TMCs	In 2040, 145mn equipped vehicles, **196mn smart-phone users of ITS services**, 45k RSU, **153k RSIs, 402 TMCs**	In 2040, **200mn equipped vehicles, 193mn smart-phone users of ITS services, 156k RSUs**, **196k RSIs, 425 TMCs**
Specific objective 1: Increase interoperability and cross-border continuity of ITS applications, systems and services supporting a common ITS market			
Increased financial and administrative capacity to accelerated ITS deployment	Increased coherence with other legislation and requirements for B2G access to in-vehicle data	Data mandates impose administrative capacity increases	Service mandates impose administrative capacity increases
Increased interoperability and continuity of services across Member States	Updates of priority areas and increased coherence of ITS Directive with other initiatives such as TEN-T	Include deployment mandates (data & services) in scope of the Directive (using common specifications)	Standards for in-vehicle generated data for road operation + service mandates for essential services
Creation of common standards, principles and quality requirements for emerging ITS services	Updates of priority areas, requirements for B2G access to in-vehicle data, specifications for C-ITS, coherence with other legislation	Include deployment mandates (data & services) in scope of the Directive (using common specifications)	Standards for in-vehicle generated data for road operation
Increased interoperability of data generated by all modes	Updates of priority areas	Include deployment mandates for data and services in scope of the Directive	Same as PO2
Specific objective 2: Establish a clear and effective coordination and concertation process for all ITS stakeholders (including stakeholders relevant in the multimodal context of the Directive)			
Stronger cooperation in ITS governance, industry buy-in	Further improve and streamline interaction with ITS stakeholders	Legal provisions on EU-wide coordination of NAPs	Same as PO2
Comparable monitoring of ITS deployment across MSs	Streamline reporting obligations and mandate common format & KPIs	Same as PO1	Same as PO1
Specific objective 3: Ensure improved data availability, access and quality standards used and facilitate the exchange and usage of data supporting ITS services			
Solutions for (trust) issues with data protection, privacy and liability	Increased coherence with other legislation and initiatives such as TEN-T + legal provisions on C-ITS trust model	Same as PO1	Same as PO1

Indicator	PO1	PO2	PO3
Increased incentives / awareness to collect and share ITS data	Update deployment principles + increased coherence with other initiatives	Multiple data mandates ensure data collection	Multiple service mandates ensure data collection
Societal, economic and environmental benefits (all monetary values in present value 2021-2040)			
Fuel consumption	Limited impact. 0.16% reduction in 2040 or -0.6bn€ compared to the baseline	Positive impact. 0.34% reduction in 2040 or -2.1bn€ compared to the baseline	Very positive impact. 0.62% reduction in 2040 or -2.4bn€ compared to the baseline
CO_2 emissions	Limited impact. 0.30% reduction in 2040 or -0.6bn€ compared to the baseline	Positive impact. 0.70% reduction in 2040 or -2.1bn€ compared to the baseline	Very positive impact. 1.10% reduction in 2040 or -2.4bn€ compared to the baseline
Pollutant emissions – PM, NOx, VOC	Limited, 0.17bn€ reduction compared to the baseline	Limited, 0.23bn€ reduction compared to the baseline	Limited 0,25bn€ reduction compared to the baseline
Accidents	Limited, 0.9% reduction in 2040 or -6.7bn€ compared to the baseline	Moderate impact, 1.1% reduction in 2040 or -12.3bn€ compared to the baseline	Very positive. 4.1% reduction in 2040 or -29.5bn€ compared to the baseline
Travel time	Moderate, 43.0bn€ reduction compared to the baseline	Very positive, 138,8bn€ reduction compared to the baseline	Very positive, 144,5bn€ reduction compared to the baseline

PO2 and PO3 are expected to fulfil objective SO3 to a larger extent than PO1 with the introduction of the data mandates. Additionally, PO3 also goes beyond what PO2 can achieve against SO1, thanks to the introduction of service mandates and the development of standards for in-vehicle data sharing. Finally, SO2 is already broadly fulfilled through the measures streamlining ITS stakeholder coordination as introduced in PO1, however PO2 and PO3 go a step further by institutionalising the NAP coordination mechanism. This assessment is summarised in Table 25 below where it can be seen that PO3 is expected to achieve all SOs to the largest extent.

Table 25: comparison of policy options on effectiveness

	PO1	PO2	PO3
SO1: Increase interoperability and cross-border continuity of ITS applications, systems and services supporting a common ITS market	+	+++	++++
SO2: Establish a clear and effective coordination and concertation process for all ITS stakeholders (including stakeholders relevant in the multimodal context of the Directive)	++	++(+)	++(+)
SO3: Ensure improved data availability, access and quality standards used and facilitate the exchange and usage of data supporting ITS services	+	+++	++++
Societal, economic and environmental benefits	+	+++	++++
+: *Indicate increases in the level of achievement of the specific objectives* (+): *Indicate a minor increase in the level of achievement of the specific objectives*			

7.2. Efficiency

The efficiency is assessed by comparing the costs and benefits that have been monetized. Table 26 shows the main monetized costs and benefits associated with the policy options. Chapter 6.1 discusses additional administrative costs, but as their order of magnitude is millions, compared to billions for other costs (see also the sensitivity analysis in chapter 7.5).

All policy options show net benefits and a positive cost benefit ratio. The many (light) policy measures under PO1 result in net benefits at around €44 billion. Costs are expected to be slightly higher under PO2 due to the mandate for data collection and the costs linked to installing relevant equipment (i.e. RSUs and RSIs) but the respective benefits are three times greater (mainly due to much greater time-related savings), leading to a net benefit of €145 billion, over three times higher than that of PO1. PO3 has even higher net benefits (€159 billion), mainly resulting from even higher benefits related to accident reduction, despite a doubling of the costs (mainly related to in-vehicle systems) due to the mandate to fit new vehicles with C-ITS equipment. The increased costs for new vehicles, render this policy option less efficient than PO2, but it remains significantly more efficient than PO1 yielding more benefits per cost unit required. The benefit-costs ratios vary significantly between all three policy options but, unlike the net benefits, these are highly dependent on the uncertainties in the cost estimates and the limitations of the modelling framework. On the other hand, for each policy option additional benefits are expected from the deployment of MaaS and mobility management services, which are currently not captured by the modelling exercise. As the costs of these services are already included in the calculation, this means that an even more positive cost to benefit ratio can be expected. Moreover, additional costs and benefits, not covered by this assessment, can be expected from future ITS services (such as CCAM) that will be facilitated by the ITS Directive revision (more in the sensitivity analysis in chapter 7.5).

Table 26: Costs and benefits of the policy options relative to the baseline for EU27, expressed as present value over 2021-2040 (EUR bn)

	PO1	PO2	PO3
Roadside units	0.2	0.2	1.1
Roadside infrastructure	0.9	3.2	3.3
National access points	0.1	0.4	0.4
Central ITS sub-systems	0.1	0.6	0.6
In-vehicle systems	6.2	6.2	15.4
Smartphone and applications	0.0	0.0	0.0
Total Costs	7.5	10.6	20.8
Reduction in external costs of accidents	6.7	12.3	29.5
Time saved	43.0	138.8	144.5
Reduction in external costs of CO2 emissions	0.6	2.1	2.4
Reduction in external costs of air pollutants	0.2	0.2	0.3
Fuel saving	0.6	2.1	2.4
Total Benefits	51.1	155.5	179.1
Total Net Benefits	43.6	144.9	158.3
Benefit/Cost ratio	6.8	14.7	8.6

Source: Ricardo et al. (2021)

As travel time savings are so significant it could be considered to build a policy option focusing specifically on the measures that most influence them. However, all measures aim at tackling issues that hinder the deployment of ITS, and all ITS contribute to reduced travel time (e.g. measures aimed specifically at road safety also influence travel time as accidents in a highly congested network often lead to complete gridlock). The opposite is also true but to a lesser extent; measures aiming at improving travel time do not necessarily have a great influence on road safety. Furthermore, though reduced travel time is clearly the biggest impact, the reduction in external costs of accidents is also significant.

Reductions in fuel, CO2 emission and air pollutants may seem small in comparison but do not yet include the potential benefits from multimodal mobility services as no reliable data on their impact exists today. It is also impossible to estimate today to what extent automation will accelerate the uptake of (shared) zero emission vehicles. These mid to long-term developments have the potential to increase all benefits, tackle some of the negative externalities of transport and contribute to its overall sustainability. It should also be noted that the baseline scenario includes the 'Delivering the European Green Deal' and the pathway towards climate neutrality. This translates into significant uptake of zero- and low-emission vehicles in the baseline that limits the impact of the initiative on fuel use, CO2 emissions and air pollutant emissions.

Finally, unlike PO1, where uptake of ITS services is voluntary, PO2 and PO3 include deployment mandates (for data and services respectively), making their impacts more certain.

7.3. Coherence

All developed policy options are coherent with the goals of the ITS Directive and broader transport policies. PO2 scores significantly better than PO1 by ensuring the interoperability and deployment of ITS services through data collection mandates, and thus increases the certainty of achieving benefits relevant for overall transport policy goals. PO3 in addition provides extra support to the continuity of services through the service mandates and contributes greatly to Vision Zero, i.e. no road fatalities by 2050.

The revision of the ITS Directive specifically aims to tackle the problem driver of the limited exchange and use of data. This is partially caused by stakeholder concerns regarding data protection and privacy partially and the uncertainty regarding the coherence between the ITS Directive and more recent pieces of the EU legal framework. All policy options aim to specifically improve coherence with GDPR, ePrivacy Regulation and passenger rights rules through the introduction of appropriate references to the provisions of these regulations. The ITS Directive is thus introducing specific references to the requirements of the other existing regulations and clarifies how potential sharing of data should comply with the framework developed by already existing legislations (even without such provisions none of the policy options affect the application of this legislation).

Table 27: Comparison of options on coherence

	PO1	PO2	PO3
ITS Directive	+	++	+++
Transport policies (e.g. Smart and Sustainable Mobility Strategy, Vision Zero)	+	++	+++
GDPR, E-privacy & EECC proposals	+	+	+
Overall coherence	+	++	+++

Similarly, all policy options include measures intended to strengthen coherence with expected upcoming legal instruments (i.e. Mobility Data Space, in-vehicle data architecture, TEN-T and

Rail Freight Corridors Regulation). Where the details of these regulations have been already agreed, these POs are developed in a way that there is no overlap of contradiction in their provisions. Where such details are not yet known, the relevant measures included in all policy options foresee the need to align when those legal framework are more concretely designed.

7.4. Proportionality

PO1 relies on voluntary deployment and thus allows Member States and individual deployment projects to decide whether or not to invest in ITS services. In this sense, PO1 is proportional to achieving the intended objective.

PO2 imposes mandatory collection of crucial data. While it is a more stringent measure than PO1, this will result in a significant uptake of ITS services based on that data and the expected benefits, both direct and indirect, are also proportionally higher. In that sense, PO2 is proportional.

PO3 imposes mandatory deployment of essential services, and an obligation on vehicle manufacturers to equip all their new vehicle types with C-ITS stations. While some vehicle models are already equipped, this policy option would make that mandatory for all new vehicles since 2028. This is the most stringent measure but also the one that yields the highest benefits, particularly on road safety and to a lesser extent on fuel efficiency and CO2 emissions. In that sense, PO3 is proportional.

None of the policy options goes beyond what is necessary to achieve the main objective of ITS services deployment and take-up. Progressively ambitious policy options are designed in order to promote an increasing level of fulfilment of the specific objectives. The most intervening policy options provide a reasonable period before mandates enter into force, and where this is done, a phased coverage of the transport network is introduced considering the time needed to organise the collection and sharing of the necessary data to support essential ITS services.

7.5. Summary of comparison of options, including stakeholder views

As described in more detail in chapter 5.3 the policy options are built incrementally, with the more intervening measures split between PO2 and PO3. That means that PO1 already contains a large amount of policy measures, which are widely supported by all stakeholders, not least because amongst others they help future-proof the Directive and target improved stakeholder concertation. So while all policy options address all specific objectives, in the following we will see how the measures related to mandatory data collection (PO2) and mandatory service provision (PO3) have a profound impact.

PO1 is significantly less effective as it lacks the more intervening measures that accelerate the deployment and thus the usage of ITS services. PO2 is more effective but PO3 is most effective. In addition, the mandates in PO2 and PO3 provide for the most certainty in achieving the specific and overall objectives.

PO1 is least efficient and has significantly lower net benefits than other policy options. PO2 has the highest benefit-cost ratio at 14.7 but PO3 has the highest net benefits at 179.1b€ with a significant 140% increase in road safety benefits for a total of 29.5b€.

All policy options are coherent with the objectives of the ITS Directive and have specific measures to increase coherence with other legislation. The mandates included in PO2 however increase the certainty of achieving benefits relevant for overall transport policy goals. This applies even more for PO3, which is also most coherent with Vision Zero (i.e. zero road fatalities by 2050)

All policy options are proportional, even the more stringent options, as the latter also generate benefits matching their ambition and intervention level. In addition there is general agreement amongst stakeholders on the scope of action needed and the options proposed. Nevertheless, the biggest costs (those related to the mandates) trigger some reservations.

Particularly, on the mandatory collection of data, though nobody questions the identified datasets nor the fact these are crucial, some Member States question the need to cover their entire network, or the ambition level in terms of timeline. A phased approach, both in terms of network coverage and timeline (starting for instance with data changes first, and providing a comprehensive dataset later), is indeed justifiable and is already included in the IA. However, the ambition should remain to deploy as fast as possible and, where relevant, cover the entire network. Otherwise remote regions could end up being underserved, or even isolated, not just from ITS but from mobility services altogether.

Similarly, the mandatory equipment of vehicles to deliver C-ITS services is well supported, in terms of its relevance for road safety but also as a necessary enabler for higher levels of automation. In addition strong synergies exist between such equipment and eCall (already included in all vehicles since 2018), access to in-vehicle data (an ongoing initiative from DG GROW, see also 5.2) and infotainment systems (expected to be prevalent in the timeline envisaged by this initiative). Nevertheless, views diverge when addressing the technical details and technologies to be included in such equipment. Those discussions are however outside the scope of this initiative and impact assessment.

7.6. Sensitivity analysis

MaaS and mobility management services

Table 28: hypothesised benefits of MaaS and mobility management services

Scenario	Distance class	Reduction in transport time	Reduction in transport costs
Low sensitivity	Short	3%	3%
	Long	1.5%	1.5%
High sensitivity	Short	6%	6%
	Long	3%	3%

Source: Ricardo et al. (2021)

To include the impact of MaaS and mobility management services, assumptions were made on the potential improvements in travel time and travel cost of non-road trips. These potential improvements were considered to be smaller in longer (non-urban national and international trips), compared to shorter (urban and non-urban short trips), as can be seen in Table 28. Both scenarios were then introduced and the impacts assessed in the ASTRA-TRUST model. The majority of ITS services is targeted at improving road transport and not at fostering modal shift. Those goals are not mutually exclusive but can lead to so-called rebound effects.

Table 29: modal shift including MaaS and mobility management services

Year	Mode	Baseline	PO1	PO2	PO3	PO3 low	PO3 high
2030	Car	80.2%	80.2%	80.5%	80.5%	80.3%	80.0%
	Bus	9.4%	9.4%	9.2%	9.2%	9.3%	9.5%
	Train	10.5%	10.4%	10.3%	10.3%	10.4%	10.5%
2040	Car	79.9%	80.0%	80.3%	80.2%	80.0%	79.7%
	Bus	9.0%	8.9%	8.8%	8.8%	9.0%	9.2%
	Train	11.1%	11.1%	10.9%	10.9%	11.0%	11.2%

Source: ASTRA / TRUST model

As can be observed in Table 29 MaaS and mobility management services (within the limits imposed by the absence of reliable sources for their potential) can mitigate those rebound effects from other ITS services, or even introduce a modal shift towards more sustainable modes in the high sensitivity scenario. Furthermore, in the future ITS services are expected to foster the deployment of mobility services based on highly automated vehicles. Such services could (and indeed should) be fully integrated in a multimodal transport system, offering a viable alternative to private vehicle ownership and have a far-reaching and positive impact on the modal shift. Table 30 shows the full results of the analysis on all benefits. In the low sensitivity run, total benefits increase by 11% relative to PO3, with comparable improvements across each impact category.

Table 30: Overview of 2021-2040 present value for PO3 and the sensitivity runs for EU27 (EUR bn)

Cost / Benefit	PO3 - Difference relative to the baseline	PO3 - sensitivity low		PO3 - sensitivity high	
		Difference relative to the baseline	% change to PO3	Difference relative to the baseline	% change to PO3
Roadside units	1.1	1.1	0%	1.1	0%
Roadside infrastructure	3.3	3.3	0%	3.3	0%
National access points	0.4	0.4	0%	0.4	0%
Central ITS sub-systems	0.6	0.6	0%	0.6	0%
In-vehicle systems	15.4	15.4	0%	15.4	0%
Smartphone & applications	0.0	0.0	0%	0.0	0%
Total costs	**20.8**	**20.8**	**0%**	**20.8**	**0%**
Accident reduction benefits	29.5	32.3	9%	42.8	45%
Time saved benefits	144.5	161.2	12%	194.6	35%
CO2 emission benefits	2.4	2.8	15%	4.1	69%
Other emissions benefits	0.3	0.4	40%	0.7	179%
Fuel saving benefits	2.4	2.8	15%	4.1	69%
Total benefits	**179.1**	**199.4**	**11%**	**246.3**	**38%**
Total net benefits	**158.3**	**178.6**	**13%**	**225.5**	**42%**
Benefit/Cost ratio	**8.6**	**9.6**	**n/a**	**11.8**	**n/a**

Source: ASTRA / TRUST

Total net benefits increase by 13% to €179 billion. In the high sensitivity run, total benefits increase by 38%, while total net benefits increase by 42% to €226 billion. In both cases, additional benefits are driven mainly by increased time savings as a direct result of the use of more efficient multimodal and mobility management services. The modal shift potential of these services is also expected to lead to safety benefits as safer modes can be expected to be increasingly used in the context of multimodal transport. Fuel savings and CO2 emission gains are lesser contributors to the increased benefits estimated in this sensitivity runs.

At the same time, the total costs induced by PO3 remained the same in both scenarios as the additional costs of these services where already introduced in the initial assessment of impacts. All in all, the sensitivity analysis indicates that even if there are only moderate benefits from the increased deployment of MaaS and mobility management services, the performance of PO3 can be expected to improve and yield considerable additional benefits.

Cost sensitivity analysis

There is a relatively high degree of accuracy on the per unit cost inputs. However, the translation of ITS infrastructure deployment assumptions into service deployment and ultimately service usage involves additional calculation steps and assumptions, introducing more uncertainty. In particular, engagement with stakeholders has highlighted particular challenges around projecting the number of RSUs and RSIs required[89]. Furthermore, as discussed in chapter 6.1, relevant stakeholders have pointed to the high potential cost burden that may fall on the public sector (including road authorities) for data collection, processing and making data available to support ITS services. These three key steps can each entail activities at either the national or local level, although collecting data and estimating costs on each is challenging as different institutional set-ups of authorities exist in every Member State. Some relevant examples were identified, for example the city of Gothenburg spent a total of 300k€ over three years to digitize its traffic regulations[90], while the Dutch transport ministry spends 10m€ yearly on data collection and operation of a national data warehouse, which also hosts the National Access Point[91]. The support study for the revision of the Delegated Regulation on real-time traffic information[92], which is most relevant for this IA, estimates a present value (2021-2030) of costs from a partial data collection mandate for the EU28 at €18m[93]. This includes personnel cost for data collection, processing and maintenance for RTTI data as well as costs for coordination, standardization and training activities. To cover the large variations in these cost elements, a sensitivity analysis on costs of ITS infrastructure deployment has been developed and applied to PO3.

[89] Stakeholder feedback during the workshop highlighted the uncertainty and differences in opinion surrounding the likely scale and location of RSU deployment.
[90] Information provided by city authorities and compiled by Polis for Ricardo as part of the IA support study
[91] Source: Interview with Netherlands Ministry of Infrastructure and the Environment, carried out in April 2021 by Ricardo
[92] https://op.europa.eu/en/publication-detail/-/publication/043ee22b-643b-11eb-aeb5-01aa75ed71a1
[93] Ricardo's own analysis of data used to support calculated from support study for the revision of the Delegated Regulation on real-time traffic information, recharging/refuelling points; and access to vehicle data for road operation purposes.

In the first scenario ('cost sensitivity 1'), all costs are increased by 50%, while in the second ('cost sensitivity 2') the costs burden on the components related to data collection and processing[94] are increased by a further 50% (100% in total). Table 31 shows that under each scenario, the net present value of benefits in PO3 does not decrease significantly. Despite a significant increase in total costs from 20.3 billion EUR to 31.2 billion EUR in sensitivity run 2, the strong net benefit highlights the robustness of the model results to cost increases. Moreover, in all sensitivity runs, the benefits to cost ratio of the policy options remains positive.

Table 31: Overview of 2021-2040 present value of the costs, benefits, and net benefits for the cost sensitivity cases relative to the baseline for EU27 - with and without the cost sensitivities applied (EUR bn)

	PO3	Cost sensitivity 1	Cost sensitivity 2
Roadside units	1.1	1.7	2.2
roadside infrastructure	3.3	4.9	6.5
National access points	0.4	0.6	0.8
central ITS sub-systems	0.6	0.9	1.2
In-vehicle systems	15.4	23.1	23.1
Smartphone and applications	0.0	0.0	0.0
Total costs	**20.8**	**31.2**	**33.8**
Total Benefits	**179.1**	**179.1**	**179.1**
Total net benefits	**158.3**	**147.9**	**145.3**
Benefit/Cost ratio	**8.62**	**5.75**	**5.29**

8. PREFERRED OPTION

8.1. Policy option 3: Mandating provision of essential services

PO2 is preferred over PO1, as it achieves significantly larger benefits and has the highest cost benefit ratio. The mandatory collection of data and the resulting uptake of ITS services greatly increases its effectiveness in achieving the objectives of the ITS Directive and makes it more coherent. Limiting the mandatory collection of data to crucial data and the very significant resulting benefits also mean it is proportional.

The difference in net benefits between PO2 and PO3 is smaller than the difference between PO1 and PO2, but they remain very significant and constitute a considerable increase in safety related benefits (29,5b€ or 140% higher in PO3 than PO2). The benefit-to-cost ratio of the additional measures in PO3 (in other words comparing only the additional costs and benefits) is lower than that of the measures in PO2, but is still positive at 2.5. In other words, the service mandates and related equipment proposed in option 3 are, also when evaluated separately, a good investment. Furthermore, the same equipment can be used to deliver ever more advanced C-ITS services, increasing the benefits at no extra cost, which is likely already the case by the time this measure enters into force. Option 3 is also the most coherent option and through the accelerated deployment of C-ITS is the one that best prepares for higher levels of automation by connecting vehicles with each other. This in turn would give the European automotive and ITS industry an advantage, leading to higher levels of new business opportunities and job creation, and more significant research and innovation impacts. Lastly, the mandatory

[94] Including roadside infrastructure, data collection and central sub-system costs.

provision of essential ITS services for road safety, despite considerable compliance costs, is also proportional.

So while PO2 scores higher on benefit-cost ratio, PO3 comes out on top on all other criteria and is thus the preferred policy option. More particularly, it generates the highest net benefits, is the most effective option, best prepares for a more automated future, best achieves the specific objectives of the ITS Directive and best ensures the swift and coherent deployment of ITS services, in line with the objectives of the Smart and Sustainable Mobility Strategy. Finally, as the policy options are built incrementally, all measures that generate the high benefit-cost ratio of PO2 are included in the preferred option.

8.2. REFIT (simplification and improved efficiency)

REFIT Cost Savings – Preferred Option(s)		
Description	*Amount*	*Comments*
Update and streamline reporting obligations	Not quantified	Recurrently reduces administrative costs of Member States
Mandate reporting based on common format & KPIs	Not quantified	Recurrently reduces administrative costs of Member States
Improve the coherence of the ITS Directive with the existing legal framework (e.g. GDPR)	Not quantified	Reduces administrative and compliance costs of all stakeholders that deploy ITS services
Improve the coherence of the ITS Directive with expected initiatives (e.g. TEN-T Regulation)	Not quantified	Reduces administrative and compliance costs of all stakeholders that deploy ITS services

9. HOW WILL ACTUAL IMPACTS BE MONITORED AND EVALUATED?

Monitoring and evaluation should build on a simple approach that is transparent and easily accessible. It is not the intention to create a very complex and complicated system of KPIs, noting that Member States reports transmitted every 3 years to the Commission should themselves already include KPIs that allow the monitoring of the deployment of ITS services and of the availability and accessibility of data on the NAPs. Current KPIs for reporting should be updated (and made mandatory when relevant) to better allow this monitoring.

More specifically, the Commission services will monitor the implementation and effectiveness of this initiative through a set of core indicators that will measure the progress towards achieving the specific objectives, based on the measures that are part of the preferred option PO3. Some of the indicators are of a qualitative nature and show if the desired deliverables are being achieved and implemented, while others are based on data to be collected that will need to be analysed further.

Specific objective	Progress indicators	Source of data
Increase interoperability and cross-border continuity of ITS applications, systems and services supporting a common ITS market	• KPIs[95] on the deployment of ITS services, including services mandated by the proposal. • Qualitative assessment of the ITS activities of public and private stakeholders.	• Member State reports • CEF-funded projects
Establish a clear and effective coordination and concertation	• Number of meetings and level of participation from all public and private stakeholder categories.	• Commission

[95] List of KPIs available on https://ec.europa.eu/transport/themes/its/road/action_plan/its_national_reports_en

Specific objective	Progress indicators	Source of data
process for all ITS stakeholders (including the multimodal context)	• Number of coordination projects (CEF, DEP) and participating stakeholders	
Ensure improved data availability, access and quality standards to facilitate the exchange and usage of data supporting ITS services	• KPIs for data availability and accessibility on NAPS, including mandated data. • Qualitative assessment of the ITS activities of public and private stakeholders.	• Member State reports

Considering that ITS is a fast-moving sector, it is foreseen that the Commission services will report to EP and Council every 3 years on the implementation of the Directive and its Delegated Acts, taking into account the analysis of national reports on ITS deployment (MS also report to the Commission every three years). This is intended to determine whether the measures in place have resulted in an improvement of the situation and to verify whether the objectives of the initiative have been reached. This reporting shall be carried out based on the core progress indicators below, in line with Commission requirements on evaluation, and will be part of the report that the Commission shall submit every three years to the European Parliament and to the Council on the progress made for the implementation of the Directive.

Annex 1: Procedural information

1. LEAD DG, DECIDE PLANNING/CWP REFERENCES

The lead DG is Directorate General for Mobility and Transport (MOVE), Unit B4, Sustainable & Intelligent Transport.

DECIDE reference number: PLAN/2020/7429 - Revision of the Intelligent Transport Systems Directive, planned adoption data Q4 2021.

The development of this initiative was announced under item A 4 a) in Annex 1 to the Commission Work Programme 2021[96] and under action 38 of the Sustainable and Smart Mobility Strategy[97]. The Inception Impact Assessment was published on 8 October 2020[98].

2. ORGANISATION AND TIMING

The Inter Service Steering Group (ISSG) for the impact assessment on the revision of Directive 2010/40/EU ("ITS Directive") was set up in July 2020 and included the following DGs and Services: SG, SJ, CLIMA, CNECT, COMP, ENER, ENV, FISMA, GROW, JRC, JUST, REGIO, RTD, SANTE.

In total, 5 meetings of the ISSG were organised to discuss the impact assessment. These meetings took place on 2 September 2020, 15 December 2020, 4 March 2021, 17 June 2021 and 23 July 2021 (all virtual meetings). Further consultations with the ISSG were carried out by e-mail.

The ISSG approved the Impact Assessment roadmap, the Terms of Reference for the External Support Study and the questionnaire for the Open Public Consultation and discussed the main milestones in the process, in particular the different deliverables of the support study.

3. CONSULTATION OF THE RSB

The Regulatory Scrutiny Board will receive the draft version of the impact assessment report by 25 August 2021. The Board meeting will take place on 22 September 2021.

4. EVIDENCE, SOURCES AND QUALITY

The starting point for the drafting of the impact assessment was the evaluation of the ITS Directive.[99] 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.

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96 https://ec.europa.eu/info/publications/2021-commission-work-programme-key-documents_en
97 https://eur-lex.europa.eu/resource.html?uri=cellar:5e601657-3b06-11eb-b27b-01aa75ed71a1.0001.02/DOC_2&format=PDF
98 https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12534-Intelligent-transport-systems-review-of-EU-rules-_en
99 Ex-post evaluation of the Intelligent Transport Systems Directive 2010/40/EU - SWD(2019) 369

The Commission sought external expertise through a contract for a support study with RICARDO Nederland B. V, supported by Ricardo-AEA Limited, TRT and M-Five, which was launched in November 2020. The findings of the impact assessment report build on the final report from this contract.

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

Annex 2: Stakeholder consultation

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 November 2020.

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[100] engaged main target groups through different methods, combining:

- Publication of the Inception Impact Assessment (IIA), and a request for submission of comments to the IIA by all interested stakeholders which ran from 8 October 2020 until 19 November 2020.
- An Open Public Consultation (OPC) was launched on 3 November 2020 and remained open until 2 February 2021
- Targeted consultation
    - An online survey for all key stakeholder groups was launched on 15 February 2021 and remained open until 26 March 2021
    - An interview programme with 53 stakeholders from all key stakeholder groups was launched on 16 February 2021 and remained open until 6 May 2021. Furthermore, six exploratory interviews with key stakeholders were conducted in the inception phase of the study (November/December 2020)
- Six stakeholder workshops that took place between December 2020 and June 2021.
- Meetings of the ITS Committee on 17 December 2020 and 28 June 2021

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

[100] More detail can be found in Annex F of the support study

2. CONSULTATION METHODS

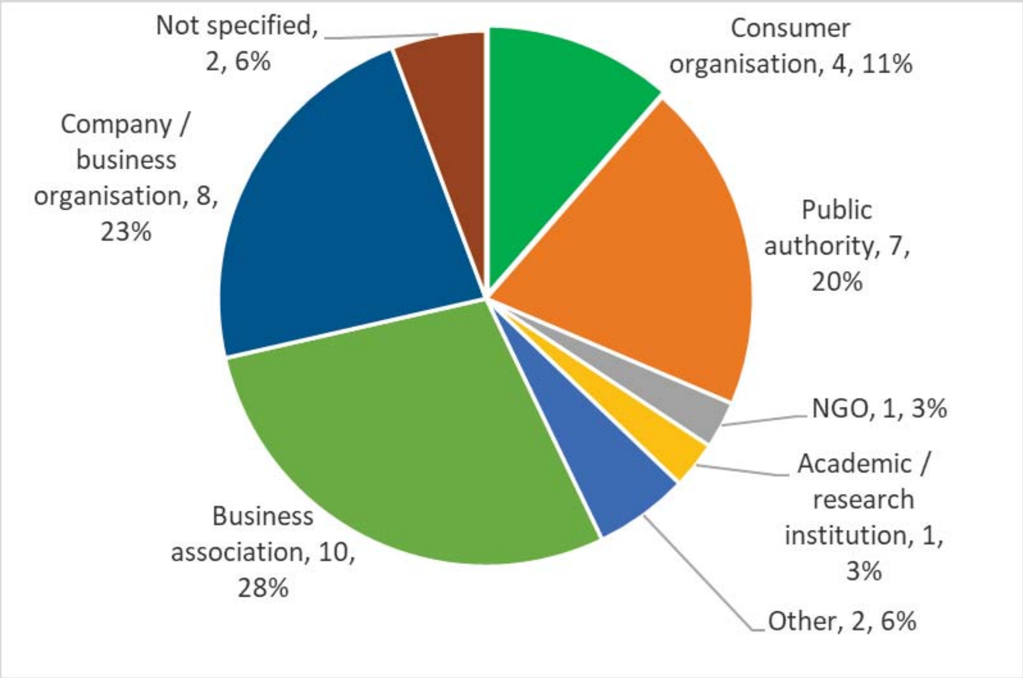
Publication of the Inception Impact Assessment

The Inception Impact Assessment[101] for the initiative was published on 8 October 2020 and was open for feedback until 19 November 2020. In the IIA, the Commission identified three 'key problem drivers', i.e., that there was:

- A lack of interoperability and continuity of applications, systems and services;
- A lack of concertation and effective stakeholder coordination; and
- Unresolved issues related to the availability and sharing of data supporting ITS services.

Thirty-four responses were received through the feedback mechanism and an additional two by mail, however some were related contributions (supporting documents or longer versions of the responses provided in the survey) and there was one repeat response.

Figure 15: Summary of responses by stakeholder type (number and % of responses)



The responses were generally favourable of the initiative and many respondents either set out their views in each of these areas or focused on one of these in particular. The initial intention had been to present the responses according to these three problem drivers followed by other issues that had been mentioned. However, after having reviewed the responses it was clear that many would lose their coherence if they were presented in this way. The exception to this was

[101] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12534-Intelligent-transport-systems-review-of-EU-rules-_en

in relation to the third key problem driver relating to data availability and sharing, which was the focus of nine responses, although this issue was covered to some detail in many responses.

Open Public Consultation (OPC)

The Open Public Consultation was launched on the Commission website on 3 November 2020 and was open for responses until 2 February 2021 (13 weeks).[102] 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.[103]

The OPC received 149 responses, of which only 4 respondents were based outside the EU.

Figure 16: Geographical distribution of responses received

Country of origin	Number of responses	% of responses	Country of origin	Number of responses	% of responses
Belgium	38	25.5%	Poland	4	2.7%
Germany	29	19.5%	Greece	2	1.3%
France	21	14.1%	Ireland	2	1.3%
Sweden	11	7.4%	Luxembourg	1	0.7%
Finland	8	5.4%	Denmark	1	0.7%
Austria	7	4.7%	Malta	1	0.7%
Italy	6	4%	Norway	1	0.7%
Netherlands	5	3.4%	Switzerland	1	0.7%
Czechia	4	2.7%	Israel	1	0.7%
Spain	4	2.7%	China	1	0.7%

Figure 17: Classification and number of stakeholders responding to the OPC

Stakeholder group	Number of responses	% of responses
Academic/research institution	3	2%
Business association	37	24.8%
Company/business organisation	46	30.9%
Environmental organisation	1	0.7%
Consumer organisation	3	2%
EU citizen	12	8.1%
Non-governmental organisation	12	8.1%
Public authority	22	14.8%
Trade union	1	0.7%

[102] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12534-Intelligent-transport-systems-review-of-EU-rules-/public-consultation_en

[103] Included in annex F of the support study

Stakeholder group	Number of responses	% of responses
Other	11	7.4%

Targeted consultation

The following key and relevant stakeholder groups were targeted:

- **EU Public bodies** (including European institutions, standardisation bodies, international organisations and public banks).
- **Public authorities and other** (including ministries within Member States and regions, as well as organisations that represent city and regional networks).
- **Industry stakeholders** (including ITS service providers, ITS organisations, infrastructure managers, mobility service providers, digital map providers, vehicle manufacturers and their suppliers, technology and telecommunication suppliers, and public transport).
- **Civic Society and research** (including consumer bodies, disability and elderly advocacy groups, research organisations with specific ITS expertise and organisations that represent transport employees and trade unions).

Whilst both the survey and interviews overlapped in thematic areas, the questions asked had a slightly different focus with the survey focussing more on collecting quantitative information, and the interviews focussing more on qualitative inputs.

Online survey

An online survey[104] was launched on 15th February 2021. The survey focused on obtaining input on the expected impacts (economic, social and environmental) of the measures under consideration in comparison to the baseline, the possible issues that may arise, to help assess the level of support for specific measures, and where relevant, input on the cost implications of each measure.

In order to reach a wide audience, the support of relevant umbrella organisations (including ERTICO-ITS, MaaS Alliance, CEDR, ACEA and UITP) which shared the survey questionnaire with their members, was relied upon.

The survey was in English and remained open for a period of six weeks (15/02/21-26/3/2021) using the online platform Alchemer. A total of 36 responses were received. Of these, four also took part in an interview, three participated in the IIA, and eight completed the OPC. 24 unique stakeholders took part only in the survey.

In-depth interviews

[104] https://survey.alchemer.eu/s3/90315608/Survey-Impact-Assessment-on-the-revision-of-the-Directive-on-Intelligent-Transport-Systems-2010-40-EU

Six **exploratory semi-structured interviews** were initially undertaken with selected stakeholders during the inception phase of the study. They included:

- ACEA - European Automobile Manufacturers' Association
- POLIS - Network of European Cities and Regions
- AustriaTech - Company of the Austrian Federal Government dealing with developments in mobility and technology
- CEDR - Organisation of European National Road Administrations
- UITP - International Association of Public Transport
- ASECAP - European Association of Operators of Toll Roads

The purpose of the exploratory interviews was to assist in refining the problem definition and the policy options, as well as supporting developing the field research tools. More specifically, these interviews assisted in ensuring that all issues that could be relevant to the problem definition and the definition of the policy options were correctly identified early in the process, as well as supporting in identifying all relevant information sources for the study. Furthermore, the topics discussed in the interviews contributed to the design and development of the draft survey questions and interview guides.

The main interview programme ran between 16 February and 6 May 2021. Just like the survey, the aim of the interviews was to allow discussing impact assessment parameters and to validate the choice of policy measures (following initial screening) and policy options (following the initial packaging). They focused on obtaining detailed input on the expected impacts (economic, social and environmental) of the measures under consideration in comparison to the baseline, the possible issues that may arise and to identify the level of support for specific measures, and, where relevant, the cost implications of each measure.

A total of **53 main interviews (**plus the **six exploratory interviews**), were undertaken with stakeholders during the study. Of the stakeholders involved, four also took part in the survey, 16 participated in the IIA, and 30 completed the OPC. 22 unique stakeholders took part only in the interviews.

The table below outlines the interviews conducted and responses received to the online survey, as well as the total number of unique stakeholders involved in the targeted consultation.

Type of stakeholder	Number of interviews conducted	Number of respondents to the online survey	Total number of individual stakeholders participated
Public bodies	5 (+1 exploratory)	3	8
Public authorities and other public bodies	18 (+2 exploratory)	10	27
Industry and associations	23 (+3 exploratory)	19	40
Civic society	7	4	11
TOTAL	**59**	**36**	**86**

Stakeholder workshops

A series of six workshops were organised to support the impact assessment.

Workshop	Date	Objectives	Type of workshop	No. of registered participants
1	15 December 2020	• Overview of proposed study, including methodology • Overview of IIA responses • Discussion on definition of main problems	Open for all interested stakeholders	285
2	14 January 2021	• Validation of key data and assumptions related to specific problem areas with technical experts	Restricted to stakeholders/experts with a technical background	18
3	19 January 2021	• Validation of key data and assumptions related to specific problem areas with legal and policy experts	Restricted to stakeholders/ experts with a legal and/or policy background	26
4	3 March 2021	• Overview of study progress to date • Summary of OPC responses • Presentation and discussion on proposed policy options	Open with separate sessions restricted to selected participants identified from initial registration	310
5	14 April 2021	• Presentation of the high-level impact assessment methodology to validate intervention logic and key assumptions	Restricted to stakeholders with an expertise in policy assessments	25
6	24 June 2021	• Presentation of the draft final results from the impact assessment • Gathering feedback on the preferred policy option, including on legal, political and technical feasibility to inform the final report	Open for all interested stakeholders	202

Annex 3: Who is affected and how?

1. PRACTICAL IMPLICATIONS OF THE INITIATIVE

The deployment of ITS services can be expected to lead to a number of benefits for various stakeholders. The impacts of specific services across a number of impact indicators including time and congestion savings, fuel efficiency, emissions reduction and transport safety are elaborated in Annex 3. In summary, it can be concluded that the lagging deployment of ITS services is expected to affect the following stakeholder categories:

- Transport service users first and foremost as they will be able to use more advanced ITS services or will enjoy only partial and delayed benefits. Missed benefits will include travel cost and time reductions, safety benefits and improved quality of transport services extending all modes of transport that would be expected to be produced by various ITS services.
- Member States and local authorities are also expected to miss out on the benefits of improved traffic management while the fragmented, uneven and discontinuous deployment of ITS services may also incur increased deployment costs. It will also be detrimental to road operators and traffic managers, who will have less access to new solutions to more efficiently manage their networks.
- ITS service providers (including micro-mobility service providers), vehicle manufacturers and other service providers that rely on equal access and availability of qualitative data to provide their services can be also expected to be significantly affected in their capacity to develop and offer services at optimal cost and quality levels.
- Society as a whole is expected to miss out on the expected reduction of traffic safety incidents, congestion and other external costs of transport, achieved by better traffic management, improved transport system performance and the promotion of a modal shift towards public transport and active mobility modes. In addition, this creates costs of emergency services, health care costs and production losses.
- It would also put the European automotive and ITS industry at a disadvantage compared to its competitors, leading to lower levels of new business opportunities in the digitalisation of transport along with lower levels of job creation, and less significant research and innovation impacts on the overall European economy. As the jobs of millions of Europeans depend directly or indirectly on the automotive and wider transport industries, it is critical that the sector is provided with the conditions to keep up with global market players.
- The telecom sector is also affected as C-ITS and CCAM services can use their cellular network and technologies to deliver services and this can thus constitute a new growth market.

2. SUMMARY OF COSTS AND BENEFITS

I. Overview of Benefits (total for all provisions) – Preferred Option		
Description	***Amount***	***Comments***
Direct benefits		
Reduction of travel time relative to the baseline	€144.5 billion	The effect of the reduction of travel time resulting from the deployment of ITS services that improve transport efficiency

I. Overview of Benefits (total for all provisions) – Preferred Option		
Description	***Amount***	***Comments***
(i.e. present value 2021-2040)		(and indirectly from the deployment of ITS services that improve road safety as accidents can create significant delays in a saturated transport system). The reduction of travel time is estimated at around €144.5 billion relative to the baseline over the 2021-2040 period, expressed as present value.
Reduction of fuel consumption (i.e. present value 2021-2040)	€2.4 billion	It is the effect of the reduction of fuel consumption resulting from the deployment of ITS services that improve transport efficiency. The reduction of fuel consumption is estimated at around €2.4 billion relative to the baseline over the 2021-2040 period, expressed as present value.
Indirect benefits		
Reduction of external costs related to road safety (i.e. present value 2021-2040)	€29.5 billion	Indirect benefit to society at large. It is the effect of the reduction of accidents resulting from the deployment of ITS services that improve road safety. The reduction includes fatalities, serious and minor injuries and their external costs is estimated at around €29.5 billion relative to the baseline over the 2021-2040 period, expressed as present value.
Reduction of external costs related to CO_2 emissions relative to the baseline (i.e. present value 2021-2040)	€2.4 billion	Indirect benefit to society at large. It is the effect of the reduction of CO_2 emissions resulting from the deployment of ITS services that improve transport efficiency. The reduction in the external costs of CO_2 emissions is estimated at around €2.4 billion relative to the baseline over the 2021-2040 period, expressed as present value.
Reduction of external costs related to air pollution emissions relative to the baseline (i.e. present value over 2021-2040)	€0.3 billion	Indirect benefit to society at large. It is the effect of the reduction of air pollution emissions resulting from the deployment of ITS services that improve transport efficiency. The reduction in the external costs of air pollution emissions is estimated at around €0.3 billion relative to the baseline over the 2021-2040 period, expressed as present value.
Innovation / competitiveness in the mobility sector		Provisions for static and dynamic transport data on national (and common) access points of Member States will foster an ITS market that will contribute to the development of new innovative services that foster a more inclusive multimodal mobility system. Such commonly available and accessible data can particularly benefit service innovation and other innovation, including by SMEs. It is also expected to play a strong enabling role in the development of the emerging and highly competitive field of CCAM. Moreover, standardisation of interoperability of data and services will enable better innovative service development which will finally benefit all transport users.

II. Overview of costs – Preferred option							
		Citizens/ Consumers		Businesses		Administrations	
		One-off	Re-current	One-off	Re-current	One-off	Recurrent
Investments related to the equipment of (roadside and central)	Direct costs					RSU: €0.8 bn RSI:	Maintenance and operation costs Road-side units: €0.3 bn Road-side infrastructure: €0.3 bn

II. Overview of costs – Preferred option							
		Citizens/ Consumers		Businesses		Administrations	
		One-off	Re-current	One-off	Re-current	One-off	Recurrent
infrastructure in support of ITS services						€2.9 bn NAP: <€0.1 bn	National access points: €0.4 bn
Compliance costs related to the equipment of vehicles with dedicated equipment in support of ITS services	Direct costs			€10.5 bn	€4.9 bn		
Administrative costs related to the digitalisation of public transport data and monitoring costs	Direct costs						The costs to public authorities from the requirements to review and update the national policy frameworks (NPFs) and report on the implementation are similar as in the baseline. Monitoring costs may increase to some extent to report on compliance with the mandatory provision of crucial data and essential services. The additional costs relative to the baseline can't be quantified. The provision of standardised data formats, common reporting format supported by common reporting KPIs and alignment of reporting requirements (from Delegated Regulations and Directive) will simplify overall reporting under the Directive.

Annex 4: Analytical methods

1. Description of the modelling tool used

The analytical framework used for the purpose of this impact assessment builds on the PRIMES-TREMOVE, ASTRA and TRUST models, complemented by the assessment of ITS deployment and cost and benefit analysis, drawing on the impact assessment support study.[105]

The baseline scenario has been developed using the PRIMES-TREMOVE model by E3Modelling. PRIMES-TREMOVE has a successful record of use in the Commission's energy, transport and climate policy assessments. In particular, it has been used for the impact assessments underpinning the 'Fit for 55' package, the impact assessments accompanying the 2030 Climate Target Plan[106] and the Staff Working Document accompanying the Sustainable and Smart Mobility Strategy[107], the Commission's proposal for a Long Term Strategy[108] as well as for the 2020 and 2030 EU's climate and energy policy framework.

ITS deployment has been assessed by Ricardo in the context of the impact assessment support study. ASTRA and TRUST are the main models used to assess the impacts of the policy options presented in this impact assessment, drawing on the ITS deployment. The assessment with the ASTRA and TRUST models has been undertaken by TRT. For the baseline scenario ASTRA and TRUST models have been calibrated on the results of the PRIMES-TREMOVE model.

PRIMES-TREMOVE model

The PRIMES-TREMOVE transport model projects the evolution of demand for passengers and freight transport, by transport mode, and transport vehicle/technology, following a formulation based on microeconomic foundation of decisions of multiple actors. Operation, investment and emission costs, various policy measures, utility factors and congestion are among the drivers that influence the projections of the model. The projections of activity, equipment (fleet), usage of equipment, energy consumption and emissions (and other externalities) constitute the set of model outputs.

The PRIMES-TREMOVE transport model can therefore provide the quantitative analysis for the transport sector in the EU, candidate and neighbouring countries covering activity, equipment, energy and emissions. The model accounts for each country separately which means that the detailed long-term outlooks are available both for each country and in aggregate forms (e.g. EU level).

In the transport field, PRIMES-TREMOVE is suitable for modelling *soft measures* (e.g. eco-driving, labelling); *economic measures* (e.g. subsidies and taxes on fuels, vehicles,

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[105] Ricardo et al. (2021), Impact Assessment Support Study for the revision of the Intelligent Transport System Directive (2010/40/EU), Study contract no. MOVE/B4/SER/2020-230
[106] SWD/2020/176 final.
[107] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020SC0331
[108] https://ec.europa.eu/clima/sites/clima/files/docs/pages/com_2018_733_analysis_in_support_en_0.pdf

emissions; ETS for transport when linked with PRIMES; pricing of congestion and other externalities such as air pollution, accidents and noise; measures supporting R&D); *regulatory measures* (e.g. CO_2 emission performance standards for new light duty vehicles and heavy duty vehicles; EURO standards on road transport vehicles; technology standards for non-road transport technologies, deployment of Intelligent Transport Systems) and *infrastructure policies for alternative fuels* (e.g. deployment of refuelling/recharging infrastructure for electricity, hydrogen, LNG, CNG). Used as a module that contributes to the PRIMES model energy system model, PRIMES-TREMOVE can show how policies and trends in the field of transport contribute to economy-wide trends in energy use and emissions. Using data disaggregated per Member State, the model can show differentiated trends across Member States.

The PRIMES-TREMOVE has been developed and is maintained by E3Modelling, based on, but extending features of, the open source TREMOVE model developed by the TREMOVE[109] modelling community. Part of the model (e.g. the utility nested tree) was built following the TREMOVE model.[110] Other parts, like the component on fuel consumption and emissions, follow the COPERT model.

Data inputs

The main data sources for inputs to the PRIMES-TREMOVE model, such as for activity and energy consumption, comes from EUROSTAT database and from the Statistical Pocketbook "EU transport in figures[111]. Excise taxes are derived from DG TAXUD excise duty tables. Other data comes from different sources such as research projects (e.g. TRACCS project) and reports.

In the context of this exercise, the PRIMES-TREMOVE transport model is calibrated to 2005, 2010 and 2015 historical data. Available data on 2020 market shares of different powertrain types have also been taken into account.

ASTRA model

ASTRA is a strategic model based on the Systems Dynamics Modelling approach simulating the transport system development in combination with the economy and the environment until the year 2050.

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[109] Source: https://www.tmleuven.be/en/navigation/TREMOVE

[110] Several model enhancements were made compared to the standard TREMOVE model, as for example: for the number of vintages (allowing representation of the choice of second-hand cars); for the technology categories which include vehicle types using electricity from the grid and fuel cells. The model also incorporates additional fuel types, such as biofuels (when they differ from standard fossil fuel technologies), LPG, LNG, hydrogen and e-fuels. In addition, representation of infrastructure for refuelling and recharging are among the model refinements, influencing fuel choices. A major model enhancement concerns the inclusion of heterogeneity in the distance of stylised trips; the model considers that the trip distances follow a distribution function with different distances and frequencies. The inclusion of heterogeneity was found to be of significant influence in the choice of vehicle-fuels especially for vehicles-fuels with range limitations.

[111] Source: https://ec.europa.eu/transport/facts-fundings/statistics_en

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 (e.g. GDP, input-output tables, employment, consumption and investment both at aggregate and at sectoral level)
- 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 by segment and drivetrain)
- Environment (including air pollutant emissions, CO_2 emissions, energy consumption).

The economy module simulates the main 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, 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 ASTRA model. For instance, the economy module provides the level of income to the fleet module, in order to estimate vehicle purchase. The economy 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 immediately feed into changes of the transport behaviour and alter origins, destinations and volumes of European transport flows.

The indicators that ASTRA can produce cover a wide range of impacts; in particular transport system operation, economic, environmental and social indicators. 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.

Strategic assessment capabilities in ASTRA cover a wide range of transport measures and investments with flexible timing and levels of implementation.

Geographically, ASTRA covers all EU Member States plus United Kingdom, Norway and Switzerland. The model is built in Vensim software and is developed and maintained by TRT, M-Five and ISI Fraunhofer.

Data inputs

ASTRA is calibrated on the EUROSTAT database and data from the Statistical Pocketbook "EU transport in figures[112]. In the context of this exercise, ASTRA model is calibrated on historical data for 2000-2015.

TRUST model

TRUST is a European scale transport network model developed and maintained by TRT and simulating road, rail, inland waterways and maritime transport activity. TRUST covers the whole Europe and its neighbouring countries and it allows for the assignment of passenger and freight origin-destination (OD) matrices at NUTS3 level of detail (about 1600 zones) on the multimodal transport network[113].

Road rail, inland waterways and maritime transport modes are covered in separate modules, each with its own matrices that are then assigned simultaneously on the multimodal transport network.

TRUST is built in PTV-VISUM software environment. The assignment algorithm used is Equilibrium Assignment which distributes demand for each origin/destination pair among available alternative routes, according to Wardrop first principle. This principle assumes that each traveller is identical, non-cooperative and rational in selecting the shortest route, and knows the exact travel time he/she will encounter. If all travellers select routes according to this principle the road network will be at equilibrium, such that no one can reduce their travel times by unilaterally choosing another route of the same OD pair. This principle has been extended to consider generalised travel cost instead of travel time, where generalised travel cost can include the monetary cost of in-vehicle travel time, tolls, parking charges and fuel consumption costs. The impedance function is defined in terms of generalised time from an origin O to a destination D. Travel costs are defined separately by link types using combinations of fixed, time-dependent and distance-dependent parameters. Travel time is estimated endogenously by the model as result of the assignment. Speed-flow functions are used to model the impact of traffic on free-flow speeds, given links capacity. The model iterates until a pre-defined convergence criterion for equilibrium is reached.

TRUST can be used in the context of impact assessments and for supporting policy formulation and evaluation. It is particularly suitable for modelling road charging schemes for cars and heavy goods vehicles as well as policies in the field of infrastructure.

Data inputs

The main data sources for inputs to the TRUST model are the EUROSTAT database and the Statistical Pocketbook "EU transport in figures[114], TENtec Information system[115] and ETISplus database.

[112] Source: https://ec.europa.eu/transport/facts-fundings/statistics_en
[113] Further information on TRUST is available on http://www.trt.it/en/tools/trust/
[114] Source: https://ec.europa.eu/transport/facts-fundings/statistics_en
[115] https://ec.europa.eu/transport/themes/infrastructure-ten-t-connecting-europe/tentec-information-system_en

ITS deployment

For assessing the level of ITS deployment an excel tool has been developed, which implies several steps. First, ***ITS service types have been grouped into a series of service bundles*** to which common deployment assumptions for the baseline and each policy option are applied. The process for developing the service bundles was informed by the extensive literature review and consultation with stakeholders.

Table 32: ITS service bundles

Service bundle	ITS Services types	Rationale	Service end-users
Bundle 1a: Information and booking services for travellers	• Multimodal travel information service (including linking between modes) • Multimodal travel information and booking/re-selling service (MaaS)	ITS services focused on providing dynamic travel information and booking services to support journeys carried out by travellers.	Active modes, micro mobility, public transport, car users, taxis
Bundle 1b: Information and booking services for drivers	• Travel information service / Road traffic information & navigation services • Real-time traffic information service • Parking (and pricing) information • Re-charging/re-fuelling location and pricing information	ITS services focused on providing dynamic travel information and booking services to support journeys carried out by drivers. Delivered via smartphone and/or in-vehicle systems.	Car users, public transport, taxis, trucks
Bundle 2: Travel management services	• (Enhanced) Traffic network and incident management systems • Mobility management services	ITS services supporting mobility, network and traffic management by road operators and transport authorities.	Car users, trucks, taxis, public transport (active modes)
Bundle 3: Road safety and security (excluding C-ITS)	• SRTI service • S&S truck parking location information and reservation system • eCall (current scope only)	ITS services (non-C-ITS) intended to create safety and security benefits	Car users, trucks, active modes, taxis (public transport)
Bundle 4: Vehicle-to-vehicle (V2V) C-ITS	• V2V C-ITS (e.g. Emergency electronic brake light & Hazardous location notification)	Day 1 V2V services, with strong safety benefits. Applicable to all road types.	Active modes, car users, trucks, taxis
Bundle 5: Vehicle-to-Infrastructure (V2I) C-ITS	• V2I C-ITS (e.g. Shockwave damping, In-vehicle speed limits & Weather conditions, GLOSA & Signal violation)	Day 1 V2I services that deliver a range of benefits, with a particular focus on traffic efficiency.	Car users, public transport, trucks, active modes, taxis
Bundle 6: Future C-ITS services	• C-ITS cooperative perception services (day 2) and automation support services (day 3) –	Longer term C-ITS services (2030+).	Car users, trucks, taxis, public transport etc.

Note: Bundles 4 and 5 consider a hybrid communication approach.

In a second step, ***differences between Member States are assessed by considering a country grouping***. Member States are grouped into three categories: ‘Front Runner’, ‘Planned Adopter’, or ‘Follower’, which are based on their technology and institutional levels of ITS deployment. Several indicators have been used to develop an overall ranking for each Member State:

- **Involvement in ITS deployment projects.** This is based on the count of project involvement for each Member State, normalised by country population size and ranked (where 1 is greatest project involvement. A list of C-ITS projects was collected as part of past studies[116,117] and expanded to include ITS projects in the context of the impact assessment support study.

- **National Access Point (NAP) status.** This is based on an analysis of EU EIP A2 Annual NAP Report 2019 and latest list of NAPs (14th January 2021) providing the status of NAPs for S&S truck parking, SRTI, RTTI, and MMTIS. Scores were assigned to each country depending on the level of deployment. The status of deployment of datasets for NAPs were ordered from highest (e.g. operational) to lowest (e.g. no information or not operational) and scores allocated respectively. Scores were then combined for each type of NAP (i.e. SRTI and RTTI) and a final ranking was calculated, where 1 stands for the most advanced NAP status.

- **Level 2 and 3 ITS deployment.** Based on the analysis provided by the CEDR TEN-T 2019 Performance Report on the distribution of ITS levels for each Member State, an assessment of Level 2[118] and 3[119] ITS deployment has been undertaken. The combined deployment level has then been ranked, where 1 stands for the highest proportion of ITS deployment of Levels 2 & 3.

- **C-ITS hybrid ITS station deployment.** The share of TEN-T corridor/core network equipped with C-ITS hybrid infrastructure has been derived from a comprehensive analysis of existing and forthcoming C-ITS deployment projects across Europe and building on the dataset developed in the context of previous studies[120,121]. A ranking of 1 stands for greater levels of road network coverage.

The table below presents the ranking for each of the indicators, including the total score and the assigned country grouping. A lower score denotes more advanced levels of deployment. The cut-off points between the groupings have been selected based on both step changes in scores and comparisons with other studies. They have also been validated by stakeholder feedback.

Table 33: ITS assessment indicators and country groupings

Country	ITS projects	NAP Status	ITS L2 & L3 deployment	C-ITS deployment	Total score	Grouping
France	13	3	2	2	20	Front Runner
Netherlands	4	10	2	4	20	Front Runner
Slovenia	3	10	5	6	24	Front Runner
Finland	2	6	10	9	27	Front Runner
Czech Republic	9	10	5	5	29	Front Runner
Austria	8	3	17	3	31	Front Runner
Germany	16	3	6	8	33	Front Runner
Sweden	5	10	12	7	34	Front Runner
Belgium	15	16	4	1	36	Planned Adopter
Denmark	6	10	14	11	41	Planned Adopter
Spain	10	10	9	15	44	Planned Adopter

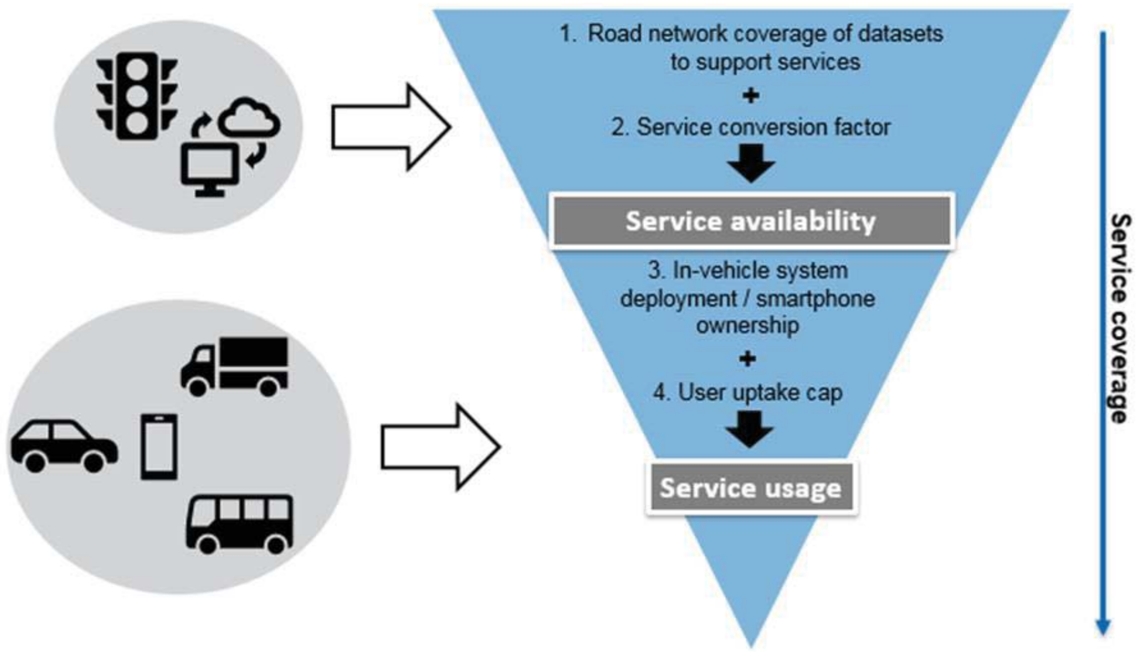
116 Ricardo et al. (2016), Study on the Deployment of C-ITS in Europe: Final Report.
117 Ricardo et al. (2019), Support study for Impact Assessment of C-ITS.
118 Traffic information system (road administration passively manages the network e.g. information about traffic/weather conditions is provided to road users).
119 Traffic management system (road administration actively manages)
120 Ricardo et al. (2016), Study on the Deployment of C-ITS in Europe: Final Report.
121 Ricardo et al. (2019), Support study for Impact Assessment of C-ITS.

Country	ITS projects	NAP Status	ITS L2 & L3 deployment	C-ITS deployment	Total score	Grouping
Luxembourg	1	3	20	24	48	Planned Adopter
Italy	18	3	19	14	54	Planned Adopter
Portugal	11	25	10	10	56	Planned Adopter
Greece	7	17	17	17	58	Planned Adopter
Hungary	26	10	15	12	63	Planned Adopter
Estonia	26	14	13	24	78	Follower
Croatia	12	19	24	24	79	Follower
Lithuania	26	19	11	24	80	Follower
Poland	21	19	16	24	80	Follower
Ireland	26	14	18	24	83	Follower
Malta	26	26	7	24	83	Follower
Romania	17	23	24	24	88	Follower
Bulgaria	19	21	24	24	89	Follower
Cyprus	26	21	24	24	96	Follower
Latvia	26	24	24	24	98	Follower
Slovak Republic	26	26	24	24	100	Follower

Source: Ricardo et al. (2021), Impact Assessment support study

In the third step, the ***ITS deployment rates are estimated.*** The aggregate impact of policy measures in each policy option on the ITS deployment is estimated in this step. This also takes into account the deployment dependencies of each service. In addition to deployment dependencies, other factors considered include: the type of service (i.e. C-ITS), whether they are mature services or not, and their primary targeted geographic deployment areas (motorways, urban).

Figure 18 Graphic explaining how ITS services usage is estimated in the modelling



The deployment level takes into account both the availability of the ITS service (driven by data availability/accessibility) and the uptake by the end-user. The projections for the ITS and C-ITS data network coverage are combined with a service conversion factor to estimate the extent of roads along which ITS services are available. Different infrastructure uptake rates are considered for different road types and between country groupings. Data on the total road network length by road type from the TRUST model road network for the EU27 has been used to this end.

The uptake by the end-user considers the use of smartphones by drivers or travellers and/or the penetration of in-vehicle systems into new vehicles. The use of smartphones by drivers can cover service penetration into both new and existing vehicle fleet for Bundles 1b to 3, but services are assumed to only be deployed into new vehicles via in-vehicle systems for Bundles 4, 5 and 6[122]. These values are combined with an end-user uptake limit to reflect that not all travellers and drivers who could use an ITS service will actually use it. In the OPC, citizens were asked about the reasons for not using ITS services. The majority (42 of 75 responses) stated that they do not know which systems are available for each situation, while just under half (31 of 75 responses) noted they have concerns about privacy and re-use of personal data. Other challenges identified include limited added value, ease of use/access, and concerns about the security of the system. Different uptake rates for passenger cars, heavy goods vehicles and buses are considered, based on differences in decision making on whether to use a service. User uptake rates between country groupings are assumed to be the same.

In the fourth step, the ***ITS deployment scenarios are combined with the primary impact data*** for different ITS services to calculate the percentage improvements over time. The primary impact data for different ITS services covers:

- The reduction in fuel consumption;
- The reduction in air pollution emissions;
- The reduction in the accident rates;
- The reduction in travel time.

The assumptions on primary impact and cost data are provided in section 5 of Annex 4.

In the final step, the percentage improvements over time are used in the ASTRA and TRUST modelling framework to derive the impacts of the policy options.

The services in Bundle 1a (Information and booking services for travellers) are treated slightly differently to the other bundles as the impacts are realised at the individual traveller level, rather than at a vehicle level. For this bundle, impacts on travel time and cost are provided separately, although these impacts are combined with the impacts from other bundles in the ASTRA and TRUST models.

As explained above, since a number of ITS service types have similar functionality, multiple services are likely to overlap and be applicable to the same driving situations. The approach for accounting for the overlaps between services, in order to avoid double-counting impacts, is described in section 6 of Annex 4.

[122] Penetration rates of ITS services are applied on new or existing vehicles by vehicle age.

2. BASELINE SCENARIO

In order to reflect the fundamental socio-economic, technological and policy developments, the Commission prepares periodically an EU Reference Scenario on energy, transport and GHG emissions. The socio-economic and technological developments used for developing the baseline scenario for this impact assessment build on the latest "EU Reference 2020 scenario" (REF2020)[123]. The same assumptions have been used in the MIX scenario underpinning the impact assessments accompanying the 'Fit for 55' package.

Main assumptions of the Baseline scenario

The main assumptions related to economic development, international energy prices and technologies are described below.

Economic assumptions

The modelling work is based on socio-economic assumptions describing the expected evolution of the European society. Long-term projections on population dynamics and economic activity form part of the input to the model and are used to estimate transport activity.

Table 34: Projected population and GDP growth per Member State

	Population			GDP growth	
	2020	2025	2030	2020-'25	2026-'30
EU27	447.7	449.3	449.1	0.9%	1.1%
Austria	8.90	9.03	9.15	0.9%	1.2%
Belgium	11.51	11.66	11.76	0.8%	0.8%
Bulgaria	6.95	6.69	6.45	0.7%	1.3%
Croatia	4.06	3.94	3.83	0.2%	0.6%
Cyprus	0.89	0.93	0.96	0.7%	1.7%
Czechia	10.69	10.79	10.76	1.6%	2.0%
Denmark	5.81	5.88	5.96	2.0%	1.7%
Estonia	1.33	1.32	1.31	2.2%	2.6%
Finland	5.53	5.54	5.52	0.6%	1.2%
France	67.20	68.04	68.75	0.7%	1.0%
Germany	83.14	83.48	83.45	0.8%	0.7%
Greece	10.70	10.51	10.30	0.7%	0.6%
Hungary	9.77	9.70	9.62	1.8%	2.6%
Ireland	4.97	5.27	5.50	2.0%	1.7%
Italy	60.29	60.09	59.94	0.3%	0.3%
Latvia	1.91	1.82	1.71	1.4%	1.9%
Lithuania	2.79	2.71	2.58	1.7%	1.5%
Luxembourg	0.63	0.66	0.69	1.7%	2.0%
Malta	0.51	0.56	0.59	2.7%	4.1%
Netherlands	17.40	17.75	17.97	0.7%	0.7%
Poland	37.94	37.57	37.02	2.1%	2.4%
Portugal	10.29	10.22	10.09	0.8%	0.8%
Romania	19.28	18.51	17.81	2.7%	3.0%
Slovakia	5.46	5.47	5.44	1.1%	1.7%
Slovenia	2.10	2.11	2.11	2.1%	2.4%
Spain	47.32	48.31	48.75	0.9%	1.6%
Sweden	10.32	10.75	11.10	1.4%	2.2%

[123] https://ec.europa.eu/energy/data-analysis/energy-modelling/eu-reference-scenario-2020_en

Population projections from Eurostat[124] are used to estimate the evolution of the European population, which is expected to change little in total number in the coming decades. The GDP growth projections are from the Ageing Report 2021 by the Directorate General for Economic and Financial Affairs, which are based on the same population growth assumptions. [125]

Beyond the update of the population and growth assumptions, an update of the projections on the sectoral composition of GDP was also carried out using the GEM-E3 computable general equilibrium model. These projections take into account the potential medium- to long-term impacts of the COVID-19 crisis on the structure of the economy, even though there are inherent uncertainties related to its eventual impacts. Overall, conservative assumptions were made regarding the medium-term impacts of the pandemic on the re-localisation of global value chains, teleworking and teleconferencing and global tourism.

International energy prices assumptions

Alongside socio-economic projections, transport modelling requires projections of international fuel prices. The 2020 values are estimated from information available by mid-2020. The projections of the POLES-JRC model – elaborated by the Joint Research Centre and derived from the Global Energy and Climate Outlook (GECO[126]) – are used to obtain long-term estimates of the international fuel prices.

The COVID crisis has had a major impact on international fuel prices[127]. The lost demand cause an oversupply leading to decreasing prices. The effect on prices compared to pre-COVID estimates is expected to be still felt up to 2030. Actual development will depend on the recovery of global oil demand as well as supply side policies[128].

The table below shows the international fuel prices assumptions of the baseline and policy options of this impact assessment.

Table 35: International fuel prices assumptions

in $'15 per boe	2000	‘05	‘10	‘15	‘20	‘25	‘30	‘35	‘40	‘45	‘50
Oil	38.4	65.4	86.7	52.3	39.8	59.9	80.1	90.4	97.4	105.6	117.9
Gas (NCV)	26.5	35.8	45.8	43.7	20.1	30.5	40.9	44.9	52.6	57.0	57.8
in €'15 per boe	2000	2005	‘10	‘15	‘20	‘25	‘30	‘35	‘40	‘45	‘50
Oil	34.6	58.9	78.2	47.2	35.8	54.0	72.2	81.5	87.8	95.2	106.3
Gas (NCV)	23.4	31.7	40.6	38.7	17.8	27.0	36.2	39.7	46.6	50.5	51.2

Source: Derived from JRC, POLES-JRC model, Global Energy and Climate Outlook (GECO)

Technology assumptions

124 EUROPOP2019 population projections: https://ec.europa.eu/eurostat/web/population-demography-migration-projections/population-projections-data

125 The 2021 Ageing Report : Underlying assumptions and projection methodologies https://ec.europa.eu/info/publications/2021-ageing-report-underlying-assumptions-and-projection-methodologies_en

126 https://ec.europa.eu/jrc/en/geco

127 IEA, Global Energy Review 2020, June 2020

128 IEA, Oil Market Report, June 2020 and US EIA, July 2020.

Modelling scenarios is highly dependent on the assumptions on the development of technologies - both in terms of performance and costs. For the purpose of the impact assessments related to the "Climate Target Plan" and the "Fit for 55" policy package, these assumptions have been updated based on a rigorous literature review carried out by external consultants in collaboration with the JRC[129].

Continuing the approach adopted in the long-term strategy in 2018, the Commission consulted on the technology assumption with stakeholders in 2019. In particular, the technology database of the PRIMES-TREMOVE model (together with PRIMES, GAINS, GLOBIOM, and CAPRI) benefited from a dedicated consultation workshop held on 11th November 2019. EU Member States representatives also had the opportunity to comment on the costs elements during a workshop held on 25th November 2019. The updated technology assumptions are published together with the EU Reference Scenario 2020. The same assumptions have been used in the context of this impact assessment.

Policies in the Baseline scenario

The policies included in the Baseline scenario build on the MIX scenario framework underpinning the impact assessments accompanying the 'Fit for 55' package, relying on a combined approach of carbon pricing instruments and regulatory-based measures to deliver on the ambition of at least 55% emissions reductions by 2030 and climate neutrality by 2050.

In the context of this impact assessment, the Baseline scenario excludes the revision of the TEN-T Regulation and other policy initiatives supported by it (e.g. the forthcoming revisions of the Intelligent Transport Systems Directive, Rail Freight Corridors Regulation, Combined Transport Directive)[130].

The Baseline scenario assumes no further EU level intervention beyond the current ITS Directive. It assumes the continuation of the application of the ITS Directive provisions and the preparation of standards for the already defined priority areas. It also covers:

- The existing ITS activities such as regional and national deployment projects (e.g. C-Roads and ITS corridors) which are expected to result in important ITS deployment at regional level, although with poor coverage of services, low levels of interoperability and no widespread adoption.
- Industry announcements and identified trends around ITS deployment.

The policy measures reflected in the MIX scenario, relevant for the transport sector, are summarised below:

- Extension of the EU ETS to the maritime sector, as well as to the road transport and buildings sectors;

[129] JRC118275

[130] In the context of the MIX scenario the revision of the TEN-T Regulation, the revision of the Intelligent Transport Systems Directive, the revision of the Rail Freight Corridors Regulation and of the Combined Transport Directive were represented in a stylised way, ahead of the adoption of the specific legislative proposals.

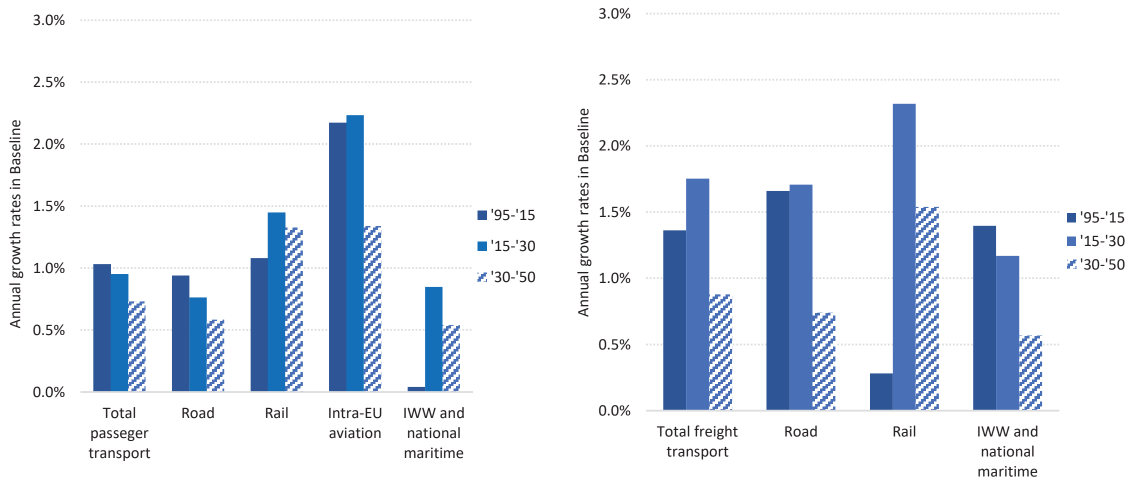
- Revision of the Renewable Energy Directive;
- ReFuelEU aviation and FuelEU maritime initiatives;
- Revision of the Directive on alternative fuels infrastructure;
- Gradual internalisation of external costs ("smart" pricing);
- Incentives to improve the performance of air navigation service providers in terms of efficiency and to improve the utilisation of air traffic management capacity;
- Further actions on clean airports and ports to drive reductions in energy use and emissions;
- Measures to reduce emissions and air pollution in urban areas;
- Pricing measures such as in relation to energy taxation and infrastructure charging;
- Revision of roadworthiness checks;
- Other measures incentivising behavioural change;
- Medium intensification of the CO_2 emission standards for cars, vans, trucks and buses (as of 2030), supported by large scale roll-out of recharging and refuelling infrastructure. This corresponds to a reduction in 2030 compared to the 2021 target of around 50% for cars and around 40% for vans.

These policies come in addition to other EU level policies and the National Climate and Energy Plans, included in the Reference scenario 2020 and also reflected in the MIX scenario. The full list of policies included in the Reference scenario 2020 is provided in the Reference scenario publication.

Baseline scenario results

EU transport activity would continue to grow in the Baseline scenario by 2030 and by 2050, albeit at a slower pace than in the past. This is despite the significant impact of COVID pandemic on transport activity. Freight transport activity for inland modes (expressed in tonne-kilometres) would increase by 30% between 2015 and 2030 (1.8% per year) and 55% for 2015-2050 (1.3% per year). Passenger traffic (expressed in passenger-kilometres) growth would be lower than for freight with a 15% increase by 2030 (1% per year) and 33% by 2050 (0.8% per year). The annual growth rates by mode, for passenger and freight transport, are provided in Figure 19.

Figure 19: Passenger and freight transport activity in the Baseline scenario (average growth rate per year)



Source: Baseline scenario, PRIMES-TREMOVE transport model (E3Modelling)
Note: For aviation, domestic and international intra-EU activity is reported, to maintain the comparability with reported statistics.

Road transport would maintain its dominant role within the EU. The share of road transport in inland freight would remain relatively stable by 2030 and slightly decrease by 2 percentage points by 2050. For passenger transport, road modal share is projected to decrease by 2 percentage points between 2015 and 2030 and by additional 2 percentage points by 2050. Passenger cars would still contribute 71% of passenger traffic by 2030 and more than two thirds by 2050, despite growing at lower pace relative to other modes.

Rail transport activity is projected to grow significantly faster than for road, driven in particular by the assumed completion of the TEN-T core network by 2030 and of the comprehensive network by 2050, supported by the CEF, Cohesion Fund and ERDF funding, but also by the measures of the 'Fit for 55' package that increase the competitiveness of rail relative to road transport and air transport. Passenger rail activity is projected to go up by 24% by 2030 relative to 2015 (62% for 2015-2050). High speed rail activity would grow by 68% by 2030 relative to 2015 (155% by 2050), missing however to deliver on the milestone of the Sustainable and Smart Mobility Strategy of doubling the traffic by 2030 and tripling it by 2050. Freight rail traffic would increase by 41% by 2030 relative to 2015 (91% for 2015-2050) also missing to deliver on the milestone of the Sustainable and Smart Mobility Strategy of increasing the traffic by 50% by 2030 and doubling it by 2050.

Domestic and international intra-EU air transport would grow significantly (by 39% during 2015-2030 and 82% by 2050) following the recovery from the COVID-19 pandemics, although at lower pace than projected in the past. The lower growth is also driven by the measures of the 'Fit for 55' package.

Transport activity of inland waterways and national maritime also benefits from the completion of the TEN-T core and comprehensive network and would grow by 19% during 2015-2030 and by 33% by 2050. When considering all short sea shipping, waterborne transport activity (inland waterways and short sea shipping) would grow by 19% by 2030 and 44% by 2050 missing however to deliver on the milestone of the Sustainable and Smart Mobility Strategy of increasing activity by 25% by 2030 and by 50% by 2050.

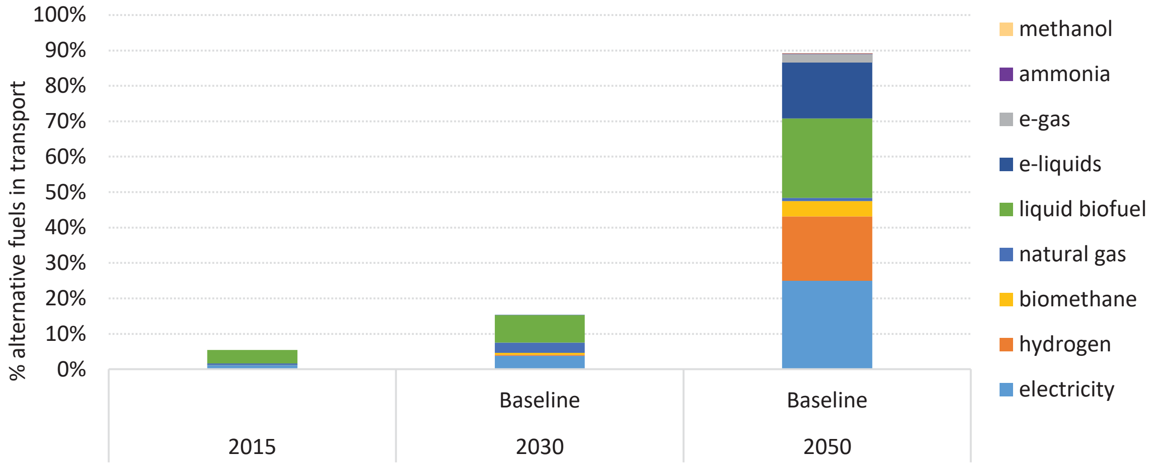
Total energy use in transport, including international aviation and international maritime, is projected to decrease by 9% between 2015 and 2030 and by 42% by 2050, which in the context of growing activity shows the projected progress in terms of energy efficiency driven also by the measures of the 'Fit for 55' package. These developments are mainly driven by the CO_2 emission performance standards for new light duty and heavy duty vehicles, supported by the roll-out of recharging and refuelling infrastructure and also by the shift towards more energy efficient modes such as rail and waterborne transport.

Alternative fuels[131], including renewable and low carbon fuels, are projected to represent over 15% of transport energy demand (including international aviation and maritime transport) in the Baseline scenario by 2030 and around 89% by 2050.

Electricity use in transport would steadily increase over time as a result of uptake of zero and low-emission powertrains in road transport and further electrification of rail. Its share in the total energy use in transport would go up from around 1.2% in 2015 to close to 4% in 2030 and 25% in 2050. The uptake of hydrogen would be facilitated by the uptake of fuel-cell powertrains in road transport and the FuelEU initiative for the maritime transport, supported by the increased availability of refuelling infrastructure, and is projected to represent slightly over 18% of energy use in transport by 2050. Around 8% of all transport fuels in 2030 would be of biological origin, going up to close to 27% by 2050. Finally, hydrogen-based fuels (e-liquids, e-gas, methanol and ammonia) would provide another 18% for the transport fuel mix by 2050.

[131] According to the Directive 2014/94/EU, 'alternative fuels' refer to fuels or power sources which serve, at least partly, as a substitute for fossil oil sources in the energy supply to transport and which have the potential to contribute to its decarbonisation and enhance the environmental performance of the transport sector. They include, inter alia: electricity, hydrogen, biofuels, synthetic and paraffinic fuels, natural gas, including biomethane, in gaseous form (compressed natural gas (CNG)) and liquefied form (liquefied natural gas (LNG)), and liquefied petroleum gas (LPG).

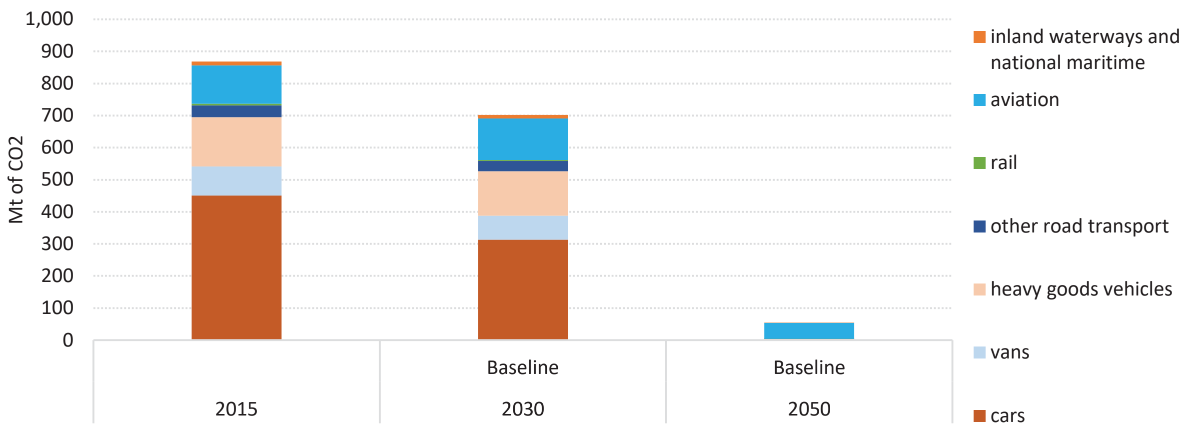
Figure 20: Share of alternative fuels used in transport (including international aviation and maritime) in the Baseline scenario



Source: Baseline scenario, PRIMES-TREMOVE transport model (E3Modelling)

CO_2 emissions from transport including international aviation but excluding international maritime, are projected to be 19% lower by 2030 compared to 2015, and 94% lower by 2050.

Figure 21: CO2 emissions from transport (including international aviation but excluding international maritime) in the Baseline scenario



Source: Baseline scenario, PRIMES-TREMOVE transport model (E3Modelling)

Compared to 1990, this translates into 1% emission reductions by 2030 and around 90% by 2050. When accounting the intra-EU aviation and intra-EU maritime in the transport emissions, the Baseline projections show reductions of 21% by 2030 and 97% by 2050 relative to 2015. When all intra-EU and extra-EU aviation and maritime emissions are accounted in the transport emissions, the Baseline scenario results in 17% decrease in transport emissions by 2030 and 93% decrease by 2050 compared to 2015 levels.

NOx emissions are projected to go down by 56% between 2015 and 2030 (87% by 2050), mainly driven by the electrification of the road transport and in particular of the light duty vehicles segment. The decline in **particulate matter** (PM2.5) would be slightly lower by 2030 at 52% relative to 2015 (91% by 2050).

As explained above, the Baseline scenario in the ASTRA and TRUST models are calibrated to the results of the PRIMES-TREMOVE model.

ITS deployment in the Baseline scenario

As explained above, the **ITS deployment** is estimated from projections on service availability and end-user uptake. The level of service availability (expressed as portion of road network covered) is calculated applying a service conversion factor [132] to the estimated availability of relevant datasets along the road network.

The uptake of services by users is then considered, which accounts for the ability of users to access services (i.e. smartphone ownership) and a user uptake factor that recognises other aspects causing travellers and drivers to not use ITS services. These may include concerns over data privacy, service applicability, or even an awareness that the service exists or acknowledgement of the benefits of using specific ITS services.

Service availability

The availability of the services for each ITS service bundle is estimated from the data coverage and a service conversion factor. Depending on the ITS service bundle a range of sources has been used to capture the level of network coverage while the relevant conversion factors have been determined in consultation with stakeholders. The relevant information for each bundle is provided below:

- For **Bundle 1b** covering information and booking services for drivers, the data coverage estimations for RTTI data sets are used[133]. In 2021, data coverage for Front Runner countries is estimated at 72% for TEN-T roads, 47-52% across other motorways and urban roads, and significantly lower for other inter-urban roads (16%). Coverage is estimated to be lower for the other two country groupings.

- For **Bundle 1a** (information and booking services for travellers), **Bundle 2** (Travel management services) and **Bundle 3** (Road safety and security applications), data coverage is based on the RTTI data and adjusted according to the respective statuses of MMTIS and SRTI dataset availability in NAPs across EU27 as reported in the EU EIP A2 Annual NAP Report[134] and latest list of NAPs (14th January 2021)[135].

  - Bundle 1a: In 2021, data coverage for Front Runner countries is estimated at 66% for TEN-T and urban roads, 48% across other motorways and 12% for other inter-urban roads.

  - Bundle 2: In 2021, data coverage for Front Runner countries is estimated at 44% for TEN-T roads, 30-31% across other motorways and urban roads, and 7% for other inter-urban roads.

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132 The probability that the availability of data lead to development of services utilizing them.
133 VVA et al. (2020), Supporting study on activities 3.2, 3.3 and 3.4 of the new working programme of the ITS Directive.
134 EU EIP, 2019. *EU EIP A2 Annual NAP Report*
135 https://ec.europa.eu/transport/sites/default/files/its-national-access-points.pdf

- Bundle 3: In 2021, data coverage for Front Runner countries is estimated at 75% for TEN-T roads, 55% across other motorways and urban roads, and 14% for other inter-urban roads.

- For **Bundle 4** (vehicle-to-vehicle C-ITS services), the availability of services is assumed to be linked to the deployment of in-vehicle systems, which is covered in the end-user uptake assumption layer.

- For **Bundle 5** (vehicle-to-infrastructure C-ITS services), data coverage across the road network is estimated from a review of existing C-ITS deployment activities and the portion of TEN-T road network along which infrastructure supporting hybrid C-ITS has been deployed. In 2021, network coverage for Front Runner countries is estimated at 19% for TEN-T roads, 3% for urban roads and 0% for other inter-urban roads. Coverage is estimated to be lower for the other two country groupings.

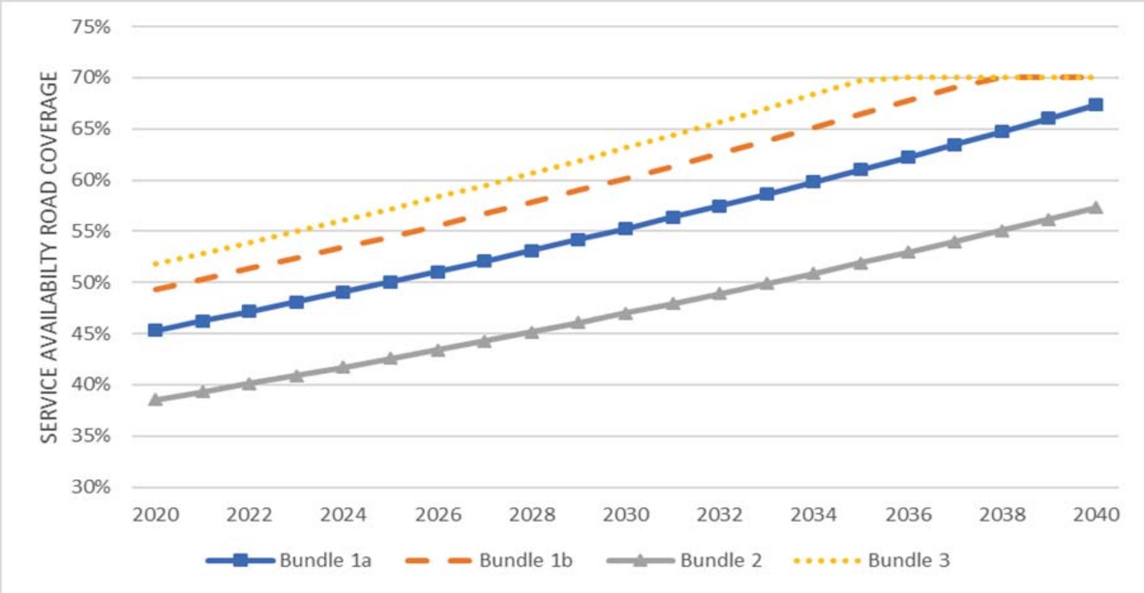
An annual increase in data coverage of 2% for **Bundle 1a-3** is assumed under the baseline[136], while for **Bundle 5**, the rate of deployment estimated between 2015 and 2020 is projected until 2023 and then assumed to be constant (25% for TEN-T roads in Front Runner countries), in line with the end date of most current deployment projects. To date, deployment of C-ITS services has been relatively slow and fragmented across the EU owing largely to the large investment costs required and the uncertainty due to a lack of coordinated infrastructure and vehicle deployments. In absence of further EU level intervention, it is projected that the progress on infrastructure deployment, data generation and sharing and stakeholder coordination will stall, although maintenance of existing units is assumed.

A service conversion factor of 0.7 is assumed for **Bundles 1a, 1b and 3**, while for **Bundle 2**, a higher factor of 0.9 is assumed due to the closer alignment between the data collection and service provision by stakeholders. The service conversion factors were presented and validated with stakeholders during the 3rd workshop that took place on 19th January 2021.

Figure 22 below shows the expected development of service availability in the baseline for **Bundles 1 to 3**, on the basis of the data availabilities and a 0.7 service conversion factor. It represents service availability along TEN-T roads, which are assessed to display the highest levels of deployment across all road type. In Bundle 1a, service availability in urban roads is estimated to be equal to TEN-T roads while in the other bundles, service availability reduces across other motorways and interurban roads. The figure represents service availability in Front Runner countries only. The level of coverage is estimated to be 10% lower for Planned Adopters and 20% lower for Followers.

136 VVA et al. (2020), Supporting study on activities 3.2, 3.3 and 3.4 of the new working programme of the ITS Directive.

Figure 22: Baseline service availability across TEN-T roads in Front Runner countries



Source: Ricardo et al. (2021), Impact Assessment support study

End-user uptake

The end user uptake of each service bundle determines the conversion of service availability to final service usage. This is estimated on the basis of the level of in-vehicle system deployment and/or smartphone ownership (depending on the bundle) and an end user uptake factor. A combination of sources has been used to estimate the evolution of smartphone ownership among the travellers and drivers who could use ITS services[137, 138, 139, 140].

As shown in Figure 23 a sharp increase in smartphone ownership is expected until 2025 followed by a levelling off in the following years and a maximum value of roughly 97% by 2040.

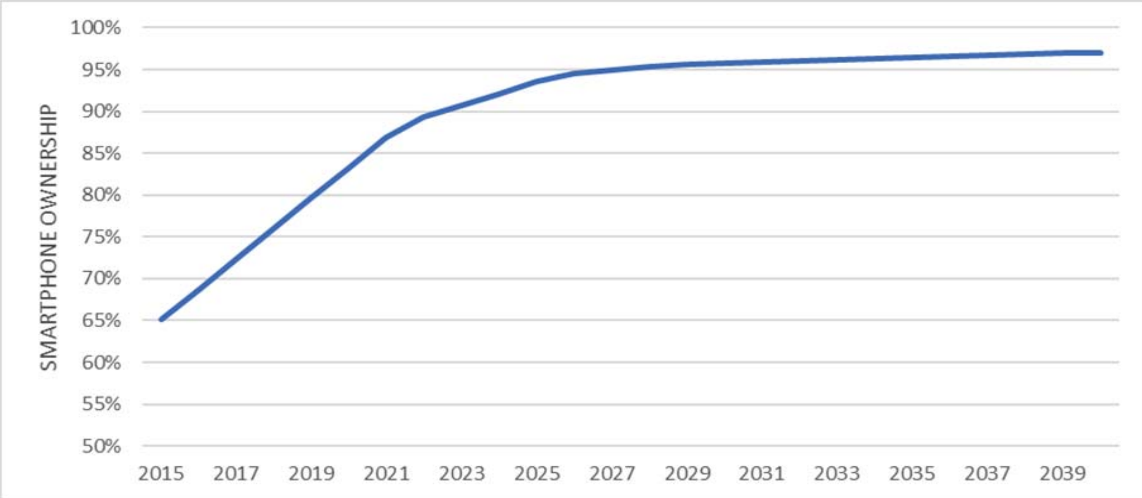
[137] Anderson, M. P. A., 2017. *Technology use among seniors.* [Online] Available at: http://www.pewinternet.org/2017/05/17/technology-use-among-seniors/ [Accessed 01 05 2021]

[138] Ricardo Energy & Environment, 2018. *Safety of life study,* s.l.: 5GAA.

[139] Eurostat, 2020. *Being young in Europe today - digital world.* [Online] Available at: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Being_young_in_Europe_today_-_digital_world [Accessed 20 05 2021]

[140] Silver, L., 2019. *Smartphone Ownership Is Growing Rapidly Around the World, but Not Always Equally.* [Online] Available at: https://www.pewresearch.org/global/2019/02/05/smartphone-ownership-is-growing-rapidly-around-the-world-but-not-always-equally/ [Accessed 15 06 2021]

Figure 23: Projection of smartphone ownership among potential ITS users



Source: Ricardo et al. (2021), Impact Assessment support study

The capability of passenger cars to support ITS services (excluding C-ITS) is assumed to be aligned with the cellular connectivity of new vehicles. Available sources indicate this could go up from 46% in 2018 to 100% by 2022.[141,142]

Bundle 1a can be supported by smartphones only, **Bundles 1b, 2 and 3** can be supported by smartphones and connected vehicles, while **Bundles 4 and 5** can only be supported by dedicated in-vehicle C-ITS systems.

The assumptions used for estimating the end user uptake are provided below:

- For **Bundle 1a** (information and booking services for travellers), end-user access to services is based on the proportion of total travellers with a smartphone.
- For Bundle 1b (information and booking services for drivers) and Bundle 3 (Road safety and security applications), the maximum value between smartphone and in-vehicle system projections is used to determine end-user access to ITS services in new cars. Smartphone ownership is assumed to drive ITS access in the existing passenger car fleet. Uptake is fixed at 90% for public transport and freight vehicles reflecting the greater penetration of connected devices in these vehicles and more rational and commercially minded decision making behind whether to utilise a service that will bring safety and efficiency benefits.
- For **Bundle 2** (Travel management services), uptake by the driver is assumed to be passive and so user uptake is fixed at 100% across both new and existing vehicles.
- For **Bundles 4 and 5**, end user uptake is derived from assumptions on deployment of in-vehicle systems in new vehicles only. In the baseline, deployment in new vehicles reaches 100% in 3 full model cycles (7 years for passenger cars and 9 years for heavy goods vehicles and buses), starting from 2019. No aftermarket uptake of C-ITS services (**Bundle 4 and 5**) is assumed. A study on the feasibility

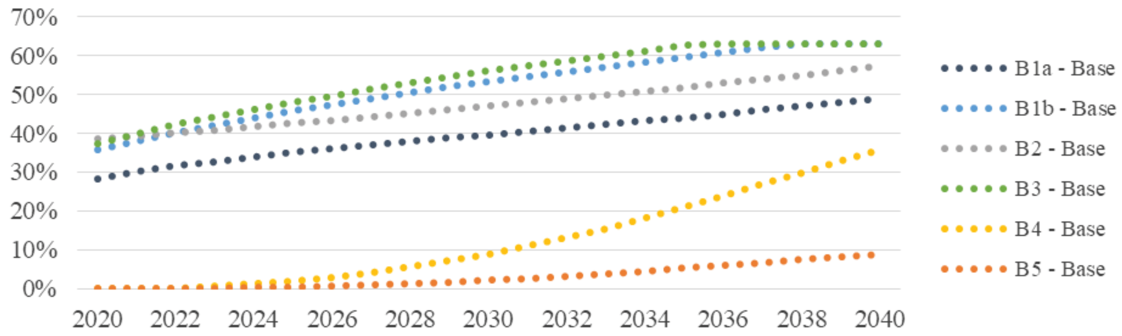
[141] Data Task Force, 2020. *Data Task Force - Final report & recommendations*
[142] Ricardo Energy & Environment, 2018. *Safety of life study,* s.l.: 5GAA.

of retrofitting for Advanced Driver Assistance Systems (ADAS)[143] shows very low retrofit shares in the baseline in the total European fleet (0.2-0.4%). These services can only be supported by in-vehicle systems and not by smartphones.

- A service uptake cap factor of 0.8 is also applied to end-user uptake in passenger cars for **Bundles 1b and 3.** For Bundle 1a, the uptake cap factor is 0.7, reflecting the lower uptake rate of multimodal service among travellers.

Figure 24 presents the estimated service usage in the baseline for a combination of country grouping, road and user types, which represent the upper range of service usage. Services in Bundles 1-3 start from a higher level of usage in 2021 compared to C-ITS services (Bundles 4-5) that depend on the continued roll out of dedicated infrastructure and deployment of equipped vehicles, which takes time. For bundle 6 no service usage is project and for bundle 1a geographical scope is urban roads, rather than TEN-T.

Figure 24: Overall service usage in the baseline of each service bundle – for Front Runner countries across TEN-T roads



Source: Ricardo et al. (2021), Impact Assessment support study

3. ASSUMPTIONS ON THE ITS DEPLOYMENT IN THE POLICY OPTIONS

This section provides the detailed assumptions on service availability and end user uptake in the policy options relative to the baseline. The information supporting the data inputs and assumptions comes from the findings of a literature review, but feedback from stakeholders as part of surveys, interviews and workshops has also been used to develop, test validate the assumptions.

Service availability

The tables below present the service availability deployment assumptions for the policy options, namely the data coverage and the service conversion.

Table 36: Data coverage in the policy options

PO1	PO2	PO3
Link with the measures of the policy options		
Increased interoperability of data (where available) for emerging services due to standards development in new priority areas	PO1 + Increased availability of data due to mandates for data sharing and quality for MMTIS, RTTI and S&S truck parking services	PO2 + Improved accessibility of in-vehicle data due to standard development

[143] VTT, ECORYS, 2020. *Study on the feasibility, costs and benefits of retrofitting advanced driver assistance to improve road safety*, s.l.: European Commission

(i.e. multimodal services, traffic/mobility management, CCAM) No direct impact on data availability Increased availability of in-vehicle data due to common access requirements		
Impact on deployment		
• Bundles 1, 2 – annual coverage increase rate rises to 2.5% • Bundle 3 – annual coverage increase rate rises to 3% post-2025 for TEN-T and post-2030 for other roads • Bundle 4 - same as baseline • Bundle 5 – from 2023, deployment projected at 25% of deployment rate between 2015 and 2023	• Bundle 1 – coverage reaches 100% by 2028 for TEN-T and 2030 for other roads • Bundle 2 - same as PO1 • Bundle 3 – reaches half of the gap from PO2 to 100% by 2030 and other roads increase annual increase rate to 3% post-2025 • Bundle 4 - same as baseline • Bundle 5 – Same as PO1	• Bundle 1 & 2 - same as PO2 • Bundle 3 – coverage reaches 100% by 2030 for TEN_T and other roads same as PO2 • Bundle 4 - same as baseline • Bundle 5 – from 2023, deployment projected at the same rate as deployment rate between 2015 and 2023. For other roads project at 50% the rate of TEN-T.

Table 37: Service conversion in the policy options

PO1	PO2	PO3
Link with the measures of the policy options		
Small improvement due to streamlined interaction with ITS stakeholders Services deployment unblocked due to GDPR/ePrivacy alignment and C-ITS Trust model Improvement in services development as ITS stakeholders are more involved in implementation. Small uptake in development of services relying on in-vehicle data due to improved transparency and increased support of business due to C-ITS Trust model	PO1 + Small improvement in services deployment due to better data sharing through NAP coordination institutionalisation	PO2 + Increased deployment of services due to SRTI and Day 1 C-ITS services mandate
Impact on deployment		
• Bundles 1 & 3 - increase 5 p.p. to 75% • Bundle 2 - same as Baseline • Bundle 4 & 5 – enhanced deployment in vehicles (see user uptake assumptions)	• Bundles 1 & 3 – 100% service conversion for TEN-T and 90% for other roads, 2 years after full coverage of data accessibility. • Bundle 2 - same as Baseline	• Bundles 1 & 3 - same logic applied as in PO2 • Bundle 2 - same as Baseline

End-user uptake

End-user uptake assumptions determine whether end-users are able to use an available service, and accounts for a likelihood of whether they would use the service. In the OPC, the biggest barrier for citizens using ITS services have been identified as being: not knowing which systems are available in a given a situation, followed by concerns on the use of personal data and the ease of use of systems. For Bundle 1a, the assumptions cover uptake by travellers not limited to driving, while for all other bundles, uptake is based on assumed penetration of ITS services into the vehicles, either via in-vehicle systems or smartphones. Different uptake rates for passenger cars, heavy goods vehicles and buses are considered, but the uptake rates between country groupings are assumed to be the same. Table 38 presents the end-user uptake assumptions for the policy options.

Table 38: End-user uptake in the policy options

PO1	PO2	PO3
Link with the measures of the policy options		
Increase in user uptake due to GDPR, ePrivacy and passenger rights alignment Small increase for C-ITS services due to improved trust (C-ITS trust model) Further increase use of C-ITS due to C-ITS trust model institutionalisation	Same as PO1 No direct impact on user uptake - second order effect as a result of improved services availability and effectiveness	Same as PO1 No direct impact on user uptake - second order effect as a result of improved services availability and effectiveness
Impact on deployment		
• Bundles 1 & 3 - for cars the user uptake cap increases +5p.p to 85% in 2025. For freight/PT, uptake fixed at 90% • Bundle 2 – Same as baseline • Bundles 4 & 5 - All new vehicles equipped in 2 full model vehicle cycles	• Bundles 1 & 3 – for cars, the user uptake cap increases further +5p.p. to 90% in 2025. For freight/PT, uptake fixed at 90% • Bundle 2 – Same as baseline • Bundles 4 & 5 - same as PO1	• Bundles 1 & 3 same as PO2 • Bundle 2 – Same as baseline • Bundles 4 & 5 - all new vehicles equipped in 2 vehicle facelift cycles (4 years for cars and 5 years for freight/buses)

The usage increase over time of all service bundles in all policy options is presented in the following three figures:

Figure 25: Figure 8: Service usage of information and booking bundles in front runner countries across policy options

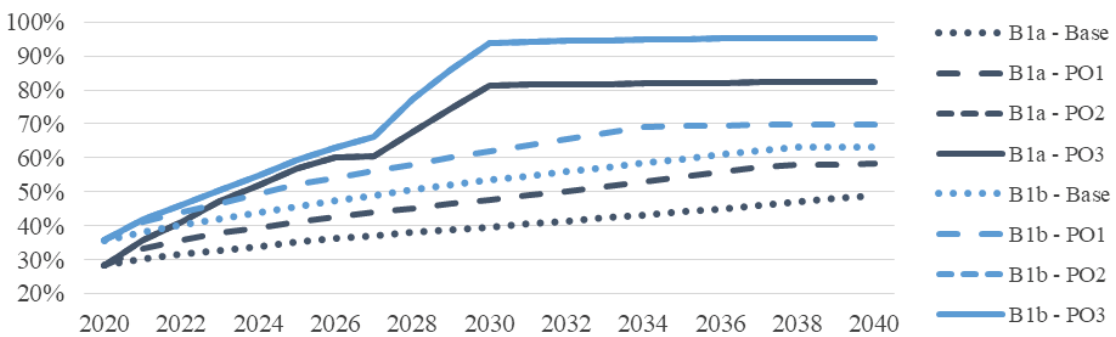


Figure 26: Service usage of travel management and road safety bundles in front runner countries across policy options

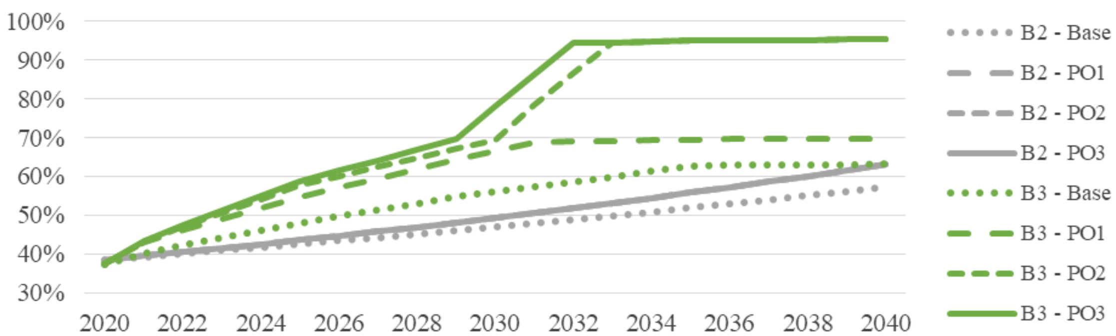
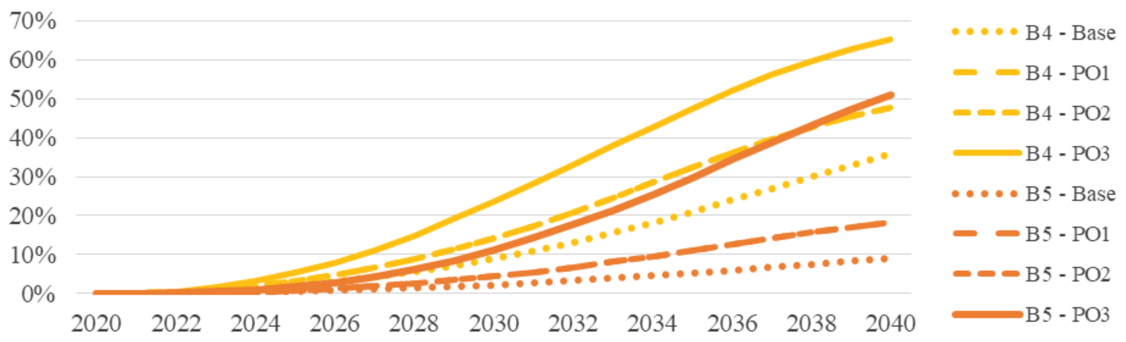


Figure 27: Service usage of C-ITS bundles in front runner countries across policy options



4. Assumptions on ITS service cost data

This section provides the assumptions for the ITS technology and service costs, which are an important component of the cost-benefit analysis. The cost data collected for the 2016 and 2019 C-ITS studies has been used as a starting point and has been reviewed and expanded for costs related to broader ITS services.

The hardware and associated software and services used to deliver ITS services can be broadly categorised into:

1. **Smartphones**, which support the use of most ITS services by individuals in the transport system. Smartphones can support the deployment of services among travellers and in new and existing vehicles. The functionality of using smartphones in vehicles is increasing with many manufacturers offering smartphone integration technologies such as ‘mirroring’.
2. **In-vehicle systems**, which are fitted by the vehicle manufacturer and are attached to the vehicle communication buses to enable cellular and/or direct communications that support the delivery of C-ITS services to drivers. It is assumed there is no aftermarket uptake of C-ITS services (Bundle 4 and 5). A study on the feasibility of retrofitting for Advanced Driver Assistance Systems (ADAS) showed very small shares of retrofitting in the total European fleet (0.2-0.4%) (DG MOVE, 2020).
3. **Roadside ITS infrastructure** such as RSUs, VMSs, sensors, cameras, and smart traffic lights, which generate and collect data to be used for ITS services, facilitate the delivery of ITS services and enable communications between vehicles and the road infrastructure supporting V2I C-ITS services.
4. **Central ITS systems**, which may be part of a centralised traffic management system and include NAPs. These systems can support ITS services for an entire city, road operator, or national highway system etc.

For each of them, the following cost categories are considered:

- Upfront costs, i.e. one-off costs incurred at the point of installation/commissioning.
- Ongoing costs, i.e. the recurring costs associated with operating each sub-system.

- Equipment lifetime, to establish the need to account for replacement costs within the lifetime of the cost-benefit analysis (2015 to 2040).

- The cost owner, to enable an estimation of the impact of different cost items on the various key stakeholders in the deployment of C-ITS services.

Building on the cost data available for C-ITS service, the EU EIP evaluation reports on each of the 5 European funded corridors were reviewed; Arc Atlantique II, Crocodile, MedTIS, Next ITS, Ursa Major. Cost data was also extracted from the support study on activities 3.2, 3.3 and 3.4 of the new working programme of the ITS Directive (Tavares, 2020) and the C-MOBILE ex-ante cost-benefit analysis (C-MOBILE, 2018).

Technology Learning Rates

Many systems deployed to support the rollout of ITS services are at a relatively early stage of maturity and costs are likely to improve over time. To account for this, a learning rate of 15% is applied to all up-front costs for in-vehicle and roadside ITS sub-systems, where for every doubling in installed volume, up-front costs reduce by 15%. These learning rates are based on an analysis of low CO_2 technologies performed by the US EPA and NHTSA (US EPA, NHTSA, 2012) and account for feedback received from experts as part of the 2019 C-ITS study (Ricardo, 2019).

To avoid a strong decrease in costs due to the step increase in units in early years, starting volumes have been defined for vehicles and RSUs. Only when these starting volumes are reached, learning rates begin to apply. For vehicles the starting volume is set to 30 million units. For roadside ITS infrastructure the starting volume is set to 30,000 units. Before the starting volumes are reached, a uniform 2% annual reduction is assumed (Analysys Mason, 2017).

Smartphones

Smartphones serve as the end-user interface to deliver an ITS service, applicable to several of the service bundles considered in this impact assessment. Smartphones owned by the user will require a specific app (developed by the ITS service provider) and cellular connection in order to use the ITS service in question.

Route navigation services may be delivered through other personal ITS devices, such as personal navigation devices (PNDs), although current market trends suggest that smartphones are the principle device used by consumers for such services[144] and this market share is expected to increase even further with the continued development of applications and the roll-out of 5G. Therefore, in this impact assessment, drawing on the impact assessment support study, it has been assumed that ITS services on personal devices will only be delivered though smartphones.

In the future, technically, it is possible that smartphone devices will be able to access vehicle data and be used to support secure communications for C-ITS services (Bundle 4 and 5) but in this impact assessment it is assumed that C-ITS services can only be delivered

[144] https://www.euspa.europa.eu/system/files/reports/market_report_issue_6_v2.pdf

via in-vehicle systems. There are examples today of smartphones supporting similar services to those offered by C-ITS, but these are classified in Bundle 3 as SRTI services.

Smartphone related costs are considered in Bundles 1A, 1B, 3.

A summary of the upfront and ongoing costs associated with smartphones is included in the table below. These are discussed in more detail in the following sections including sources of cost data, applicability to bundles and deployment dependencies.

Table 39: Breakdown of costs for smartphones

	Cost item	Input	Unit	Cost owner	Relevant bundles
Upfront costs	Equipment	€0	Per smartphone	End-user	1A, 1B, 3
	App cost	€0	Per smartphone	End-user	1A, 1B, 3
	App development	€500,000	Per app platform	App developer	1A, 1B, 3
Ongoing costs (per year)	Data	€0	Per smartphone	End-user	1A, 1B, 3
	App subscription	€0	Per smartphone	End-user	1A, 1B, 3
	Software updates	20% capex (i.e. €100,000)	Per app platform	App developer	1A, 1B, 3

Upfront costs

Equipment and app cost

In the cost-benefit analysis for this impact assessment, the upfront costs associated with end-users are assumed to be zero. That is, the cost for equipment (i.e. smartphone) and the upfront cost for the app. It is assumed that end-users will already be in possession of a smartphone, thus it does not represent an additional cost.

Concerning the cost to download ITS apps, a free model has been assumed. In this business model, an application is developed and maintained by an app developer who bears the cost, although they may be supported by a public body or OEM. There will be no upfront fee to download the app and no subscription fees to access the service. The funding body of the applications may choose to recoup some of its costs through e.g. allowing advertising within the app.

It should be noted that there are also other business models available, such as a subscription-based model or app store/online marketplace-based model, in which the latter would incur an upfront cost. However, analysis of the current market shows that the top four navigation apps, accounting for 98% of the market, all employ a free model[145]. There is a possibility that as these apps incorporate new features and become more complex, a cost may be incurred either through a subscription or upfront cost. However, in absence of such information, it has been assumed that the upfront cost for all smartphone apps will be zero throughout the time period considered in the assessment.

App development

Upfront app development costs are borne by the app developer, which could be either a private ITS service provider or a public body such as a road authority. The costs for developing smartphone apps vary considerably depending on the nature of the app. In this

[145] https://themanifest.com/mobile-apps/popularity-google-maps-trends-navigation-apps-2018

impact assessment, up-front app development costs are assumed to be €500,000 per app in line with the C-ITS deployment study (Ricardo, 2019). This reflects the upper end of app development costs reflecting the technical complexity, communications compatibility and scale that would be required. This value is in line with estimated app development costs given by COMeSafety 2 and Score@F project as well as general online website resources[146].

While there may be a number of individual platforms developed initially, it is expected that these will be merged together in the future, with several operating in multiple Member States depending on the nature of the service. In this impact assessment, it is assumed that there will be a maximum of one major app for each Member State (27 in total) and that a new app will be developed for each relevant service bundle. It is assumed that the number of service platforms developed scales linearly with the service availability. Thus, for every 3.7% (100%/272) service availability, one app will be required.

<u>Ongoing costs</u>

Concerning end-users, there are two types of ongoing costs associated with ITS smartphone services, both of which have been assumed to be zero in this assessment:

- **Subscription fees**: As discussed above, no annual subscription fees is assumed for the use of the ITS smartphone application, as all services are assumed to be provided for free by road authorities and private service providers. It is recognised that some MaaS platforms have a subscription model however, this fee would typically provide access to various transport modes and so is not an additional cost (and may actually represent a cost saving). For users who are regularly using public transport and other services, the MaaS platform serves as convenience rather than having an impact on the end user cost. In the absence of reliable information on the costs of MaaS subscriptions and to what extent they represent a cost or a cost saving, it has been assumed that the subscription cost will be roughly equal to the traveller costs and thus the same as in the baseline.
- **Data**: Use of C-ITS applications in smartphones will require the user to transmit and receive additional data via the cellular network. However, in this assessment it is assumed that the cost of data will already be included in the end-user's mobile phone contract and thus does not represent an additional cost. There is already an increasing trend for smartphone users to increase their data plans[147], which is expected to be large enough to cover the data usage for ITS in the majority of cases.

For app developers, ongoing costs are expected for the ongoing operation and maintenance of their apps, as well as research and development to improve their service and provide necessary software updates. Other costs include monitoring, engagement and marketing. These costs combined are assumed to be 20% of the upfront costs, with sources indicating that 15-20% represents the industry norm[148].

[146] https://www.velvetech.com/blog/how-much-mobile-app-cost/
[147] https://www.ericsson.com/en/mobility-report/articles/shifting-mobile-data-consumption-data-plans
[148] https://www.businessofapps.com/app-developers/research/app-development-cost/

In-vehicle systems

In-vehicle systems are fitted by the vehicle manufacturers and are attached to the vehicle communication buses. These can enable both V2V communications and V2I along suitably equipped roads, as well as acting as the user interface for ITS services. Retrofitted vehicle ITS sub-systems are not considered and these costs are only relevant for new vehicles.

In the assessment it is assumed that in-vehicle systems support hybrid communications (both cellular and direct) in line with a technology neutral approach to service delivery. The same cost is applied to each vehicle type i.e. passenger vehicles, freight vehicles, and public transport.

A simple business model is assumed in the assessment, whereby costs are only included for the additional equipment/software required to deliver ITS services in new vehicles. Additional up-front equipment, installation and software development costs are included at cost price (i.e. OEM costs), whilst a number of additional ongoing costs are incurred by both the OEM and end-user.

Some of the costs assumed to be incurred by the OEMs will eventually be passed on to the consumer through applying a mark-up (for example the NHTSA study assumes a 51% mark-up between OEM cost and consumer price on all vehicle components (Harding, 2014) and such a cost will often be included in the cost of the new vehicle.

A summary of the upfront and ongoing costs associated with in-vehicle systems is included in the table below. These are discussed in more detail in the following sections including sources of cost data, applicability to bundles and deployment dependencies.

Table 40: Breakdown of costs for in-vehicle systems

	Cost item	Input	Unit	Cost owner	Relevant bundles
Upfront costs	Hardware, installation, integration, and licensing	€288	Per vehicle	OEM	4, 5
	Software development	€500,000	Per model	OEM	4, 5
Ongoing costs	Maintenance	5% of equipment costs	Per vehicle	End-user	4, 5
	Secure Communications	€2.36	Per vehicle	End-user	4, 5
	Data / app subscription	€0	Per vehicle	End-user	4, 5
	Software updates	€100,000	Per model	OEM	4, 5

Upfront costs

Hardware, installation, integration, and licencing

To enable ITS services based on a hybrid communication approach (that supports both cellular and direct communications), a number of in-vehicle components are required, including: two transmitter/receivers, two antennas, an electronic control unit, and additional wiring. Two antennas and transmitter/receivers are assumed to be necessary – one will be used to send and receive basic safety messages, whereas the other will be required for the security aspects of V2X communication, such as receiving certificates and certificate revocation lists (NHTSA, 2014). The breakdown of costs, expressed in 2015 prices, are provided in the table below and followed by a more detailed description.

Table 41: Breakdown of costs included in hardware, installation, integration and licencing

Cost	Value (€)
Transmitter/receiver	160.0
Antenna	12.3
Electronic Control Unit	55.4
Wiring	11.1
On-board cellular equipment	12.3
Installation	8.5
Integration	28.5
Total	288.1

The equipment costs used in this assessment draw on the C-ITS Deployment study. There are different technologies that support direct communication (e.g. DSRC and PC5), but the costs are assumed to be similar (Ricardo Energy & Environment, 2020) and no distinction is made between them. Equipment costs that are not included in the assessment are the in-vehicle screen GPS costs. Although each of these are necessary to enable the delivery of an ITS service, 97% of new vehicles are equipped with GPS systems already[149] and the majority of OEMs are already including in-vehicle screens. Thus, in the assessment it is assumed that all new vehicles have them in place and therefore do not represent an additional cost.

Installing the additional equipment in vehicles also has implications in terms of labour costs.

Integration costs include activities such as linking the equipment required to receive and process the signals for C-ITS services to the rest of the vehicle's safety and other systems and carrying out all safety and functionality testing required for certification.

These costs are only applicable to Bundle 4 and Bundle 5. However, given that the equipment only needs to be installed once to enable C-ITS communication (both V2V and V2I), the cost applies once per vehicle. The costs outlined above apply to each vehicle equipped and therefore will scale with vehicle deployment.

Software development costs

Software must be developed to support a range of ITS services, i.e. the software to process the incoming/outbound signals and to decide what to do with them, before sending further signals to the vehicle's CAN bus to request responses from various vehicle systems (e.g. displays, avoidance manoeuvres, etc.).

The initial software development costs would be approximately €1mn per model, based on a team of ten engineers working for a year to develop the software (BMW, 2014). Software could be shared to some extent across different vehicle models, due to significant overlap between the software deployed to different vehicle models from the same OEM. However, the differing complexity of different categories of vehicles (e.g. A-category versus E-

[149] https://www.euspa.europa.eu/system/files/reports/market_report_issue_6_v2.pdf

category) would mean that individual vehicle models would still incur approximately 50% of the total development costs described above. Hence, in the assessment the figure of €500,000 per model has been assumed for each OEM. This figure has been transformed into a cost per vehicle using the number of vehicles sold and the number of models per OEM, accounting for a 4-year facelift cycle.

These costs are only applicable to Bundle 4 and Bundle 5. However, given that the same software will be used for V2V and V2I (excluding minor updates) the cost applies once per vehicle i.e. the cost is not duplicated for Bundles 4 and 5. The costs outlined above apply to each vehicle equipped and therefore will scale with vehicle deployment.

Ongoing costs

Ongoing costs for end-users are composed of maintenance, secure communications, data and application costs and OEM development of in-vehicle software:

- The additional equipment installed to support C-ITS services in new vehicles is likely to lead to incremental maintenance costs above those that would normally be incurred. A maintenance cost equal to 5% of the capital cost of ITS equipment per year is assumed in this assessment. It is assumed that this cost is borne by the vehicle end-user.
- A secure communications management system is necessary for vehicles to provide and receive secure and trusted communications. The cost of secure communications was estimated in the C-Mobile report to be €2.36 per vehicle per year (C-MOBILE, 2018). It is assumed that this cost is borne by the vehicle end-user.
- The cost of data to enable hybrid communications is estimated to be €2.49 in the C-Mobile report (C-MOBILE, 2018). However, it is unlikely that OEMs will pass this cost on the end-users as the value is minimal and instead will be included in the upfront cost of the vehicle.
- In some cases, OEMs may charge a subscription fee for the software or access to new services. However, no additional software subscription cost has been assumed relative to the baseline as it will be incorporated into the cost of the vehicle.
- A number of studies point to the potential effect of C-ITS services on insurance costs (particularly for safety-focused C-ITS services), however due to the lack of data available to support this assertion, these benefits were not included in the analysis.

Ongoing costs for OEMs are linked to necessary software updates, which are assumed to be 20% of the upfront costs (i.e. €100,000 per year), which is in line with the software updates cost required for smartphones.

Roadside ITS Infrastructure

Roadside ITS infrastructure is necessary for generation of data and delivery of services. It includes equipment such as RSUs, VMSs, sensors, cameras, and smart traffic lights. For the purposes of this assessment, the costs are divided into two main groups:

- **C-ITS Stations (RSUs)** allow V2I communications along specific stretches of roads, most likely deployed at intersections (relevant to Bundle 5). It is assumed that all deployment of ITS stations are new units.

- **Roadside infrastructure (RSI)** encompasses all other infrastructure on the roadside that is required for the generation and collection of data and delivery of ITS services.

It is assumed that the cost of deploying, running and maintaining roadside ITS infrastructure is assigned to relevant public authorities. Deployment and upgrades occur to stretches of road and signalised traffic junctions at a rate determined by service availability in each policy option. In some cases, existing infrastructure will need to be upgraded to ensure that services can be delivered, while in other cases RSI will need to be newly deployed.

Full deployment of C-ITS services is not assumed to require full coverage of RSUs along the whole road network. A hybrid approach combining direct and cellular communication is the approach supported by most stakeholders (Ricardo Energy & Environment, 2020), with RSU deployments focused on hot spot locations where there is high data traffic or a guaranteed level of performance is required. Intersections are locations where C-ITS use cases are typically most safety critical with high performance requirements and so the number of intersections across Europe represents the maximum stock of RSUs with deployment scaling in line with service availability assumptions.

RSI will be needed throughout the road network to ensure that sensors and cameras generate relevant data, and VMS can deliver services to users on the road. The type and scale of RSI varies between bundles and therefore different costs can be expected. However, for simplicity, it has been assumed that each service bundle requires the same type and scale of RSI to ensure delivery of the ITS service.

Costs associated with integrating roadside ITS infrastructure with local traffic controllers are covered in installation costs, while costs associated with integration into central traffic management centres (TMCs) are dealt with separately in the central ITS sub-system category.

A summary of the upfront and ongoing costs associated with roadside ITS infrastructure is included in the table below.

Table 42: Breakdown of costs for roadside ITS infrastructure

	Cost item	Input	Unit	Cost owner	Relevant bundles
Upfront costs	RSU equipment and installation	€14,116	Per RSU	Public body	5
	RSI equipment and installation	€68,104	Per unit	Public body	1A, 1B, 2, 3, 4, 5
	RSI upgrade	€18,151	Per unit	Public body	1A, 1B, 2, 3, 4, 5
Ongoing costs	RSU Maintenance	5% of CAPEX	Per unit	Public body	5
	RSI Maintenance	10% of CAPEX	Per unit	Public body	1A, 1B, 2, 3, 4, 5
	Power consumption	€18.40	Per unit	Public body	1A, 1B, 2, 3, 4, 5
	Data	€100	Per unit	Public body	1A, 1B, 2, 3, 4, 5
	Secure Communications	€37.91	Per unit	Public body	1A, 1B, 2, 3, 4, 5

<u>Upfront costs</u>

RSU equipment and installation

The costs for ITS station equipment and installation were taken from the C-ITS deployment study and updated with inputs from literature. The total upfront cost to install a new RSU capable of delivering C-ITS functionality has been calculated to be €14,116. A breakdown of the costs in presented in the table below, followed by a more detailed description.

Table 43: Breakdown of costs included in RSU installation (in 2015 prices)

Cost	Value (€)
Equipment/hardware	6,617
Installation	7,500
Total	14,117

This is composed of:

- An equipment/hardware cost: The equipment cost for a new roadside ITS sub-system with traffic monitoring sensors is estimated to cost €6,001.2, as reported in the C-Mobile study (C-MOBILE, 2018). This cost is also in line with the C-ITS deployment study, based on stakeholder's interviews, and other EU studies such as SAFESPOT (BASt et al., 2010).
- Installation and mounting costs will vary depending on the complexity of installation. Research shows that a number of activities are typically required for RSU installation and that costs will be highly site (and possibly Member State) dependent. A report by the US DoT (NHTSA, 2014) suggests that in addition to equipment and installation costs, the following activities must be considered:
    - Radio survey per site – to determine optimum placement of the ITS-G5 radio and antenna for maximum coverage
    - Map / GID generation – to accurately map the road layout, especially at intersections
    - Planning – estimated to be 5% of total cost
    - Design – costs related to installation of RSUs in each location
    - System integration and licence – administration costs associated with the new RSU
    - Traffic control – during installation of the unit, including any safety signage
- The C-Mobile report suggests that a simple installation may cost €3,000, whereas a more complex installation would be in the region of €12,000. An average value of €7,500 has been assumed, as in the C-ITS deployment study.

These costs are associated only with Bundle 5 (V2I services). To apply and scale these costs with deployment, an EU stock of 180,000 RSUs is assumed (Wimmershoff, 2011) (on the basis that RSUs will be deployed at intersections only) and distributed among Member States based on country groupings. It is assumed that the number of RSUs deployed scales linearly with the service availability.

RSI Installation and Upgrade

As described above, RSI encompass all roadside infrastructure excluding RSUs, that facilitate the delivery of all ITS services by supporting the collection of road data and bringing all infrastructure into a digital ecosystem. In some cases, the RSI will exist and need to be upgraded and in other cases new deployment is needed. The costs for RSI were determined based on EU EIP evaluation reports and cost data from US DoT[150]. As noted above, service bundles will require different type and scale of RSI deployment to facilitate the delivery of ITS services. This is dependent on several factors, such as nature of the service, existing infrastructure, location and road type. Given the complexity of RSI deployment, individual projects have been analysed and average costs per individual piece of equipment have been used to determine a cost per RSI unit.

The estimated costs for RSI used in this assessment are:

- **Installation of a new unit** is estimated at €68,105. This includes the cost for equipment (€60,605) and the installation costs (€7,500), which is assumed to be the same as RSUs.
- **Upgrade to existing RSI unit** is estimated at €18,151. This figure is estimated to be 25% of new equipment cost (€15,151) and the installation costs are assumed to be €3,000, equal to a 'simple' installation cost of RSUs.

These costs are associated with **all** bundles but only need to be applied once as the RSI will jointly facilitate the provision of all services. In the assessment, the following assumptions on the current status of RSI are made:

- An additional 10% of existing traffic signals need to be deployed, and an additional 100% of the existing other RSI need to be deployed.
- 70% traffic signals exist but require an upgrade, and 25% other infrastructure exist but require an upgrade. (Ricardo Energy & Environment, 2020)

An EU stock of RSI that need to be installed as new and upgraded is calculated based on the assumptions above and the currently installed stock, estimated from a US connected vehicle infrastructure footprint analysis (U.S. DOT, 2014). The number of RSI units deployed and upgraded scales linearly with the service availability.

Ongoing costs

The annual ongoing costs per unit for public authorities are broken down into:

- Regular ITS station maintenance is assumed to be 5% of the capital cost per year. Several studies have cited this percentage for maintenance, such as the COBRA study and US focussed NHTSA US DoT Connected Vehicle Field Infrastructure Footprint Analysis (TNO, 2013) (NHTSA, 2014)
- Regular maintenance for RSI units is assumed to be 10% of the capital cost per year. This is an average based on the EU EIP evaluation reports and Member States National ITS Reports. It is worth noting that the maintenance costs may vary depending on the service provided as noted in the German report that this value is significantly too high

[150] https://www.itskrs.its.dot.gov/costs

for network control systems, while the estimated value applies relatively well for route control systems. However, the same figure is used in the assessment for simplicity.

- Power consumption: In the C-ITS Deployment study, the power consumption cost per year was estimated at **€18.40.** This was derived from stakeholder input.
- Data costs, are based on the COBRA study, and are calculated to be €200 per year, per new roadside ITS sub-system (TNO, 2013). Half this figure has been used (**€100 per year),** to account for the assumption that half of the units will have wired backhaul and therefore do not incur cellular data costs.
- Secure communications: An extensive study was carried out by the US DoT to assess the cost of secure communications. It assumes that a security credentials management system will need to be developed and implemented (most likely by a private company) and suggests an annual cost of $50 per roadside unit to keep security credentials up to date (NHTSA, 2014). This is equivalent to €37.91 per year.

Central ITS sub-systems

A central ITS sub-system is necessary to collect, process, and store mobility data in order to create value and enable the delivery of effective ITS services. Two main components are considered: NAPs and traffic management centres (TMCs).

While NAPs already exist in almost all Member States, it is necessary to upgrade the NAPs to ensure that the data architecture supports the data categories to deliver all types of ITS services. TMCs do not exist throughout all Member States and in some cases new TMCs will need to be developed while other may require upgrading. In addition to the TMC and NAP installation upgrade costs, ongoing costs related to maintenance and data collection and management will also be incurred by public authorities.

Concerning private operators, investment is required to initially develop the backend system (e.g. cloud, service provider platform), as well the ongoing operation and maintenance costs. However, these costs vary significantly between different private operators and collecting specific cost data is difficult and is not representative of all operators. In addition, private operators will take a commercial approach to developing their own systems and will only do so where there is a business case (i.e. balancing their investment with the revenue generated by their services). Therefore, in the assessment only the central ITS sub-system costs relevant to public authorities are considered.

A summary of the upfront and ongoing costs associated with central ITS sub-systems are included in the table below.

Table 44: Breakdown of costs for central ITS sub-systems

	Cost item	Input	Unit	Cost owner	Relevant bundles
Upfront costs	NAP set up	€273,500	Per NAP	Public body	1A, 1B, 2, 3, 4, 5
	TMC installation and integration	€2,500,000	Per TMC	Public body	1A, 1B, 2, 3, 4, 5

	Cost item	Input	Unit	Cost owner	Relevant bundles
	TMC upgrade	€175,000	Per TMC	Public body	1A, 1B, 2, 3, 4, 5
Ongoing costs	NAP Maintenance	€2,000,000	Per NAP	Public body	1A, 1B, 2, 3, 4, 5
	TMC Maintenance	€250,000	Per TMC	Public body	1A, 1B, 2, 3, 4, 5
	Data Collection - MMTIS	€600,000	Per NAP	Public body	1A, 1B
	Data Collection - RTTI	€1,000,000	Per NAP	Public body	1B, 2
	Data Collection - SRTI	€300,000	Per NAP	Public body	2, 3, 4, 5
	Data Collection – S&S Truck Parking	€100,000	Per NAP	Public body	3
	Integration of transport providers on NAP	€17,946	Per NAP	Public body	1A

Upfront costs

NAP set up

Following various EU Delegated Regulations, EU Member States are obliged to set up NAPs to facilitate access, easy exchange and reuse of transport related data, in order to help support the provision of EU-wide interoperable ITS services to end users. Member States are free to decide which form their NAP will take. Across the EU, NAPs can either be databases, data warehouses, data marketplaces (i.e. supported by private providers), repositories, and registers, web portals or similar depending on the type of data concerned. The cost to set up the data architecture is dependent on the NAP approach taken. In the assessment the median value from the evaluation of the ITS Directive of €273,500 has been used.

According to the annual NAP report (EU EIP, 2021), NAPs are operational in most EU Member States for each type of data. In the assessment, the NAP set up cost only applies to those Member States that have not already established an NAP and it is assumed that only one NAP is required to support all service bundles such that the maximum stock is one per MS. The upgrade of NAPs, to consider new data categories or road networks, is considered in the ongoing costs.

TMC Installation and Upgrade

It is assumed that roadside ITS infrastructure will be connected to a TMC. In line with the C-ITS Deployment Study, the two costs relevant to deploying TMCs are the cost for developing a TMC interface for each Member State and an interface to local traffic controllers for roadside ITS infrastructure. Both of these costs combined are estimated to be **€2,500,000,** which includes integration costs.

In some cases, TMCs will already exist but will need to be upgraded to ensure they are at a sufficient operational standard. From the Hungarian ITS report, a modernisation of a TMC was reported to cost approximately **€175,000**. Each TMC may not require the same level of investment, but in the assessment the same value has been assumed for all TMC upgrades.

These costs are associated with **all** bundles but will only need to be applied once as the TMC will jointly facilitate the provision of all services. The following assumptions on the current status of TMCs are made:

- The total number of TMCs needed across Europe equals the number of urban nodes (500), distributed between the country groupings by total road length.
- 15% of the total are fully operational and do not need upgrading. This value is estimated from the current number of core urban nodes divided by the extended number of urban nodes.
- For Front Runners countries, 25% of total TMC stock needs to be installed (75% upgraded), for Planned Adopters 50% of total TMC stock needs to be installed (50% upgraded) and for Followers 75% of total TMC stock needs to be installed (25% upgraded).

The number of TMC units installed and upgraded scaled linearly with service availability.

<u>Ongoing costs</u>

NAP maintenance

NAP Maintenance costs include upgrades to accommodate new or evolving data types, data delivery, data storage and personnel to operate the NAP and fix problems that may arise. The total cost for data storage depends on the penetration of data accessibility on roads and the amount of data to be stored according to the characteristics of each data category. In line with the operating costs of the Italian NAP, this cost has been estimated at **€2,000,000** per NAP. This can be considered as a representative value, despite the fact that the overall operating costs for NAPs vary significantly[151].

TMC Maintenance

The cost for maintaining the TMC back-office and local controller interfaces is estimated at 10% of capital costs based on the COBRA study (TNO, 2013), or **€250,000** per TMC.

Data collection

This cost category considers the additional personnel that would need to be involved in the additional data collection that might be required and the expected costs for making available data accessible in the correct format. The costs were determined from stakeholder input and an assessment of the size of data categories and the respective number of data providers. They are estimated to be:

- MMTIS : **€600,000 per year**

[151] AT reported an operating cost of €10,000 per year while NL reported an operating cost of €10,000,000 per year.

- RTTI : **€1,000,000 per year**
- SRTI : **€300,000 per year**
- S&S truck parking : **€100,000 per year**

Although the data collection is applicable to more than one bundle, each cost will only apply once as the data collection process only occurs once to ensure the data is in the correct format to be used to provide different services. These costs are in line with the cost for operating the Italian NAP, which has a fully operational NAP for all data categories, receiving information from 144 parties that includes bilateral agreements with 14 of them. The total ongoing costs for the NAP was reported at €4,000,000, in line with the estimates used in this assessment (including NAP maintenance). This is assumed to be a middle range value, as NL and AT reported ongoing costs for NAPs of €10,000,000 and €10,000, respectively.

Integration of transport providers on NAP

It is necessary to integrate transport providers on the NAP to facilitate the services that fall under Bundle 1A. Each service provider that is integrated will share data with the NAP in the correct format so that multimodal services can be facilitated. According to stakeholders during the interviews, this typically requires 1-2 person months. For simplicity, it has been assumed that each Member State will employ one person to conduct the integration of transport providers. Hence, the cost is estimated at 1 FTE per NAP, which is equal to €17,946.

5. PRIMARY INPUT DATA

5.1. Bundle 1a- Multimodal travel information service

Service Overview

Multimodal digital mobility (MDM) services provide European travellers with comprehensive door-to-door information allowing for well-informed travel decisions according to their needs. It seamlessly integrates information from different transport modes, based on a strong backbone of rail and local public transport.

The development of MDM services will enable the development of a more efficient transport system; it will widely benefit citizens, as, for example, it is not always easy to get the right information about cross-border transport and connections; it should also allow for the possibility to go for a journey that least affects the environment.

Delegated regulation (EU) 2017/1926 stipulates that each Member State shall set up a NAP, which constitutes a single point of access for users to at least the static travel and traffic data and historic traffic data of different transport modes. This includes modes such as air, high-speed rail, conventional rail, maritime, metro, tram and bus. Such data can be used by either public bodies or private operators to provide the multimodal travel information service to the user.

Impacts

Effective multimodal travel information services are significant for both travellers and operators. Such systems make it easy for travellers to find and use the best means of transport available. They help operators to run their systems and reduce the costs of interacting with travellers. Multimodal travel information services are important for encouraging the use of sustainable transport and for making efficient use of the road system in future. Thus, in addition to providing benefits for travellers and operators, multimodal travel information services can also contribute to high level public policy objectives such as reducing congestion and emissions and improved network management through modal shift away from private car use to public transport and active modes.

In general, there is limited evidence of the impacts of multimodal travel information services, although it is widely accepted that it has a positive effect on congestion and modal shift. The main sources of information for the impacts of this service have been the Study on ITS Directive, Priority Action A: The Provision of EU-wide Multimodal Travel Information Services (TRL, 2016) and a literature review carried out by KiM Netherlands Institute for Transport Policy Analysis (KiM, 2018).

Table 45: Overview of key data source – Study on ITS Directive, Priority Action A: The Provision of EU-wide Multimodal Travel Information Services

The objective of the study overall was to support the European Commission in the development of a policy framework to enable the provision of EU-wide multimodal travel information services. A detailed Cost Benefit Analysis (CBA) was conducted by looking at different scenarios in which different elements of potential policy measures are considered. The assessment took account of the economic, social, environmental, and market impacts that the policy options might have over a 15 year period (2016-2030), with implementation of the different elements phased in over varying timescales. Using input from experts nominated by Member States and existing services, the study identified the implementation and operational costs associated with the key deployment measures.

Safety

The primary effect of Multimodal Travel Information Services is expected to be on congestion/travel time and modal shift; hence the safety impacts are expected to be minimal. No safety impacts are therefore anticipated on an EU level as a consequence of this service and it is not included as part of the model.

Fuel Consumption

The primary effect of Multimodal Travel Information Services is expected to be on congestion/travel time and modal shift; hence the fuel consumption impacts at an individual user / vehicle level are expected to be minimal. However, there might be an impact on fuel consumption at the overall transport system level as a result of modal shift. While this is not included directly in the model, the impact is reflected through the modal shift that is captured in the model.

Emissions

The primary effect of Multimodal Travel Information Services is expected to be on congestion/travel time and modal shift; hence there is an associated emission impacts at an individual user / vehicle level. While this is not included directly in the model at an individual user level, the impact is reflected through the modal shift that is captured in the model.

Congestion/Travel Time

From the study on Provision of EU-wide Multimodal Travel Information Services, a number of assumptions/estimates were made on the improvement of travel time[152]:

- EU-wide journey planning services would enable people travelling across borders to save time while planning their journey; a 10-minute time saving was assumed per trip.
- EU-wide journey planning services with dynamic information would enable people travelling across borders by rail to save time during disrupted trips as in some cases it is possible to revise the journey plan to reduce the impact of disruption. 3% of rail trips were estimated to be disrupted, 20% of these were assumed to be re-planned, with a 30-minute time saving assumed per re-planned trip.
- It was assumed that air passengers would not be in a position to revise their journey plans during disrupted trips and that passengers using other modes would not be in a position to save time in the case of delays of less than 30 minutes.
- It was assumed that improved access to real-time passenger information would result in a 5-minute journey time saving for some delayed ‘infrequent’ bus services (defined here to be those with a headway over 15 minutes). Taking into account the number of bus journeys that are delayed each year and the access to dynamic information via smartphones, it was assumed that 20% of public transport trips were on infrequent services and 30% of these were equipped with real-time information. However, the provision of such information through other channels (such as smartphones) would improve accessibility to a small proportion of users. As such, the 5-minute journey time saving was assumed to be applied to 1% of these trips.

In addition to this, modal integration can decrease the average use travel times and increase urban public transport network efficiency, as shared bikes are used for first and last miles.

Modal Shift

Similarly, the study on Provision of EU-wide Multimodal Travel Information Services made assumptions on the improvement of modal shift for the last leg of the outward journey and first leg of the return journey in cross-border scenarios. The following shifts to more sustainable modes are expected to reduce congestion and emissions and improve air quality:

[152] Please note the main focus of this study was **EU-wide service** and therefore the impacts generally focus on cross-border activities, although not exclusively

- Travelling from airports, 5% of trips were assumed to switch from taxi or hire car to public transport, with an average distance of 10km between airport and final destination.

- Travelling from train stations, 12% of trips were assumed to switch from taxi to public transport with an average distance of 5km between train station and final destination.

There have been a number of private operators that have conducted surveys with their users on their travel behaviour. While serving as a useful indicator for the volume of users that have increased their use of sustainable or active modes, it is often difficult to discern the change in modal share of their journeys. The Austrian research project SMILE, which piloted a multimodal travel information tool that combined new mobility modes with traditional forms of transport, identified behaviour change amongst its users, including:

- 48% respondents increased usage of public transportation (urban public transport 26%, regional public transport 22%)

- 10% increased the use of bike sharing offers while

- 4% increased the usage of e-car sharing as well as another

- 4% increased the usage of e-bike/pedestrians

- Overall, 21% of the surveyed pilot users stated to have reduced the usage of their private car

5.2. Bundle 1a - Multimodal travel information and booking/re-selling service (MaaS)

Service Overview

MaaS is defined as integration of various forms of transport services into a single mobility service accessible on demand. For the user, MaaS can offer added value through use of a single application to provide access to mobility, with a single payment channel instead of multiple ticketing and payment operations. There are several levels of integration for the full definition of MaaS to be met:

- Integration of information (this is the same as MMTIS)

- Integration of booking and payments

- Integration of the services offer (e.g. bundling / subscription) – although certain national legislations have lighter definitions. For example, France define MaaS only as a digital service to enable the integration & selling of mobility services (L'Assemblée nationale, 2019).

A successful MaaS service also brings new business models and ways to organise and operate the various transport options, with advantages for transport operators including access to improved user and demand information and new opportunities to serve unmet demand. The aim of MaaS is to provide an alternative to the use of the private car that may be as convenient, more sustainable, help to reduce congestion and constraints in transport capacity, and potentially more cost effective.

Deployment

Since MaaS was first described in 2014, many mobility initiatives have labelled themselves as MaaS but do not meet all levels of integration. There are limited examples of fully fledged MaaS in Europe - the most notable platforms are UbiGo[153] and Whim[154]. There are many more platforms that provide only some level of integration, but these are increasingly adding a subscription/bundling integration to the platform. However, even if some MaaS initiatives have been piloted across Europe, so far most of them had problems reaching a significant scale and stable business operation, and there is still a lack of a solid MaaS experience replicable at the EU level. Thus, the uptake to date has been slower than expected.

The development of MaaS is dependent on technological, societal, market and governance developments and as such the timeline for wider adoption remains unclear. However, as knowledge on the challenges that are faced by MaaS operators and how to better address them improves, it is expected that most large EU cities will have MaaS by 2025[155].

Impacts

Given that there are only a few cases of fully-fledged MaaS and small-scale pilots, the information on impacts is limited and largely hypothesised. As highlighted earlier, the major impact is modal shift, with secondary impacts expected on congestion / travel time.

Safety

The primary effect of MaaS is expected to be on modal shift, hence the safety impacts are expected to be minimal. Although improvements of traffic safety are sometimes mentioned in literature as potential impact of MaaS[156], it is not seen as one of the major benefits MaaS could offer. No safety impacts are therefore anticipated on an EU level as a consequence of this service and it is not included as part of the model.

Fuel Consumption

The primary effect of MaaS is expected to be on congestion/travel time and modal shift; hence the fuel consumption impacts at an individual user / vehicle level are expected to be minimal. However, there might be an impact on fuel consumption at the overall transport system level as a result of modal shift. While this is not included directly in the model, the impact is reflected through the modal shift that is captured in the model.

Emissions

[153] Operating in two cities in Sweden
[154] Whim operates in five European cities but only offers bundling/subscriptions in one of these services.
[155] From ITS Virtual Congress
[156] https://www.theiet.org/media/3666/mobility-as-a-service-report.pdf

The primary effect of MaaS is expected to be congestion/travel time and modal shift; hence the emission impacts at an individual user / vehicle level are expected to be minimal. However, there might be an impact on emissions at the overall transport system level as a result of modal shift.

Congestion/Travel Time

The potential of MaaS to reduce (single-occupancy) car trips and stimulating a shift towards public, shared and active transport may result in a reduction in traffic congestion. The extent to which MaaS reduces congestion is heavily dependent on the design of the MaaS schemes implemented. In case the deployment of MaaS schemes lead to increased used of car and ride sharing schemes resulting in additional car trips and undesired shifts from public transport, congestion may even stay at the same level or increase[157].

Modal Shift

The main source of impact data is the literature review of MaaS and changes in travel behaviour preferences published by the Dutch Ministry of Infrastructure and Water Management[158]. The study identifies a number of modal shift impacts for each service provided by a given mobility platform. The impacts of each these services are presented below.

Impact of car sharing

The literature review study found that car sharing:

- is accompanied by an average decline in VKT/VMT (Vehicle Kilometres Travelled/Vehicle Miles Travelled) of between 27 and 43% per year. Reducing private car use is less likely to occur in suburban car sharing members than urban car sharing members
- between 9 and 13 privately owned vehicles were taken off the road per (station-based) car-sharing vehicle.

Impact of bike sharing

The literature shows that the impact of bike sharing on shifting private car use is highly contextual. Around 2% of users in London substituted cycling for private car use, which contrasts with rates of between 19-21% in Minneapolis, Melbourne and Brisbane. The study also found that most people who switch to shared bikes come from walking and PT, not from cars. It was found that in Dublin 77% of the total who had switched originally used walking, 16% from bus/tram and the remainder from taxis.

Overall impacts of MaaS

Results of MaaS schemes have shown that:

157 https://www.theiet.org/media/3666/mobility-as-a-service-report.pdf
158 https://www.researchgate.net/publication/330958677_Mobility-as-a-Service_and_changes_in_travel_preferences_and_travel_behaviour_a_literature_review

- In Vienna, 21% of participants reduced their use of private cars
- In Sweden, 44% of UbiGo participants decreased their use of private cars.

The literature review also found an expected increase of 14% and 17% of cycling due to MaaS for regular public transport and car users, respectively. From the regular car users, 12% expects to walk more as part of their trips if MaaS is implemented. As for public transport, there may be a risk that the implementation of MaaS shifts regular cyclists (or pedestrians) to other modes.

5.3. Bundle 1b - Travel Information Service (Road)

Service Overview

Travel information service provides the European traveller with door-to-door information for well-informed travel decisions (pre-trip) using static data. Travel information is offered by both public and private providers. It is therefore necessary to clarify the roles and co-operation of both sides. The future role of road operators as content providers is unclear today. With increasing mobile phone and vehicle tracking, private service providers can be better informed about the traffic situation than the road operator.

Delegated regulation (EU) 2015/962 stipulates that Member States should make available static data (as well as dynamic data and traffic data) through their NAP. This includes data such as physical attributes of the road network, road classification, speed limits, traffic signs reflecting traffic regulations and identifying dangers, and location of tolling stations and tolled roads. Such data can be used by either public bodies or private operators to provide the travel information service to the user either via webpage or smartphone.

Impacts

The main data sources for the impacts of the travel information service were the eSafetyForum Intelligent Infrastructure Working Group's Final Report (eSafetyForum, 2010), the iMobility Effects Database (eSafety and iCarSupport, n.d.) and the TNO report on the impact of information and communication technologies on energy efficiency in the road transport sector (TNO, 2009).

<u>Traffic efficiency</u>

The only report to assess traffic efficiency was the eSafetyForum report. This reported results for three related services: real time event information, real time traffic condition information, and travel time information. All services show a 1-15% reduction in congestion. In the absence of more precise data, the mid-point of this range was used for the modelling, i.e. an 8% improvement in traffic speed for both passenger and freight vehicles, and it has been assumed that the impact is the same across all road types.

<u>Fuel consumption and CO_2</u>

The eSafetyForum report presents results for three services: real time event information, real time traffic condition information, and travel time information, which all show a 1-10% reduction in fuel consumption/CO_2 emissions. Further information about this service is not given and the report does not state whether these are the expected benefits at an EU-level.

In a study performed by TNO on the impact of information and communication technologies on energy efficiency in the road transport sector (TNO, 2009), a service called ‘fuel efficient route choice’ was assessed. This was calculated to have a 2.1% impact on fuel consumption at an EU level. As the emphasis of this service was on maximising fuel efficiency, rather than shortest journey time, the fuel savings benefits are expected to be lower than this value.

Another similar service assessed by TNO is the freight specific, trip departure planning service. The objective of this service is to ensure fleet journey time is minimised, based on real, current and predicted traffic conditions. This is a similar function as the traffic information and smart routing service defined in this report. In the TNO study, the trip departure planning service was estimated to have a 1.8% (reduction) impact on fuel consumption/CO_2 emissions at an EU level, if implemented in all freight vehicles.

Due to limited other data for the traffic information and smart routing service, an average of the figures stated for the two TNO services was used and applied to all vehicles (except public transport) and road types. This gives a 1.95% impact on fuel consumption/CO_2 emissions for passenger and freight vehicles across all road types. This figure is supported by the iMobility Effects Database, which reports a 2% impact on CO_2 emissions at an EU level. (eSafety and iCarSupport, n.d.)

Environmental and emissions impacts

No data was identified for this impact category in the reports reviewed, therefore emissions impacts were scaled using the ratio between fuel/CO_2 impacts and emissions impacts for the in-vehicle speed limit service in urban areas (see section 5.13.2). This resulted in the following impacts on emissions:

- NOx: 0.4% reduction on motorways, 1.7% reduction on other interurban roads, 0.5% reduction on urban roads
- PM: 0.3% reduction on motorways, 0.8% reduction on other interurban roads, 0.1% reduction on urban roads
- CO: 0.2% reduction on motorways, 4.2% reduction on other interurban roads, 2.3% reduction on urban roads
- VOCs: No impact.

Safety

No data was identified for this impact category in the reports reviewed. It is likely that this service could indirectly lead to safety benefits due to reduced driver hesitation and reduced congestion, however no reports quantify this effect. In the modelling this service is assumed to have no impact on safety.

Modal Shift

The primary effect of Travel Information Services is expected to be on congestion/travel time; hence the modal shift impacts are expected to be minimal. No modal shift impacts are therefore anticipated on an EU level as a consequence of this service and it is not included as part of the model.

5.4. Bundle 1b - Real-time traffic information service

Service Overview

Real-time traffic information (RTTI) services aim to provide road users with useful, accurate and up-to-date information on the road network, traffic circulation plans, traffic regulations, recommended driving routes and real-time traffic data including estimated travel times, information about congestion, accidents, road works and road closures. Additionally, real-time traffic information services can potentially include any other information considered relevant to the planning and the execution of the trip. While there are many similarities with Travel Information Services (see section 5.3), real-time traffic information has a broader scope of data categories with more emphasis on data being made available in real-time such that drivers can receive information en-route.

As per Article 3(1) in Delegated Regulation (EU) 2015/962, Member States are required to set up a national access point, which constitutes a single point of access for users to the road and traffic data, including data updates, provided by the road authorities, road operators and service providers and concerning the territory of a given Member State. The specific data categories are listed in the annex to the delegated regulation. Such data can be used by either public bodies or private operators to provide the service to the end user via a smartphone or in-vehicle system.

Impacts

The main data sources for the impacts of the RTTI service were the evaluation reports of the CEF funded ITS Corridors on the EU EIP website. The five CEF funded ITS corridors have focused on the harmonisation of specifications and deployment of traffic management services. The evaluation library (EU EIP) gathers all available Evaluation Reports, guidance and source materials in one place and has been regularly updated throughout the duration of the activities to date. By the end of 2019, 35 EU EIP compliant evaluation reports from the current ITS Corridors were available via the EU EIP Evaluation Library. These are supplemented by an extensive archive of over 80 archive evaluation reports and guidance documents in an archive gathered from previous programmes.

Each report presents the deployment, benefit and cost KPIs following the evaluation report template developed by EU EIP.

While it is very likely that there is a positive impact of RTTI, it is not straightforward to assess the impact in quantitative terms because the ‘application’ of RTTI is not sharply defined, limited empirical results exist and other traffic management, traffic control and cooperative vehicle safety systems target the same factors as RTTI.

Traffic efficiency

In the RTTI study (VVA, coffey, TiS, 2020), Finland reported an improvement in travel time of 1.1% while Netherlands reported an improvement in travel time of 9%. These figures are assumed to represent two extreme cases (high and low) and thus have taken a median value. Converting this to increase in speed leads to figure of 5.3%. In the absence of any further data, this impact is assumed to apply to all road types equally.

<u>Fuel Consumption</u>

From the ex-ante evaluation of the NEXT-ITS corridor (EU EIP, 2018), the average effect of real-time traffic information on users on equipped sections was:

- 1% reduction in CO_2 emissions (traffic conditions and travel time)
- 0.05% reduction in CO_2 emissions (road weather)

Similarly, Finnish authorities reported a 1.2% decrease in CO_2 emissions as a consequence of RTTI. Hence, to accommodate both of these sources, the impact has been determined to be 1.1% for all vehicle types, excluding public transport for which the impact is assumed to be zero. In the absence of data for different road types, the same impact has been applied across each part of the road network.

<u>Emissions</u>

No data was identified for this impact category in the reports reviewed, therefore emissions impacts were scaled using the ratio between fuel/CO_2 impacts and emissions impacts for the in-vehicle speed limit service in urban areas (see section 5.13.2). This resulted in the following impacts on emissions:

- NOx: 0.2% reduction on motorways, 1.0% reduction on other interurban roads, 0.3% reduction on urban roads
- PM: 0.2% reduction on motorways, 0.5% reduction on other interurban roads, 0.1% reduction on urban roads
- CO: 0.1% reduction on motorways, 2.4% reduction on other interurban roads, 1.3% reduction on urban roads
- VOCs: Not included as an impact due to in-vehicle speed limits resulting in an increase of VOC's as a consequence of increased braking. The same logic does not apply to travel information services and therefore the same ratio between fuel/CO_2 impacts and emissions cannot be applied.

<u>Safety</u>

From the ex-ante evaluation of the NEXT-ITS 2 corridor (EU EIP, 2018), the average effect of real-time traffic information on users on equipped sections was:

- 0% reduction in fatal and injury accidents (traffic conditions and travel time)
- 1.5% reduction in fatal and injury accidents (road weather)

Hence, an impact value of 1.5% for TEN-T network and motorways has been used for all accident types for both passenger cars and trucks, while the impact on public transport is expected to be zero. The impact on safety has been scaled for interurban and urban roads in line with the impact observed for SRTI services, as the nature of each service is similar. This results in 1% for light injuries and material damages.

Modal Shift

RTTI services focus on real-time information for the road network and does not capture data from other modes. Hence, the model shift impacts are expected to be minimal. No modal shift effects are therefore anticipated on an EU level as a consequence of this service and it is not included as part of the model. This is confirmed by the supporting study report (VVA, coffey, TiS, 2020) and the ITS Corridor evaluations (EU EIP, 2018), which did not consider the effect on modal shift for this service.

5.5. Bundle 1b - Parking and pricing information

Service overview

Parking and pricing information services aim to provide road users with useful, accurate and up to date information of the parking options in a given area. This includes on street parking, off street parking, and park and ride facilities. Information made available through these services includes static data (such as type and location of parking) and dynamic data (such as price and availability of parking) and the service can be delivered either via a smartphone or in-vehicle system. The provision of on-street and off-street parking information is intended to bring efficiency benefits to drivers and help to reduce emissions by reducing the time spent 'cruising' at low speeds. In the case of Park & Ride information, it helps to reduce congestion in urban areas and also shift travel from cars to public transport.

Impact data

In general, there are limited data sources for each of the services within this service type:

- **On street parking information**: The only data source which covered the potential impacts of the on-street parking information service was the eSafetyForum Intelligent Infrastructure Working Group's Final Report. The information from this report was supplemented by additional desk research into the provision of parking information services and the time spent searching for parking spaces. A number of reports were used to estimate the impact of this service from first principles, as referenced below.

- **Off street parking information and management:** No other publicly available studies that specifically examine off street parking information were identified. Impacts for off street parking were assumed to be similar to on street parking, therefore the same values have been used as inputs to the modelling.

- **Park & Ride Information**: No other publicly available studies that specifically examine the impacts of this service were identified.

Given that there is no distinction between the impacts for on-street and off-street parking and no data available for park & ride services, all services have been streamlined into one group such that they only present one set of impacts.

Traffic efficiency

Traffic efficiency improvements are expected to be the main benefit of this service. No data was identified for this impact category in the reports reviewed. The following methodology was therefore used to estimate impacts on traffic efficiency from first principles:

- Identify the time spent looking for a parking space in a Member State.
  - In France, an estimated 70 million hours per year is spent 'cruising' trying to find parking (Gantelet & Lefacounnier, 2006) .
- Scale this to EU level, based on total vehicle kilometres driven in urban areas (based on data for the EU-27 from TRT's ASTRA model).
  - Gives an estimated 450,272,549 hours 'cruising' per year for the EU
- Apply an effectiveness factor to the parking information C-ITS service.
  - 3.5 times less time spent cruising for parking to final destination when parking information is shown (or a 71% effectiveness), according to a report published by the University of Zurich (Tsiaras, et al., 2015).
  - Use this number to estimate the total change in time spent driving on urban roads from deploying parking information services to all vehicles at an EU level.
  - 0.61% reduction in travel time/improvement in speed in urban areas across passenger and freight vehicles.

Park and ride schemes are designed to reduce congestion in urban areas, therefore some traffic efficiency impacts are to be expected. However, these urban efficiency gains do not occur directly with the vehicle using the service, since the impact of the service will be to increase the likelihood of the vehicle in question using Park & Ride services – thereby preventing it entering the congested urban area. This makes it very difficult to estimate the impact on efficiency from first principles. In the absence of any data for this impact category in the reports reviewed, it was assumed that this specific service would have zero impact on speed in urban areas.

Fuel consumption and CO_2

The average speed of vehicles when 'cruising' for parking spaces in urban areas was estimated at half the average speed limit for urban areas (Tsiaras, Hobi, Hofstetter, Liniger, & Stiller, 2015), i.e. 15 kph in the EU.

This speed was used as an input to Ricardo Energy and Environment's speed-emissions curve model, which is able to estimate the impact in g/km on CO_2/fuel consumption, NO_x

and PM_{10} emissions. Using the total time spent 'cruising' and average speed of 'cruising' referenced above, a total EU-level cruising distance could be determined, from which the total EU-level emissions impacts could be estimated.

The total resultant improvement in fuel consumption and CO_2 emissions was estimated from the above methodology as 0.79% across passenger vehicles in urban environments.

Environmental and emissions impacts

NO_x and PM emissions were estimated using the same speed-emissions curve model as for fuel consumption/CO_2. Total improvement in NO_x and PM emissions were estimated at 0.26% and 0.07% respectively across all passenger vehicles in urban environments.

For CO and VOC emissions, these were assumed to be proportional to fuel consumption savings, and therefore estimated at a 0.79% reduction for urban passenger vehicles.

Safety

The eSafetyForum reports that parking information and guidance will have zero impact on safety (eSafetyForum, 2010). Whilst there may be secondary impacts due to reduced congestion in urban areas, no data exists to support this and the safety impacts were therefore assumed to be zero.

Modal Shift

The on-street and off-street parking information is likely to encourage users to continue using private cars in urban areas and therefore it is not expected to have any impact on modal shift. However, park & ride information will increase the likelihood of the vehicle in question using Park & Ride services – thereby preventing shifting part of the journey to public transport and other active modes while in the city. In the absence of data, it is not possible to identify the extent of this impact.

5.6. Bundle 1b - Recharging/refuelling location and pricing information

Service Overview

Recharging and refuelling location and pricing information services aim to provide users with the associated information, ensuring that the information is accurate and up to date. This includes static data (location and conditions for use) and dynamic data (availability of recharging point), which is delivered as a service either through a smartphone or in-vehicle system. Data made be made available through NAPs as per Delegated Regulation (EU) 2015/962.

This service allows users to be informed of and book charging point time windows for fuelling and charging stations for alternative fuels. This enables a more convenient driving experience and allows for vehicle owners to plan routes according to the location of appropriate refuelling points; eBilling information may also be included. This service is applicable on all road types and is currently focused on cars, bringing vehicle operation and efficiency benefits. As technologies advance and fleet composition changes, this service will be applicable to additional vehicle types. However, it is not expected to have any impact on modes outside of road transport.

Impacts

The primary impact of this service is to provide users with adequate information as many users often lack information on where they can recharge/refuel and the availability of recharging/refuelling points – thereby making journeys more comfortable for the user and encouraging the uptake of alternatively fuelled vehicles. This service also impacts the journey time and route planning as users do not have to spend time cruising in search for an available recharging/refuelling point. In the model, only the impacts on travel time are considered.

<u>Congestion/Travel Time</u>

End-users are expected to save time in finding recharging and refuelling stations due to higher aggregation of data. Although detailed data is not available, EV users are expected to recharge once per week, with an estimated 10 minutes saved per recharging event due to the increased accessibility of information about the availability of recharging points. Other AFV users (e.g. hydrogen) are estimated to refuel once every 2 months and expected to again save 10 minutes per refuelling event (VVA, coffey, TiS, 2020).

In absence of any more specific data, the same impact as parking information has been used, due to the similar nature of these services. That is, a 0.61% increase in average speed in urban areas for passenger cars (noting that this only applies to alternatively fuelled vehicles). The impact of this service is expected to be negligible outside of urban areas given that recharging/refuelling points will be located in service stations along motorways and therefore do not cause an issue for users in locating them. Furthermore, this impact does not apply to trucks or public transport vehicles as they will use private infrastructure in urban areas.

<u>Fuel Consumption</u>

The primary impact modelled in this IA is congestion/travel time. Although this will have a minor impact on the overall fuel consumption, the effects are expected to be minimal and therefore have not been considered in the model. This is confirmed by the RTTI study report, which did not consider the effect on fuel consumption for this service (VVA, coffey, TiS, 2020).

<u>Emissions</u>

The primary impact modelled in this IA is congestion/travel time. Although this will have a minor impact on the overall emissions, the effects are expected to be minimal and therefore have not been considered in the model. This is confirmed by the RTTI study report, which did not consider the effect on emissions for this service (VVA, coffey, TiS, 2020).

<u>Safety</u>

The primary impact modelled in this IA is congestion/travel time, hence the safety impacts are expected to be minimal. No safety effects are therefore anticipated on an EU level as a consequence of this service and it is not included as part of the model. This is confirmed by the RTTI study report, which did not consider the effect on safety for this service (VVA, coffey, TiS, 2020).

Modal Shift

The primary impact modelled in this IA is congestion/travel time; hence the modal shift impacts are expected to be minimal. No modal shift effects are therefore anticipated on an EU level as a consequence of this service and it is not included as part of the model. This is confirmed by the RTTI study report, which did not consider the effect on modal shift for this service (VVA, coffey, TiS, 2020).

5.7. Bundle 2 - Traffic network management systems

Service Overview

Traffic network management systems refers to the combination of measures that serve to preserve traffic capacity and improve the security, safety and reliability of the overall road transport system. These measures make use of ITS systems and services in day-to-day operations that impact on road network performance. Traffic network management systems encompass a number of services, for example variable speed limits, dynamic lane management and traffic incident management.

Road operators utilise a range of sensor deployment and data types such as RTTI and SRTI to monitor traffic performance and implement services accordingly. Traffic network management systems are employed at the network level and delivered to all users on the road through variable message signs.

Impacts

Traffic network management systems have an impact across environmental, safety and traffic efficiency categories. It is difficult to state which of these is considered to be the primary impact, as different services are delivered in response to certain events or conditions. However, most often they are designed to improve traffic efficiency. Given that these services are deployed at a network level, the impact is the same across all vehicle types.

The key sources for these impacts are the evaluation reports of CEF funded ITS corridors. The five CEF funded ITS corridors have focused on the harmonisation of specifications and deployment of traffic management services. The evaluation library (EU EIP) gathers all available Evaluation Reports, guidance and source materials in one place and has been regularly updated throughout the duration of the activities to date. By the end of 2019, 35 EU EIP compliant evaluation reports from the current ITS Corridors were available via the EU EIP Evaluation Library[159]. These are supplemented by an extensive archive of over 80

159 https://www.its-platform.eu/filedepot/folder/1077?_ga=2.79652372.1048593557.1623322084-873712203.1621001876

archive evaluation reports and guidance documents in an archive gathered from previous programmes.

Each report presents the deployment, benefit and cost KPIs following the evaluation report template developed by EU EIP. In many cases, the evaluation reports focus on a dedicated section of the road network employing one type of service within traffic network management systems. In such cases, these impacts have been aggregated to determine the maximum possible impact of traffic network management systems.

Safety

The main impacts on safety are form the Arc Atlantique corridor, which deployed traffic management services such as hard should running and lane control systems.

- In Paris **sensors on the highway and access ramps and traffic lights on access ramps** were implemented in peri-urban setting. The expected result is up to a 20% reduction in accident risk (EU EIP, 2020).

- In the UK, '**smart motorways**' on the A2/M2 are expected to reduce personal injury accidents by 55.7% since hard should running was introduced. There is also an overall reduction in the severity of accidents with zero fatalities and fewer seriously injured expected (EU EIP, 2017).

- Another section of road network (M25) providing **variable speed limited and hard should running** (and RTTI and SRTI) has showed an improvement in safety over a 12-month period. The results show a reduction of 67% (seriously injured); 55% (killed or seriously injured); 33% (slightly injured); 15% (FWI); 35% (total). However, the evaluation notes that a conclusion on safety can't be drawn as the sample size after 12 months operation is too small (EU EIP, 2017).

- Overall, the impacts of the Arc Atlantique 2 Corridor are expect to reduce slight injuries by 236 per year, seriously injured by 28 per year, and fatalities by 11 per year (EU EIP, 2016).

- Another section on the M25 (providing the same services) was also evaluated over a 12 month period. Vehicle Hours Delay (VHD) has reduced slightly overall in the clockwise direction from 4,008 hours before the scheme was implemented, to 3,046 hours after the scheme went operational. This is a daily saving of 962 VHD. In the anti-clockwise direction, it has reduced from 3,711 hours prior to scheme implementation to 2,355 hours after the scheme came into operation. This is a daily saving of 1,357 VHD.) Furthermore, average journey time has improved clockwise in most time slices. Anti-clockwise journey times in the PM peaks are greatly improved but slightly worsened during the AM and inter-peak periods. Before the scheme the clockwise journey time ranged from 11min 33sec to 16min 3sec and after they ranged from 11min 30 sec to 15min 20sec depending on day and time of day. The clockwise improvement in journey time ranges from -0.7% to 10.5%. In the anti-clockwise direction journey time ranged from 11min 6sec to 15min 10sec and after they ranged from 11min 15 sec to 13min 2sec depending on day and time of day. The improvement in journey time ranges from -4.5% to 13.3% (EU EIP, 2015).

From the evaluation of the NEXT-ITS 2 Corridor (EU EIP, 2018), the observed safety impacts (in absolute numbers) are a reduction of 0.11 fatalities and 2.45 injury accidents per year across the network. This is a result of VMS providing information on congestion, incidents, accidents and other problems of the network.

Fuel Consumption

In France (part of the Arc Atlantique Corridor), a dynamic traffic management system consisting primarily of **VMS** is activated when necessary to divert traffic. Two separate sections were evaluated to find a total fuel saving of 2353.1 litres across both sections including both LDVs and HDVs). This equates 6.25 tons of CO_2 emissions.

Emissions

The following results were found in ex-ante evaluations specific sections of the Arc Atlantique Corridor:

- In Paris, **sensors on the highway and access ramps and traffic lights on access ramps** were implemented in peri-urban setting. The expected result is up to a 30% reduction in polluting emissions (EU EIP, 2020).

- In the UK, **'smart motorways'** on the A2/M2 are expected to reduce emissions by up to 10% due to traffic running more smoothly.

From the evaluation of the NEXT-ITS 2 Corridor, the observed fuel emission impacts (in absolute numbers) is a reduction of 11.5 kilotons of CO_2 per year across the network. This is a result of VMS providing information on congestion, incidents, accidents and other problems of the network.

Congestion/Travel Time

The following results were found in ex-ante evaluations specific sections of the Arc Atlantique Corridor:

- In Paris, **sensors on the highway and access ramps and traffic lights on access ramps** were implemented in peri-urban setting. The expected result is up to a 15% reduction in travel time during peak traffic and increase in average speed of 10km/h during peak periods. Another evaluation of a similar service deployment on a different part of the corridor found that each user has gained 6 minutes of travel time per day (EU EIP, 2020).

- In the UK**, 'smart motorways'** on the A2/M2 indicate an improvement of journey time reliability by 22% (EU EIP, 2017)

- Another section of road network (M25) providing **variable speed limited and hard shoulder running** (and RTTI and SRTI) has showed an improvement in traffic flow over a 12-month period. Vehicle Hours Delay (VHD) has reduced considerably in the clockwise direction from 6,736 hours before the scheme was introduced to 3,750 hours following scheme implementation. The results in the anticlockwise direction show a reduction from 8,263 VHD to 3,863 VHD which is a daily saving of 4,400 vehicle hours. Furthermore, the average journey time to cover this stretch of the M25 improved in both directions. Before the scheme the clockwise journey time ranged from 15min 56sec to 18min 38sec and after they ranged from 14min 40 sec to 17min 32sec depending on day and time of day. The improvement in the clockwise journey time ranges from 5.3% to 8.6%. In the anticlockwise direction journey time ranged from 16min 3sec to 22min 17sec and after they ranged from 15min 12 sec to 17min 38sec depending on day and time of day. The improvement in anti-clockwise journey time ranges from 5.4% to 20.9% (EU EIP, 2015).

- Another section on the M25 (providing the same services) was also evaluated over a 12 month period. Vehicle Hours Delay (VHD) has reduced slightly overall in the clockwise direction from 4,008 hours before the scheme was implemented, to 3,046 hours after the scheme went operational. This is a daily saving of 962 VHD. In the anti-clockwise direction it has reduced from 3,711 hours prior to scheme implementation to 2,355 hours after the scheme came into operation. This is a daily saving of 1,357 VHD. Before the scheme the clockwise journey time ranged from 11min 33sec to 16min 3sec and After they ranged from 11min 30 sec to 15min 20sec depending on day and time of day. The clockwise improvement in journey time ranges from -0.7% to 10.5%. In the anti-clockwise direction journey time ranged from 11min 6sec to 15min 10sec and after they ranged from 11min 15 sec to 13min 2sec depending on day and time of day. The improvement in journey time ranges from -4.5% to 13.3% (EU EIP, 2017).

From the evaluation of the NEXT-ITS 2 Corridor (EU EIP, 2018), the observed congestion impacts (in absolute numbers) are a reduction of 491,000 vehicle hours driven and 135,000 vehicle hours spent in congestion per year across the network. This is a result of VMS providing information on congestion, incidents, accidents and other problems of the network.

5.8. Bundle 2 – Mobility Management systems

Service Overview

Mobility management systems are somewhat less defined in literature compared to traffic network management services. In general, mobility management systems services that can be employed by public bodies to control the flow of users in the mobility system. Public authorities use multimodal and real-time traffic information to deliver services to end users, typically in in response to an event or incident (e.g. a rail stop is undergoing maintenance and replacement bus stop is required). The services are delivered to end-users via smartphones.

There are limited examples of implementation of such services and therefore no data available on the impacts under consideration. However, it is expected that the most significant impact will be increased efficiency of the mobility system and improve travel time for individual users. Further, it is possible that it will increase modal shift as it makes public transport a more reliable and attractive option. It is expected that as data from operators becomes more widely available to public bodies, mobility management systems will be rolled out.

5.9. Bundle 3 - Road safety-related minimum universal traffic information service

Service Overview

Safety-related traffic information (SRTI) services aim to provide road users with useful, accurate and up-to-date information on events or conditions impacting the road network, often delivered as alert through smartphones or in-vehicle systems. As defined in Delegated Regulation 886/2013, the events or conditions covered by are: temporary slippery road; animal, people, obstacles, debris in the road; unprotected accident area; short-term road works; reduced visibility; wrong way driver; unmanaged blockage of a road; exceptional weather conditions.

Impacts

The main objective of providing road safety-related traffic information is increasing road safety, i.e. reducing road accidents that result in fatalities, injuries and economic loss. While it is very likely that there is a positive safety impact of SRTI, it is not straightforward to assess the impact in quantitative terms because the 'application' of SRTI is not sharply defined, limited empirical results exist and other traffic management, traffic control and cooperative vehicle safety systems target the same safety factors as SRTI. The main data source for the impacts of SRTI was from the impact assessment study for SRTI (Rapp Trans et al., 2013) and the evaluation report of the NEXT-ITS Corridor (NEXT-ITS, 2016).

The Impact Assessment Study for SRTI assessed the effectiveness, coverage of service and addressed fraction of all accidents to determine the theoretical safety impacts of SRTI. The overall safety impact was determined on the basis of the following assumptions: full coverage of the road network; resolution and accuracy in time and location can be expected to come from cooperative technology; a near 100% penetration of the service; no other measures are considered to influence the safety.

The ex-ante evaluation of the NEXT-ITS Corridor was carried out taking the estimated benefits of the measures (RTTI and SRTI) into account. The expected impacts of the deployed services on the NEXT-ITS corridor are based on experience from several impact assessment studies. The share of users who are provided with the services has been investigated, based on relevant and available user statistics from each country.

<u>Congestion/Travel Time</u>

The primary effect of safety related traffic information is expected to be safety and as a result of the reduced number of accidents, the congestion and travel time is expected to improve. From the ex-ante evaluation of the NEXT-ITS corridor (NEXT-ITS, 2016), the average effect of safety related traffic information on users on equipped sections was 0.5% reduction in vehicle hours driven and 1.5% reduction in vehicle hours in congestion. The median value (1%) has been taken and an average speed increase was calculated to be 1.01%, which has been applied to cars and trucks across all road types in the absence of any further data.

Fuel Consumption

Although the primary effect of SRTI is expected to be safety, fuel consumption benefits will be realised as vehicles change their travel behaviour and route to avoid events and conditions. From the ex-ante evaluation of the NEXT-ITS corridor the average effect of safety related traffic information on users on equipped sections was a 0.4% reduction in CO_2 emissions (NEXT-ITS, 2016). This impact has been applied to cars and trucks across all motorways. For interurban roads, the impact has been scaled in line with the impacts observed for V2I services, while for urban roads the impact has been assumed to be zero.

Emissions

No data was identified for this impact category in the reports reviewed, therefore emissions impacts were scaled using the ratio between fuel/CO_2 impacts and emissions impacts for the in-vehicle speed limit service in urban areas (see section 5.13.2). This resulted in the following impacts on emissions:

- NOx: 0.09% reduction on motorways, 0.09% reduction on other interurban roads
- PM: 0.07% reduction on motorways, 0.1% reduction on other interurban roads
- CO: 0.03% reduction on motorways, 0.05% reduction on other interurban roads
- VOCs: Not included as an impact due to in-vehicle speed limits resulting in an increase of VOC's as a consequence of increased braking. The same logic does not apply to travel information services and therefore the same ratio between fuel/CO_2 impacts and emissions cannot be applied.

Safety

The direct effect of SRTI is on driver behaviour. SRTI has a main effect on drivers and passengers of cars, buses and lorries. Drivers of motorcycles will also be positively affected by SRTI. Friction-related warnings are especially relevant to motorcyclists and are likely to have a greater effect as such conditions induce a greater accident risk for motorcycles. On the other hand, there are some constraints to deliver SRTI to motorcycles which are likely to lead to a much lower penetration than for passenger cars, at least on the short and medium term. However, motorcyclists will profit from behaviour more adapted to local danger by car drivers as a result of SRTI.

The EC impact assessment study for safety related traffic information estimated safety related traffic information to maximally reduce all road traffic fatalities in Europe by 2.7 % and all traffic injuries by 1.8 %, taking into consideration the assumptions described above (excluding the cooperative technology approach on the requirement on resolution and accuracy) (Rapp Trans et al., 2013).

However, impacts may vary depending on the geographic location of the road. From the ex-ante evaluation of the NEXT-ITS corridor, the average effect of safety related traffic information on users on equipped sections was 3% reduction in fatal and injury accidents (NEXT-ITS, 2016). The evaluation noted that the effects are likely higher due to different weather conditions. As such, the impact on motorways (both TEN-T and other) was taken to be 2.7% reduction in fatalities and 1.8% reduction in injuries for all vehicle types to represent the impact for all EU Member States. For interurban and urban roads, the impacts have been scaled in line with impacts observed for V2V, which has similar use cases to SRTI.

Modal Shift

The primary effect of safety related traffic information is expected to be safety; hence the modal shift impacts are expected to be minimal. No modal shift impacts are therefore anticipated on an EU level as a consequence of this service and it is not included as part of the model.

5.10. Bundle 3 - Safe and secure truck parking location information system

Service Overview

This service aims to provide truck drivers with accurate and up to date information on the location and description of safe and secure truck parking facilities. The service provides static data to truck drivers including name and address of truck parking area, location information, number of parking spaces, price and currency of parking and description of the security, safety and service equipment in the parking area. The primary objective is to address the number of trucks parked in non-secured zones or unsafe locations like hard shoulders as a result of lack of information on available parking, which often leaves truck drivers subject to theft and accidents.

The Delegated Regulation 885/2013 establishes the specifications necessary to ensure compatibility, interoperability and continuity for the deployment and operational use of information services for safe and secure parking places for trucks and commercial vehicles on a Union level in accordance with Directive 2010/40/EU.

Impacts

The purpose of safe and secure truck parking location information systems is to prevent trucks from parking on the hard shoulder and to help drivers comply with driving time legislation in a safe way. At the same time, minor impacts on the travel time are expected as a result of truck drivers reducing the time taken to locate safe parking spaces. Although it is widely accepted that safe and secure truck parking location information systems will have positive impact on safety (i.e. a reduction in the number of accidents), there is limited empirical evidence on the extent of such safety impacts.

The main data source for the impacts on safe and secure truck parking location information systems was from the evaluation report of the intelligent truck parking system on the CROCODILE corridor (EU EIP, 2020). By November 2019, resulting from the development carried out in multiple phases of the project, the number of parking places covered by the ITP system had reached 531 in Hungary, covering more than one third of the public heavy goods vehicle (HGV) parking places available along the TEN-T network. As a result of the development, rest stations covered by intelligent truck parking-control system are now available along the motorways in Hungary at nearly every 100 km.

Variable signs posted along the road represent the primary sources of information during a journey. The LED displays integrated into static signs are identical to those devices used during the previous deployments for displaying occupancy data of the rest stations. The incoming information from the new sites are displayed either on new dynamic display units of static signs deployed earlier, on existing or on newly deployed VMS portals. In addition to roadside displays, the service has become available on web-based and mobile interfaces as well, making it easier to access the dynamic occupancy monitoring data of rest areas for HGVs. The evaluation of ITP system aimed to address whether the number of truck-related accidents had decreased on the M1 (71% of HGV parking places are covered by the ITP system) and if so, what the extent of the change is.

Congestion/Travel Time

From the evaluation of intelligent truck parking on the CROCODILE corridor, no direct relationship could be identified between the expansion of intelligent truck parking services and changes in traffic flow. However, the evaluation notes that providing information about safe parking may indirectly have a positive impact the flow of traffic through a drop in the number of accidents. By decreasing the number of accidents caused by fatigue, excessive driving, parking at prohibited locations may reduce traffic disturbances (e.g. congestions or diversions), contributing to an uninterrupted traffic flow and preventing further, secondary accidents.

Fuel Consumption

The primary effect of safe and secure truck parking location information system is expected to be safety and travel time; hence the fuel consumption impacts are expected to be minimal. No fuel consumption impacts are therefore anticipated service and it is not included as part of the model. This is confirmed by the CROCODILE evaluation report, which did not consider the effect on fuel consumption for this service.

Emissions

The primary effect of safe and secure truck parking location information system is expected to be safety and travel time; hence the emissions impacts are expected to be minimal. No emissions impacts are therefore anticipated on an EU level as a consequence of this service and it is not included as part of the model. This is confirmed by the CROCODILE evaluation report, which did not consider the effect on emissions for this service.

Safety

As highlighted earlier, the primary objective of this service is to prevent trucks from parking on the hard shoulder and to help drivers comply with driving time legislation in a safe way thereby reducing the number of accidents involving trucks. In the evaluation report of ITP on the CROCODILE corridor, the accident-related data relevant to motorway M1 was recorded and adjusted to account for increased traffic flow. The number of truck accidents recorded between 2016-2018 showed an annual decrease in absolute terms constituting a decrease of 3.9%. At the same time, it is not possible to directly attribute the safety observed to truck parking as other factors may be involved. The study on information and reservation truck parking services determined that only 1% of trucks are related to offsite parking. Thus, as a more conservative figure, 2% was used to reflect the findings of both studies. This applies only to trucks on motorways.

Modal Shift

The primary effect of safe and secure truck parking location information system is expected to be safety and travel time; hence the modal shift impacts are expected to be minimal. No modal shift impacts are therefore anticipated, and it is not included as part of the model. This is confirmed by the CROCODILE evaluation report, which did not consider the effect on modal shift for this service.

5.11. Bundle 3 - Safe and secure truck parking location reservation system

This service builds on the location information system and can be viewed as an extension of the previous service. In addition to providing end users with the static location information, it provides truck drivers with a convenience service to reserve parking spaces such that they are able to comply with driving time legislation easily. This service employs dynamic data as well as static data, including the capacity of the parking facility at any given moment. This necessitates the appropriate sensor and camera deployment to ensure that the capacity of the parking facility is monitored continuously.

Regarding specifications for priority action (f) on the provision of reservation services for safe and secure parking places for trucks and commercial vehicles, the Commission conducted several consultations with Member State experts and the main stakeholders, including an impact assessment support study (Rapp-Trans et al., 2012). The discussions highlighted that there is a low number of parking areas that could offer reservation services in 2014 (representing only 2% of parking places), and that there was, therefore, no need for specifications and standards on reservation of parking areas.

Impacts

In addition to the impact of safety discussed above in the previous service type, the main objective of reservation services is to provide end users with convenience and certainty that they will be able to use a parking facility at any given moment.

Congestion/Travel Time

As with the location system, the reservation system may have an indirect impact on the traffic flow as a result of the positive impact on safety. Nevertheless, the impact is estimated to be small and therefore is not considered in the model.

Fuel Consumption

The primary effect of safe and secure truck parking location reservation system is expected to be safety and travel time; hence the fuel consumption impacts are expected to be minimal. No fuel consumption impacts are therefore anticipated on an EU level as a consequence of this service and it is not included as part of the model.

Emissions

The primary effect of safe and secure truck parking location reservation system is expected to be safety and travel time; hence the emissions impacts are expected to be minimal. No emissions impacts are therefore anticipated on an EU level as a consequence of this service and it is not included as part of the model.

Safety

Given the limited deployment of truck reservation services and studies on this service type, no literature that discusses the impact was identified. In the absence of data, the same impact as the location information services was assumed, which is a 2% reduction in all safety categories for trucks on motorways.

Modal Shift

The primary effect of safe and secure truck parking location reservation system is expected to be safety and travel time; hence the modal shift impacts are expected to be minimal. No modal shift impacts are therefore anticipated on an EU level as a consequence of this service and it is not included as part of the model.

5.12. Bundle 4 – Vehicle-to-Vehicle (V2V) C-ITS services

The impact data presented in this section are from the 2019 C-ITS impact assessment support study, which reviewed and updated the information that was collected for the 2016 C-ITS deployment study. The services in Bundle 4 cover day 1 vehicle-to vehicle C-ITS services, that Emergency electronic brake light (EBL), Emergency vehicle approaching (EVA), Slow or stationary vehicle(s) warning (SSV), Traffic jam ahead warning (TJW), and Hazardous location notification (HLN). The General Safety Regulation (GSR) defines safety technologies and design features that need to be installed in new vehicles in order to be sold in the EU market. Although the GSR includes several safety designs features that do not require vehicle connectivity (i.e. direct vision requirements for HDVs), there are some features such as Intelligent Speed Assistance, for which manufacturers may use C-ITS type services to adhere to requirements. GSR can therefore be considered closely linked to C-ITS and certainly complimentary. Based on modelling outputs from the GSR support study, the benefits of C-ITS services on safety are reduced by 10 percent across all C-ITS services in the baseline and policy options, which is in line with the 2019 C-ITS IA support study (Ricardo, 2019). This reduction will more than account for any overlaps between the effect of C-ITS services on safety and those of the RISM/GSR Regulations[160].

[160] Other impacts are not reduced in the same way, as these are not quantified in the support study produced for the GSR Regulation.

5.12.1. Emergency electronic brake light (EBL)

Service Overview

The emergency electronic brake light is a service aimed at preventing rear end collisions by informing drivers of hard braking by vehicles ahead. Using this information, drivers will be better prepared for slow traffic ahead and will be able to adjust their speed accordingly.

In response to a vehicle suddenly braking, a message is sent to following vehicles to warn drivers of an abrupt decrease in traffic speed ahead. Emergency electronic brake lights are displayed in the following vehicles, giving drivers the opportunity to adjust their speed to avoid a potential collision. This service is applicable on all road and vehicle types, although it is envisaged to be particularly useful on congested, high speed roads, or in areas where visibility is poor. In this situation, following vehicles may not be able to see the brake lights of all vehicles ahead of them and would therefore have very limited time to react to hard braking without the service. This service currently predominantly relies on V2V ITS-G5 communication, although a number of projects are looking to demonstrate its effectiveness using high-speed (e.g. 4G/5G) cellular networks.

Impacts

The main data source for the impacts of the emergency electronic brake light was from FOTs in the DRIVE C2X project (TNO, 2014), an overview of the general methodology is provided in Table 46. This service was only tested in Germany, in partnership with the sim^{TD} project (Schimandl et al., 2013). A US DoT cost-benefit analysis report was also used as a comparison.

Table 46: Overview of key data source – DRIVE C2X project

The DRIVE C2X project used log data resulting from Field Operational Tests (FOTs) carried out on several test sites in different EU countries (Finland, France, Germany, Italy, the Netherlands, Spain, and Sweden).

The study aimed to harmonise the testing conditions as far as possible, in order to allow the data across the pilot sites to be combined. Nevertheless, several aspects differed significantly from one test site to others. These differences can be explained by cultural, country specific aspects as well as acquisition related influences (private drivers vs. employees).

The FOTs focused on functions that provide information or warnings to drivers. This means that the impact is dependent on whether and how the driver responds. Thus, the impact assessment first aimed to measure driver behaviour in order to provide input data for an impact assessment in four target areas: safety, efficiency, mobility, and environment.

Driver behaviour data was collected in two main ways: controlled tests" (CTs) and naturalistic driving (ND). In CT, drivers were called into the test and followed the driving instructions provided by the Test-Site Instructor, allowing the driver to encounter specific test situations. In the ND approach, drivers were monitored in their daily driving. Data on driver behaviour was then pooled across the test sites and used as input for the assessment of impacts.

Safety impacts were calculated by making use of the results of the field tests regarding driver behaviour, expert assessment and previous expert assessments found in the literature. Traffic efficiency and environmental impact assessment made use of simulation models. The mobility impact assessment in DRIVE C2X was based on the mobility model developed in TeleFOT project, The mobility assessment data consisted of user interviews (questionnaires and focus groups) based on experience in real traffic. The scaling up of the effects to the EU-level made use of external data.

Source: (TNO, 2014)

Other studies that considered the impacts include the eIMPACT project (TNO, VTT, Movea, PTV, BASt, 2008), and a cost-benefit analysis performed for the U.S. Department of Transport. The DRIVE C2X data was prioritised ahead of these source as it was published in 2014 (compared to 2008 for the other sources), is based on FOT data and its primary focus is on the EU, compared to the US DoT study.

Traffic efficiency

The primary effect of emergency electronic brake light is intended to be on safety, hence the traffic efficiency impacts are expected to be minimal. No traffic efficiency effects are therefore anticipated on an EU level as a consequence of this service and it is not included as part of the model. This is confirmed by the DRIVE C2X study, which did not consider traffic efficiency effects for this service.

Fuel consumption and CO_2

The primary effect of emergency electronic brake light is intended to be on safety, hence the fuel efficiency impacts are expected to be minimal. No fuel efficiency benefits are therefore anticipated on an EU level as a consequence of this service and it is not included as part of the model. This is confirmed by the DRIVE C2X study, which did not consider the effect on fuel consumption for this service.

Environmental and emissions impacts

The primary effect of emergency electronic brake light is intended to be on safety, hence the emissions impacts are expected to be minimal. No effects on emissions are therefore anticipated on an EU level as a consequence of this service and it is not included as part of the model. This is confirmed by the DRIVE C2X study, which did not consider the effect on polluting emissions for this service.

Safety

The primary objective of this service is to prevent rear end collisions, although other types of accident may also be prevented. Specifically, this service is thought to reduce the number of panic manoeuvres performed by vehicles, due to the early warning. This service can act via two mechanisms (TNO, 2014):

- Direct in-vehicle modification of the driver task – the driver behind the braking vehicle has more time to react to the braking vehicle ahead.
- Modification of interaction between vehicles – following drivers (with or without emergency brake light capability) will also have more time to react to the braking vehicle ahead.

In the DRIVE C2X study, impacts were assessed separately for: a) motorways and high speed rural roads (with a speed limit of at least 80 km/hour) and b) urban roads and low speed rural roads. The assumptions made in the DRIVE C2X study in scaling up these impacts are detailed below (TNO, 2014).

Rear-end collisions prevented via direct in-vehicle modification of the driving task:

- 60-80% of fatalities and injuries on rural roads occur on high speed rural roads, whilst all fatalities and injuries on motorways are considered to be high-speed (>80km/h).
- It is assumed that 50-70% of rear end collisions occurring on motorways and high speed rural roads could be influenced by the emergency brake light service.
  - 20-30% of these fatalities and injuries could be prevented by the emergency electronic brake light.
- It is assumed that 10-25% of rear end collisions occurring on urban roads and low speed rural roads (the remaining 20-40% of rural roads) could be influenced by the emergency brake light service.
  - 30-40% of these fatalities and injuries could be prevented by the emergency electronic brake light.

Other collision types (other than rear-end) prevented via direct in-vehicle modification of the driving task:

- Magnitude of the safety benefit was estimated to be 5-10% of the impact for rear collisions (as described above) per accident type.

Rear-end collisions prevented via modification of interaction between road users:

- When a driver reacts to hard braking ahead, following vehicles will also have increased time to react.
  - On motorways and high speed rural roads, a 0.10-0.15% reduction in fatalities is expected.
  - On motorways and high speed rural roads, a 0.02-0.03% reduction in injuries is expected.
  - On urban roads and low speed rural roads, a 0.15-0.30% reduction in fatalities is expected.

- On urban roads and low speed rural roads, a 0.10-0.20% reduction in injuries is expected.

The relatively low effectiveness of this service for interactions between road users is due to the high element of surprise and very small time margins involved in these types of crashes.

Overall for the EU-28, the DRIVE C2X study calculated a decrease in fatalities between 25 and 304 in 2030 and a decrease in injuries between 1,322 and 16,219 in 2030.

The DRIVE C2X high penetration scenario was used as an input to the model, which corresponds to a **2.7% decrease in fatalities and a 2.5% decrease in injuries**.

The US DoT also assessed the potential safety impact of this service in 2030 as part of a cost-benefit analysis and calculated a 0.88% decrease in annual light vehicle crashes, which is a significantly lower figure than DRIVE C2X. The discrepancy is likely to be due to the differences in road and driving characteristics in the USA and EU and higher traffic density on European roads.

Other impacts

As part of DRIVE C2X, user acceptance tests were not carried out for the emergency brake light functionality. The sim^{TD} project reported that driver behaviour was not significantly affected by the emergency brake light, although recommends further studies to support this. The sim^{TD} project questions whether there are benefits for drivers further behind the braking vehicle and again proposes that further research should be carried out to determine the impact of this service on all vehicles in a queue.

5.12.2. Emergency vehicle approaching (EVA)

Service Overview

This service aims to give 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.

Approaching emergency vehicles will communicate with vehicles ahead to warn drivers to clear the road. The advance warning provided by this service will give vehicles extra time to clear the road for approaching emergency vehicles in a safe and timely manner. This service is applicable for all road and vehicle types. This service currently predominantly relies on V2V direct short-range communication, although a number of projects are looking to demonstrate its effectiveness using high-speed (e.g. 4G/5G) cellular networks.

Impacts

The main data source for the impacts of the emergency vehicle approaching service was the DRIVE C2X project (TNO, 2014). An overview of the general methodology is provided in Table 46. Trials of this service were carried out at test sites in Germany, Italy and Spain. Data for this service was very limited, perhaps due to the limited real world opportunities to trial this type of service. No other publicly available studies that examine the emergency vehicle approaching service specifically were identified.

Traffic efficiency

The primary effect of the emergency vehicle approaching service is intended to be on safety, hence the traffic efficiency impacts are expected to be minimal. No traffic efficiency effects are therefore anticipated on an EU level as a consequence of this service and it is not included as part of the model. This is confirmed by the DRIVE C2X study, which did not consider traffic efficiency effects for this service.

Fuel consumption and CO_2

The primary effect of the emergency vehicle approaching service is intended to be on safety, hence the fuel efficiency impacts are expected to be minimal. No fuel efficiency benefits are therefore anticipated on an EU level as a consequence of this service and it is not included as part of the model. This is confirmed by the DRIVE C2X study, which did not consider the effect on fuel consumption for this service.

Environmental and emissions impacts

The primary effect of the emergency vehicle approaching service is intended to be on safety, hence the emissions impacts are expected to be minimal. No effects on emissions are therefore anticipated on an EU level as a consequence of this service and it is not included as part of the model. This is confirmed by the DRIVE C2X study, which did not consider the effect on polluting emissions for this service.

Safety

A reduction in collisions can be expected when this service is implemented due to the increased time drivers have available to inform their driving decisions.

The DRIVE C2X study used French accident statistics to estimate the impact of the emergency vehicle approaching warning (TNO, 2014), which show that 0.8% of fatal accidents and 1.1% of injuries included an emergency vehicle. This does not include accidents where the emergency vehicle was not directly involved. A multiplier of 1-5 was used for these accidents. Of these additional accidents, it was estimated that only 1-5% would result in injuries or fatalities.

The accidents were then categorised according to whether they occurred at an intersection or on a link section of road. Here, the following assumptions were made:

- 50-70% of emergency vehicle related (directly or indirectly) fatalities and injuries occur at intersections (Auerbach, 1988).
- 50-70% of emergency vehicle related (directly or indirectly) fatalities and injuries occurring at intersections could be prevented by the emergency vehicle approaching service.

- 60-80% of emergency vehicle related (directly or indirectly) fatalities and injuries occurring at links (the remaining 30-50% of total fatalities and injuries) could be prevented by the emergency vehicle approaching service. This higher figure is due to the lower complexity of the road layout and reflects the fact that it is likely to be easier for drivers to give way to emergency vehicles.

The results in the DRIVE C2X report were presented in terms of the overall impact in the EU-28 in 2030. It was estimated that 14-84 fatalities and 933-4954 injuries could be prevented (TNO, 2014). The high scenario in DRIVE C2X equates to a **0.8% reduction in fatalities and a 0.8% reduction in injuries**.

<u>Other impacts</u>

A survey of test participants during the DRIVE C2X study revealed some interesting insights regarding this service. 92% of participants viewed the service as useful (the highest in the study), however only 41% indicated they would be willing to pay for this feature (TNO, 2014). On a scale of 1 to 7, the average increased feeling of safety was rated at 5.6-6.0, suggesting that this service can offer an improved driving experience.

5.12.3. Slow or stationary vehicle(s) warning (SSV)

Service Overview

Slow or stationary vehicle(s) warning is 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. The warning helps to prevent dangerous manoeuvres as drivers will have more time to prepare for the hazard. This service can also be referred to as car breakdown warning.

Slow or stationary vehicle(s) signal to nearby vehicles to warn approaching drivers of their presence. These messages can then be relayed to following drivers, who can consequently plan to take an alternative route, or make evasive manoeuvres, thus improving traffic fluidity, safety and delivering efficiency benefits. This service is applicable to all road and vehicle types. As for the emergency electronic brake light service, it is anticipated that this service will be especially useful for warning vehicles of the potential danger of a rear end collision when visibility is poor. This service currently predominantly relies on V2V direct short-range communication, although a number of projects are looking to demonstrate its effectiveness using high-speed (e.g. 4G/5G) cellular networks.

Impacts

The main data source for the impacts of slow or stationary vehicle(s) warning was the DRIVE C2X project (TNO, 2014). An overview of the general methodology is provided in Table 46. This service was tested at sites in Finland, Italy, Spain and Sweden. In DRIVE C2X, this service is evaluated alongside ‘obstacle warning’ and ‘roadworks warning’, as the services perform a similar function, act via similar mechanisms and present information to drivers in a similar manner.

The eIMPACT project (TNO, VTT, Movea, PTV, BASt, 2008) evaluated the impacts of a service called ‘wireless local danger warning’, which is based on V2V communication. An overview of the general methodology is provided in Table 47. The eIMPACT definition of this service includes both obstacle/stationary vehicle warning and weather warning functionality.

Table 47: Overview of key data source – eIMPACT project

The eIMPACT project assessed the socio-economic effects of Intelligent Vehicle Safety Systems (IVSS) and their impacts on safety and traffic efficiency. Results from the impact assessment (Deliverable D4) were then used to inform a cost-benefit analysis (Deliverable D6).

The results of the study were published in 2008 and calculated the potential impacts of IVSS in the years 2010 and 2020. The impact assessment was performed for low (business as usual) and high (policy incentives) scenarios for both years. For each scenario, the fleet penetration varied by service, vehicle type (passenger car or goods vehicle) and by year (2010 or 2020). In addition to the scenarios, the maximum effectiveness of each service based on 100% penetration at EU-25 level was also calculated as part of eIMPACT. Results were given for the EU-25 as a whole and are not separated by road type, or vehicle type. Values based on 100% penetration were used as a source of data in this project.

Twelve services were evaluated, although only three were defined as having cooperative functionality:

- Intersection safety - the description of this service in the eIMPACT report also includes GLOSA/TTG functionality and is not limited to signalised intersections (also provides right of way assistance and left turn assistance).
- Speed alert - considers the service to have V2I functionality in 2020 but not in 2010.
- Wireless local danger warning - includes weather warnings and obstacle/stationary vehicle warnings, both of which are based on V2V communication.

Another service, pre-crash protection of vulnerable road users, was also evaluated. This is similar to the vulnerable road user protection service evaluated in this IA, however in eIMPACT it was not considered to be a cooperative system and was assumed to operate by detecting vulnerable road users via sensors. The two services are likely to present information to the driver in a similar manner and safety impacts will occur via similar mechanisms, therefore the data presented can reasonably be believed to be of some value.

Safety impacts were calculated by making use of expert estimations and were scaled up to EU-25 level based on current accident statistics. In addition to this, consultation with key stakeholders was an integral part of the eIMPACT project.

Source: (TNO, VTT, Movea, PTV, BASt, 2008)

Traffic efficiency

The traffic efficiency impacts of the slow or stationary vehicle(s) service are expected to be minimal as its purpose is to improve safety, rather than prevent traffic jams (TNO, VTT, Movea, PTV, BASt, 2008). In addition to this, broken down, stationary, or exceptionally slow vehicles (such as tractors) on the road are relatively infrequent events, therefore effects on traffic on an EU level will be negligible. This impact is therefore not included in the model.

Fuel consumption and CO_2

The primary effect of the slow or stationary vehicle warning is intended to be on safety, hence the fuel efficiency impacts are expected to be minimal. No fuel efficiency benefits are therefore anticipated on an EU level as a consequence of this service and it is not included as part of the model. This is confirmed by the DRIVE C2X study, which did not consider the effect on fuel consumption for this service.

Environmental and emissions impacts

The primary effect of the slow or stationary vehicle warning is intended to be on safety, hence the emissions impacts are expected to be minimal. No effects on emissions are therefore anticipated on an EU level as a consequence of this service and it is not included as part of the model. This is confirmed by the DRIVE C2X study, which did not consider the effect on polluting emissions for this service.

Safety

This service is expected to work by informing drivers of slow or stationary vehicle(s) before they would be aware of the hazard without the service and may be particularly beneficial if the hazard is in an area with low visibility. This should enable drivers to have more time to prepare and navigate safely past the slow/stationary vehicle. In the DRIVE C2X study, a decrease in speed was observed for vehicles participating in the trial.

The DRIVE C2X study used accident statistics for single vehicle accidents with an object other than a pedestrian for three road types (motorways, rural roads and urban roads) to scale up the FOT results to EU level. The following assumptions were then made to scale up the potential safety impacts:

- 10-20% of accidents with an object other than a pedestrian the object would be a broken down vehicle.
- The effectiveness of car breakdown warning would vary depending on road type. The percentage of accidents prevented by road type is given below.
    - Motorways: 70-90%
    - Rural roads: 65-85%
    - Urban roads: 30-50%

Using these findings, the authors presented data in terms of the number of expected injuries and fatalities prevented (TNO, 2014). For the year 2030, this has been estimated to be between 12-125 fatalities and 427-2794 injuries (figures assume 76% fleet penetration). The high scenario in DRIVE C2X equates to an average **1.1% decrease in fatalities and a 0.7% decrease in injuries**.

The eIMPACT study also covered this service as part of the wireless location danger warning (one aspect of which is obstacle/stationary vehicle warning). In total, this service is estimated to have a 4.5% reduction in fatalities and a 2.8% reduction in injuries. This estimate assumes 100% penetration and the results are presented for EU-25 level. These values are much larger than those predicted by DRIVE C2X, however this is likely due to the fact that in eIMPACT, weather conditions were also considered as part of the wireless location danger warning service.

To check for agreement between the two sources, the DRIVE C2X safety impacts for slow or stationary vehicle(s) and weather warning were added together. This gave a total impact of 4.56% on fatalities and a 4.04% impact on accidents. The impact on fatalities compares well to eIMPACT data, however the combined impact on injuries for slow or stationary vehicle and weather warning predicted by DRIVE C2X is larger than that predicted by eIMPACT.

The DRIVE C2X data has been used in preference to the eIMPACT data for input into the model, as it is based on FOT data and because it provides a separate impact for slow or stationary vehicle warning, whereas eIMPACT does not.

Other impacts

User acceptance for the car breakdown, or slow or stationary vehicle warning was one of the highest observed during the DRIVE C2X project and was widely noted to be a very helpful feature. Drivers particularly liked the increased feeling of safety gained by reducing the surprise of encountering a slow, stationary, or broken down vehicle in the road (TNO, 2014).

5.12.4. Traffic jam ahead warning (TJW)

Service Overview

The Traffic Jam Ahead Warning (TJW) provides an alert to the driver on approaching the tail end of a traffic jam at speed - for example if it is hidden behind a hilltop or curve. This allows the driver time to react safety to traffic jams before they might otherwise have noticed them themselves. The primary objective is to avoid rear end collisions that are caused by traffic jams on highways.

This service is applicable for all road and vehicle types, however its main benefit is expected to be on high speed roads (TEN-T Corridors, TEN-T Core and TEN-T Comprehensive network), where the system will be able to warn of traffic ahead faster than the driver is capable of identifying the danger. This service currently predominantly relies on V2V direct short-range communication, although a number of projects are looking to demonstrate its effectiveness using high-speed (e.g. 4G/5G) cellular networks.

Impacts

The main data source for the impacts of TJW was the DRIVE C2X project (TNO, 2014). An overview of the general methodology is provided in Table 46.

For TJW, Field tests were carried out at the test sites in Spain, Italy and Germany. The test site in Germany had such a small number of traffic jams that no impacts were found. Italy also had a small number of events recorded – since real vehicle queues did not occur at all, artificial TJW events were triggered manually in high traffic density situations on motorways. Similarly, the test site in Spain had few traffic jams occurring, mainly in urban areas. Since the TJW events from Italy and Spain came from two different traffic scenarios (highway vs. urban roads respectively), it was difficult to draw a conclusion on the effectiveness from the pooled data. Nevertheless, an assessment was made using the available information and expert judgement.

In addition to DRIVE C2X, the EasyWay study considered the safety impacts of TJW (EasyWay, 2012). The EasyWay figures were based on the eIMPACT project from 2008, which scaled the values up to EU-25 level, therefore the DRIVE C2X data were used in preference. An overview of the methodology for the EasyWay project is provided in Table 48.

Table 48: Overview of key data source – EasyWay project

The cost-benefit analysis carried out in the EasyWay study considered the impacts of C-ITS on road safety, efficiency and congestion/traffic efficiency as well as fuel consumption and emissions. The analysis was carried out for the year 2030 and assumed 100% of all vehicles will be equipped with some form of communication device that can facilitate cooperative services. The study assumed that one third will be installed by OEMs, one third will be aftermarket devices and one third will be nomadic devices.

Primary data (for 2010) was obtained from national representatives and usually came from gathered national statistics, including:

- Vehicle fleet compositions
- Vehicle kilometres driven by road type
- Road accident statistics by severity (i.e., fatalities, injured, property damage etc.)
- Congestion (i.e., delays),
- Emissions (NO_x, CO, PM2.5)
- Fuel Economy/CO2 emissions for diesel and petrol cars
- Road infrastructure deployment

In cases where data was missing, the missing data was estimated by interpolating/extrapolating between countries with similar characteristics (left undefined by authors), the resulting estimates were then sent for approval form that country's representatives in the task.

To make more robust estimates for C-ITS impacts, adaptations were made to account for changes in driving behaviour and travel behaviour. These adaptations were based on simple models taken from various literature sources. The key sources were:

- Kulmala, R.; Leviäkangas, P.; Sihvola, N.; Rämä, P.; Francics, J.; Hardman, E.; Ball, S.; Smith, B.; McCrae, I., Barlow, T.; Stevens, A. (2008). CODIA Deliverable 5: Final Study Report. CODIA Co-Operative systems Deployment Impact Assessment. Submitted to European Commission DG-INFSO

- Wilmink I., Janssen W., Jonkers E., Malone K., van Noort M., Klunder G., Rämä P., Sihvola N., Kulmala R., Schirokoff A., Lind G., Benz T., Peters H. & Schönebeck S. (2008). Impact assessment of Intelligent Vehicle Safety Systems. eIMPACT Deliverable D4. Version 1.0 April 2008.

- Janssen W.H., Brouwer R.F.T. and Huang Y. (2004). Risk trade-offs between driving behaviour and driver state. AIDE Deliverable D2.3.2.

- Nilsson G. (2004). Traffic Safety Dimensions and the Power Model to describe the effect of speed and safety. Bulletin 221. Department of Technology and Society. Lund University. Sweden.

The data required to parametrise these models were usually taken from the same papers that presented the models. For example, for *hazardous location notification*

- It is assumed that it comprises of low friction warnings and low visibility warning. The corresponding estimated safety improvements are: 5% and 12% reductions in injury crashes, respectively; and 10% and 23% reductions in fatal crashes, respectively [Kulmala et. al. (2008) Nilsson (2004)]

- Following Kulmala et. al. (2008) and Janssen et. al. (2006), the effects of increased awareness is assumed to further reduce the risk of accidents by 11%

- Kulmala et. al. (2008), utilising the results of Janssen et. al. (2006) estimated an overall headway-related crash risk decrease of 4%

- Assuming that speed awareness and headway effects are independent (an assumption that is made for all mechanism and sub-mechanisms in adapting for behavioural changes) safety impacts for *hazardous location notification* is -22% (0.915 x 0.89 x 0.96 = 0.78) for injuries and -29% (0.835 x 0.89 x 0.96 = 0.71) for fatal accidents/fatalities.

Finally, the forecasts for 2030 were estimated from the 2010 data by utilising any existing national forecasts and the forecasts provided by the eIMPACT (Wilmink et al. 2008) and CODIA projects (Kulmala et al. 2008). In addition, the general energy use and CO2 forecast were taken from European Energy and Transport Trends to 2030 (published in 2007)[161]. Note that for safety, the 2020 forecast was used for the 2030 forecast because the authors assumed that almost all additional safety improvement between 2020 and 2030

[161] http://ec.europa.eu/dgs/energy_transport/figures/trends_2030_update_2007/energy_transport_trends_2030_update_2007_en.pdf

would result from cooperative systems. As for the other estimates, all forecasts were validated by the national representatives.

Source: (EasyWay, 2012).

Traffic efficiency and congestion

In DRIVE C2X, the traffic efficiency impacts of TJW were examined using traffic simulation, which did not show any statistically significant changes in traffic efficiency (TNO, 2014). This is because TJW affects how a driver approaches the tail of a traffic jam and will not affect the duration of the traffic jam. Multiple simulation runs also found that there were no second order effects impacting the characteristics of an existing traffic jam (TNO, 2014), and hence this impact was considered insignificant for the purposes of this study. Therefore, zero impact was assumed for this impact category in the model.

Fuel consumption and CO_2

The primary effect of TJW is intended to be on safety. Hence the fuel efficiency impacts are expected to be minimal. Minor reductions in fuel consumption could occur if a driver were able to decelerate more economically. Nevertheless, the effects are small and valid only for a short distance influenced by the traffic jam. The results from DRIVE C2X confirmed that impacts on fuel efficiency were statistically insignificant and could not be scaled up to the EU level (TNO, 2014).

Environmental and emissions impacts

The primary effect of TJW is intended to be on safety. Hence the environmental impacts are expected to be minimal. Minor reductions in pollutant emissions could occur if a driver were able to decelerate more economically. Nevertheless, the effects are small and valid only for a short distance influenced by the traffic jam. The results from DRIVE C2X confirmed that impacts on pollutants were statistically insignificant and could not be scaled up to the EU level (TNO, 2014).

Safety

The primary safety benefit provided by TJW is to avoid a rear-end collision due to ensuring earlier driver awareness of a traffic jam tail (TNO, 2014). In case of high traffic flow, there might be problems of side-by-side collisions and other accident types as well if drivers carry out panic manoeuvres.

In DRIVE C2X, safety effects were presented for the EU-28 as a percentage reduction in fatalities or injuries in 2030, corresponding to various scenarios, which are based on a combination of different fleet penetration levels and the level of ambition of safety impact estimates.

Specifically, positive effects that were expected are:

- The driver will slow down earlier than without TJW.
- The driver will slow down to a lower speed than without TJW.

- The driver will not slow down earlier, but be able to react faster on approach to the traffic jam.
- The driver may also brake more smoothly when reaching the traffic jam, or to keep the lane in case of high traffic flow.

A possible rebound effect is that the driver would pay less attention to potential traffic jams due to relying on the system. However, the information provision is dependent on equipped vehicles being present to send the warning.

When the user of TJW approaches the traffic jam more smoothly, the non-users behind will most likely do so, too. The amount of fatalities and injuries in rear collisions caused by traffic jam to be prevented was assessed to be 1-5% for all driving environments due to smoother non-user driving behaviour. The impact was assessed to be 5-10% of the impact for rear collisions to other accident types except frontal collisions.

In DRIVE C2X, FOT results were scaled up to EU-28 level based on the number of traffic jams in the EU-27. This was based on data from the Netherlands, since information for the EU was not available.

In the DRIVE C2X high scenario, the overall safety impact of TJW was calculated to be up to 193 prevented fatalities and up to 16,619 prevented injuries per year in the EU-28 in 2030. This is equivalent to a 1.7% reduction in fatalities and a 2.5% reduction in injuries.

The EasyWay project calculated the impact of the traffic jam ahead warning service on injury and fatal accidents at EU-27 level. The results from this study are shown below:

- Injury accidents and injuries: Average 2.8% reduction in injuries
    - (-4.9% on motorways, -4.1% on interurban and rural roads, and -2.0% on urban roads)
- Fatal accidents and fatalities: Average 2.4% reduction in fatalities
    - (-3.3% on motorways, -2.8% on interurban and rural roads, and -1.6% on urban roads)

These values are higher than those calculated by the DRIVE C2X report (see Table 49), however the benefits are separated by road type, as desired for the modelling. It was decided to use the DRIVE C2X data as an input to the model (given the fact that it is based on FOTs) but the impact was scaled for each road type based on the ratios from the EasyWay studies. This gave the following safety impacts:

- Motorways: 2.4% reduction in fatalities, 4.4% reduction in injuries
- Other interurban roads: 2.0% reduction in fatalities, 3.7% reduction in injuries
- Urban roads: 1.2% reduction in fatalities, 1.8% reduction in injuries

Table 49: Summary of safety impacts of the traffic jam ahead warning service stated in various EU studies

Study	Fatalities (reduction)	Injuries (reduction)	Scenario
DRIVE C2X	1.74%	2.52%	76% penetration, high safety impact estimate EU-28, 2030
EasyWay	2.4% (average) 3.3% (motorways) 2.8% (interurban roads) 1.6% (urban roads)	2.8% (average) 4.9% (motorways) 4.1% (interurban roads) 2.0% (urban roads)	100% penetration EU-27, 2030

<u>Other impacts</u>

Subjective assessment carried out in DRIVE C2X using stakeholder input suggested that TJW could help to achieve very slight decreases in stress and uncertainty, and contribute to slightly increased feelings of safety and comfort (TNO, 2014). The scores provided on a rating scale however fell close to the middle (i.e. a neutral impact) and therefore the effects are considered in this IA to be insignificant overall. User acceptance was relatively high, with 79% of the respondents in the DRIVE C2X survey willing to use the function (TNO, 2014).

There were no indications of any impact on modal shift (TNO, 2014).

5.12.5. Hazardous location notification (HLN)

Service Overview

This service gives drivers an advance warning of upcoming hazardous locations in the road. Examples of these hazards include a sharp bend in the road, steep hill, pothole, obstacle, or slippery road service. Using this information, drivers will be better prepared for upcoming hazards and will be able to adjust their speed accordingly.

Hazardous locations are automatically detected by vehicles in response to changing driving behaviour or information gained from vehicle information systems. For example, a sharp bend may be detected by rapid braking and change of vehicle direction, while a pothole may be detected by a vehicle's electronic stability control system. Information concerning the specific location and type of danger is retained and sent to vehicles in the surrounding area, warning of the hazard. This service is suitable for all vehicles and road types and may be used in combination with data gained from V2I services such as weather warning and in-vehicle signage. Whilst it is expected to rely primarily on V2V ITS-G5 communication, a number of projects are looking to demonstrate its effectiveness using high-speed (e.g. 4G/5G) cellular networks.

Impact data

The main data sources for the impacts of the hazardous location notification service are the EasyWay, eIMPACT, CODIA, NordicWay Coop and eSafetyForum Intelligent Infrastructure Working Group reports. The EasyWay and CODIA projects uses estimates from eIMPACT. An overview of the general methodology for the eSafetyForum Intelligent Infrastructure Working Group Report is provided in Table 51, while an overview of CODIA is provided in Table 50.

Table 50: Overview of key data source - CODIA

The CODIA study (Co-Operative Systems Deployment Impact Assessment) aimed to evaluate the costs, impacts and benefits of five C-ITS services, namely:

- Speed adaptation due to weather conditions, obstacles or congestion (V2I)
- Reversible lanes due to traffic flow (V2I)
- Local danger / hazard warning (V2V)
- Post-crash warning (V2V)
- Cooperative intersection collision warning (V2V and V2I)

The potential impacts of the selected C-ITS services were assessed up to the year 2030 and considered the entire vehicle fleet in EU-25 countries. Data was obtained from a wide range of literature sources including scientific journals, relevant EU R&D projects (in particular the COOPERS, CVIS and SAFESPOT projects) and the US DoT, For the impact assessment. The majority of vehicle, accident and traffic data was obtained from the eIMPACT project.

As many systems were not fully defined while the study was being carried out, assumptions and key findings were validated with experts from the European Commission, related European research projects, industry, and academia.

Source: (VTT, TRL, 2008)

Table 51: Overview of key data source - eSafetyForum Intelligent Infrastructure Working Group Final Report

The eSafetyForum Intelligent Infrastructure Working Group (II WG) was formed to define Intelligent Infrastructure. The II WG aimed to answer five key questions, which are addressed in the Final Report:

What is intelligent infrastructure?

Which services contribute to the implementation of Intelligent Infrastructure?

Which technological resources are necessary for these services and which business areas need to implement them?

What needs to be done to assist/promote the implementation of these technological resources and services?

What is the relation between Intelligent Infrastructure and Intelligent Vehicles?

As part of this report, a literature review, surveying over 20 papers was performed to assess the potential benefits and added value for a number of C-ITS services. Data for three impact categories (impact on fatalities/injuries, impact on congestion, impact on CO_2 emissions) were gathered for a variety of services. Services covered which are relevant to this study are: real time event information, real time traffic information, travel time information, weather information, speed limit information, parking information and guidance, local hazard warning, dynamic route guidance, emergency vehicle warning, wrong way driving warning, road user charging, requesting green/signal priorities, and intelligent truck parking.

The final report mentions a number of limitations of the values presented, noting that "figures are all based on detailed specifications of the system in question" and that "similar systems with a different technology set-up or different content quality may have largely deviating estimates of effectiveness with regard to safety, efficiency, mobility and environment". The report stresses that local effects will be vastly different to EU scale impacts, although does not state whether the results presented are for single events, or for EU level. Further to this, penetration rates are not given for the impact data and results are not broken down by vehicle type, road type, or accident type (in the case of safety impacts).

At the time of publication (2010), few evaluation studies for cooperative systems had been performed and furthermore, the authors stated that very few quantitative estimates of the impacts have been produced. As a result, data from this study was treated with caution and was only used in the absence of any other data.

Traffic efficiency

The eSafetyForum Intelligent Infrastructure Working Group Final Report found a 2-10% reduction in congestion. The report does not specify penetration level, vehicle type or road type (eSafetyForum, 2010). Further to this, it is unclear whether this is the impact of a single event, or whether the results were scaled up to EU level (as discussed in Table 51). The lower end of this range was therefore assumed, i.e. an impact of **2% improvement in speed across all vehicle types on urban roads**.

Fuel consumption and CO_2

No data was identified for this impact category in the reports reviewed. The primary effect of the hazardous location service is intended to be on safety, hence the fuel efficiency impacts are expected to be minimal. No fuel efficiency benefits are therefore anticipated on an EU level as a consequence of this service and it is not included as part of the model.

Environmental and emissions impacts

No data was identified for this impact category in the reports reviewed. The primary effect of the hazardous location service is intended to be on safety, hence the emissions impacts are expected to be minimal. No emissions benefits are therefore anticipated on an EU level as a consequence of this service and it is not included as part of the model.

Safety

The safety impacts of this service were covered by several papers. The EasyWay study calculated the impact of the hazardous location service on injuries and fatalities by taking into consideration the expected change in vehicle speed (as discussed in Table 48). The impacts were also calculated by road type, therefore this data is used in preference to those given by the eSafetyForum Intelligent Infrastructure Working Group Final Report and the CODIA study. However, correspondence with a project representative from the NordicWay Coop project suggested that the values are lower, as displayed in Table 52. **A 30% reduction has therefore been applied to the CODIA study impact values to take into account the new NordicWay data.**

The impact on injuries and accidents calculated by EasyWay (and now scaled down by 30%) were used in the model as they build on the CODIA study and are broken down by road type. The impacts are as follows:

- Injury accidents and injuries: Average 3.1% reduction
    - This is equivalent to **-3.7% on motorways, -3.7% on interurban and rural roads, and -1.3% on urban roads**
- Fatal accidents and fatalities: Average 4.1% reduction
    - This is equivalent to **-3.6% on motorways, -3.7% on interurban and rural roads, and -1.2% on urban roads**

The eSafetyForum report (eSafetyForum, 2010) gives a value of 2-10% for the estimated reduction in fatalities/injuries. Assuming the average of this range is taken (6%), this value is significantly larger than the averages reported by EasyWay. The objective of the eSafetyForum report was to given an indication of the possible benefits, therefore the range is likely to capture all estimates, regardless of whether some data points may be outliers.

The CODIA report (VTT, TRL, 2008) also assessed the impact of local danger warnings. At 100% penetration, the authors state that a 4.2% reduction in fatalities and a 3.1% reduction in injuries is expected, provided that the system is used for all vehicle kilometres driven.

Table 52: Summary of safety impacts for the hazardous location service, as reported in EU C-ITS studies

Study	Fatalities (reduction)	Injuries (reduction)	Scenario
EasyWay	4.1% (average) 5.2% (motorways)	3.1% (average) 5.3% (motorways)	100% penetration EU-27, 2030

Study	Fatalities (reduction)	Injuries (reduction)	Scenario
	5.3% (interurban and rural roads) 1.7% (urban roads)	5.3% (interurban and rural roads) 1.9% (urban roads)	
eSafetyForum	2-10%	2-10%	Not stated
CODIA	4.2%	3.1%	100% penetration, expected impact if all vehicles were equipped, regardless of year
NordicWay	2.1%	2.5%	31-65% traffic flow penetration (all main roads) Finland, 2030

Other impacts

No data related to other impacts was identified in the reports reviewed.

5.13. Bundle 5 - C-ITS V2I motorway focused applications

The impact data presented in this section are from the 2019 C-ITS impact assessment support study, which reviewed and updated the information that was collected for the 2016 C-ITS deployment study. The services in Bundle 5 cover day 1 vehicle-to-infrastructure C-ITS services, divided into two broad service types. This section covers services that are typically more relevant to highway environments, although impacts can be realised across the network: In-vehicle signage and speed limits, Probe Vehicle Data, Roadworks Warning, Weather Conditions, and Shockwave Damping. As with Bundle 4 and described in Section 5.12, safety impact overlap with the GSR is accounted for.

5.13.1. In-vehicle signage (VSGN)

Service Overview

In-vehicle signage is a vehicle-to-infrastructure (V2I) service that informs drivers of relevant road signs in the vehicle's vicinity, alerting drivers to signs that they may have missed, or may not be able to see. The main purpose of this service is to provide information, give advance warning of upcoming hazards and increase driver awareness.

Via V2I communication, information about relevant road signs is provided to the driver. Roadside units may be mounted on traffic signs and key points along roads, informing drivers of potentially dangerous road conditions ahead, speed limits and upcoming junctions. Alternatively, this information may be transmitted via the local cellular network.

This service is applicable to all vehicle and road types, although may have particular benefits on motorways.

Impact data

Data availability for impacts directly related to in-vehicle signage was extremely limited. The DRIVE C2X project tested six specific road signs (children, merge, pedestrian crossing ahead, pedestrian crossing, stop, yield), however trials were on a small scale and quantitative assessments of specific impacts were limited to two very specific road signs (pedestrian crossing and children sign) (TNO, 2014). An overview of the general methodology of DRIVE C2X is provided in Table 46.

A report by the US Department of Transport NHTSA also estimated the impact of several road signs, however impacts were only given in terms of reduction in accidents and were not further categorised by severity.

Traffic efficiency

Although in-vehicle signage may influence traffic in a very local environment the effects are expected to be limited on an EU level, with the primary effect intended to be on safety. As in-vehicle signage is not expected to have a significant effect this impact is not included in the model. This is confirmed by the DRIVE C2X study, which did not consider the effect on traffic efficiency for this service.

Fuel consumption and CO_2

The primary effect of in-vehicle signage is intended to be on safety, hence the fuel efficiency impacts are expected to be minimal. No fuel efficiency are therefore anticipated on an EU level as a consequence of this service and it is not included as part of the model. This is confirmed by the DRIVE C2X study, which did not consider the effect on fuel consumption for this service.

Environmental and emissions impacts

The primary effect of in-vehicle signage is intended to be on safety, hence the emissions impacts are expected to be minimal. No emissions benefits are therefore anticipated on an EU level as a consequence of this service and it is not included as part of the model. This is confirmed by the DRIVE C2X study, which did not consider the effect on emissions for this service.

Safety

The DRIVE C2X study estimated safety impacts based on small scale trials of only two signs: pedestrian crossing and child sign. The impact data for the high scenario is as follows:

- Impact on fatalities: 1.04% reduction
- Impact on injuries: 0.46% reduction

As DRIVE C2X only based the impacts on the pedestrian crossing and child road signs, the impacts of other types of road signs were estimated based on data from the US DoT report (John A. Volpe National Transportation Systems Center, 2008) This report estimates that a stop sign violation warning is expected to lead to a 0.088% reduction in annual light vehicle crashes. The same impact for a merge was assumed, stop and yield sign, leading to the following impacts per road type:

- Motorways:
    - Impact on **fatalities: 1.04% reduction** (from DRIVE C2X)
    - Impact on **injuries: 0.46% reduction** (from DRIVE C2X)
- Other interurban roads:
    - Impact on fatalities: 1.04% (from DRIVE C2X) + (3 x 0.088%) (applying the value of 0.088% from US DoT report for stop sign violation and assuming the same impact for merge, stop and yield signs) = **1.30% reduction in fatalities**
    - Impact on injuries: 0.46% (from DRIVE C2X) + (3 x 0.088%) (applying the value of 0.088% from US DoT report for stop sign violation and assuming the same impact for merge, stop and yield signs) = **0.72% reduction in injuries**
- Urban roads:
    - Impact on fatalities: 1.04% (from DRIVE C2X) + (3 x 0.088%) (applying the value of 0.088% from US DoT report for stop sign violation and assuming the same impact for merge, stop and yield signs) = **1.30% reduction in fatalities**
    - Impact on injuries: 0.46% (from DRIVE C2X) + (3 x 0.088%) (applying the value of 0.088% from US DoT report for stop sign violation and assuming the same impact for merge, stop and yield signs) = **0.72% reduction in injuries**

Other impacts

No data related to other impacts was identified in the reports reviewed.

5.13.2. In-vehicle speed limits (VSPD)

Service Overview

In-vehicle speed limits are 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, or if the driver exceeds or drives slower than the speed limit.

Roadside units at key points along roads can broadcast information to drivers about speed limits, ensuring that drivers are aware of the permitted driving speed. Alternatively this information may be transmitted via the local cellular network. This service is applicable to all vehicle and road types, however, may have particular benefits when warning drivers of changing speed limits when travelling along high speed roads.

Impacts

The main data source for the impacts of in-vehicle speed limits was the DRIVE C2X project (TNO, 2014). An overview of the general methodology is provided in Table 46. This service was trialled at test sites in Finland, Italy, Spain and Sweden in DRIVE C2X and the data was used to produce EU-level impact data reported in the DRIVE C2X impact assessment.

Other studies that considered the impacts of in-vehicle speed limits include eIMPACT, eSafetyForum Intelligent Infrastructure Work Group and SAFESPOT (TNO, VTT, Movea, PTV, BASt, 2008), (SAFESPOT, 2010). DRIVE C2X refers to and builds on many of these studies; the DRIVE C2X study is therefore believed to be a more reliable source of data as it is based on more recent estimates and FOT results.

<u>Traffic efficiency</u>

The primary objectives of the in-vehicle speed limit service are to decrease speed and improve safety. The increase in delay per vehicle-km found in the DRIVE C2X study (TNO, 2014) is therefore not surprising and can be attributed to a higher awareness of speed limits. Many traffic efficiency effects observed in the DRIVE C2X study were not statistically significant, with the only significant results being found for motorways and rural roads during off-peak times. The authors argue that this is because the impact was measured at specific point on the road (which may be subject to larger variations) rather than if speed was measured over a long stretch of road. The overall delay for different road types is shown below:

- 0.6 seconds per kilometre on motorways
    - seconds per kilometre on rural roads
- No significant effect on delay on urban roads

The eIMPACT and eSafetyForum Intelligent Infrastructure Working Group studies also considered the impact of in-vehicle speed limits on speed. The results of these studies are summarised below:

- eSafetyForum: Speed limit information 2-10% reduction in congestion.
- eIMPACT - average change in speed:
    - Motorways: 1.1% increase (low demand), 0.6% increase (high demand)
    - Rural roads: 1.0% decrease (low demand), 0.9% decrease (high demand)
    - Urban roads: 1.4% decrease (low demand), 1.7% decrease (high demand)

Change in speed was only modelled for urban roads in TRT's ASTRA model. DRIVE C2X showed that in-vehicle speed limits did not have a statistically significant impact on urban roads, however further trials are needed to confirm this.

As an input to the model the average speed change from the eIMPACT project was therefore scaled for urban roads based on vehicle kilometres driven in high demand and low demand situations, to give an average **1.40% reduction in vehicle speed in urban areas**. The reduction was only applied to passenger cars and not to public transport.

Fuel consumption and CO_2

Fuel consumption benefits were seen for the in-vehicle speed limits function in the DRIVE C2X study, which is likely to be due to a smoother driving style. Specifically, greater awareness of speed limits may reduce sudden acceleration and braking manoeuvres. The DRIVE C2X FOT only found a statistically significant reduction in fuel consumption on motorways and on rural roads. The DRIVE C2X study provides impact data for two scenarios:

- speed limit information shown only in the vicinity of road signs
- speed limit information displayed continuously

A much greater impact was observed when speed limit information was displayed continuously (TNO, 2014). In practice, speed limit information may not be displayed continuously if a variety of C-ITS services are implemented into a vehicle, therefore the values for speed limit information shown only in the vicinity of road signs were used.

The impacts of in-vehicle speed limits were scaled up from FOT scale to EU-27 level based on the number of vehicle-kilometres travelled, in order to determine absolute fuel savings (in tonnes). The figures for the high penetration level (76%) were converted to percentages based on the share of vehicle kilometres travelled on each road type, which gave a **2.3% fuel saving on motorways** and a **3.5% fuel saving on other interurban roads**. These values are in the range suggested by the eSafetyForum study, which stated a 2-10% reduction in CO_2 emissions (eSafetyForum, 2010).

Environmental and emissions impacts

Minor environmental benefits were seen on motorways for the in-vehicle speed limits function in the DRIVE C2X study, which is likely to be due to a smoother driving style. Specifically, greater awareness of speed limits may reduce sudden acceleration and braking manoeuvres. However, on other interurban roads, DRIVE C2X estimates a small increase in emissions, particularly PM emissions, likely due to increased braking or speed changes when approaching new speed limits. No significant effect was observed in urban areas.

The absolute emissions changes stated in DRIVE C2X for the high penetration level (76%) were converted to percentage savings on each road type, based on vehicle-kilometres driven on EU roads. The following values were inputted into the model:

- NO_x: 0.5% reduction (motorways), 0.4% reduction (other interurban roads), zero change (urban roads)
- PM: 0.4% decrease (motorways), 4.2% increase (other interurban roads), zero change (urban roads)
- CO: 0.2% reduction (motorways), 0.2% increase (other interurban roads), zero change (urban roads)
- VOCs: 0.1% increase (motorways), 0.5% increase (other interurban roads), zero change (urban roads)

Safety

The primary function of in-vehicle speed limits is intended to be reducing speeding; an improvement in road safety is therefore expected. The DRIVE C2X study confirms this assertion and reports significant reductions in both injuries and fatalities, however the magnitude of these impacts varies depending on whether speed-limit information is shown to the driver continuously or only in the vicinity of road signs. If speed limit information is only shown in the vicinity of road signs the number of prevented fatalities is estimated to be 121-768 in 2030, whereas if information is provided continuously, an estimated 566-1772 prevented fatalities is expected. In practice, speed limit information may not be displayed continuously if a variety of C-ITS services are implemented into a vehicle, therefore the values for speed limit information shown only in the vicinity of road signs were selected for the modelling inputs.

The values for the high scenario were converted to percentages based on projected EU fatalities in 2030 (as stated in the DRIVE C2X report). This is equivalent to a **6.9% reduction in fatalities** and a **3.9% reduction in injuries, applied to passenger cars and freight for all road types in the modelling.**

A number of other studies covered the safety impacts of in-vehicle speed limits, as summarised in Table 53.

Table 53: Summary of safety impacts of in-vehicle speed limits

Study	Fatalities (reduction)	Injuries (reduction)	Scenario
DRIVE C2X	6.93%	3.93%	High penetration (100% in cars, overall 76% system penetration, high safety impact estimate) EU-28, 2030
eIMPACT	8.7%	6.2%	100% penetration EU-25, 2020

SAFESPOT	7.1%	4.9%	100% penetration EU-25, 2020
eSafetyForum	2-10%	2-10%	Not stated
CODIA	7.2%	4.8%	100% penetration for light/heavy vehicles, 55% of driven km

The eIMPACT project estimated an 8.7% reduction in fatalities and a 6.2% reduction in injuries, assuming 100% penetration at EU-25 level. In comparison with DRIVE C2X data, the impact on both fatalities and injuries is higher.

SAFESPOT also assesses the impact of in-vehicle speed alerts and estimates a 7.1% reduction in fatalities and a 4.9% reduction in injuries at an EU-25 level, assuming 100% penetration in 2020 (SAFESPOT, 2010). The estimation of impacts is based on the eIMPACT and CODIA studies and are comparable to those stated in DRIVE C2X.

The eSafetyForum study estimates a 2-10% reduction of fatalities/injuries. The average of this (6%) is comparable with the DRIVE C2X figure for fatalities avoided, however it is much higher than the figure for injuries. This may be because the impacts on fatalities and injuries were not treated separately as part of the eSafetyForum literature review.

CODIA estimated the effect of a service called 'dynamic speed adaptation' at a 100% penetration rate. The expected reduction in fatalities was stated as 7.2%, while the reduction in injuries was estimated to be 4.8%. These figures are comparable to a number of studies covered here.

We have used the DRIVE C2X figures as inputs to the model as the values are based on FOT data and build on the findings of earlier EU studies in this field.

<u>Other impacts</u>

Stakeholder inputs during the DRIVE C2X project (TNO, 2014) suggest that user acceptance for in-vehicle speed limits is in-line with other C-ITS services. Drivers found warning messages useful when they exceeded the speed limit, however only 28% felt that the system provided benefits that were not provided by other functions on the market. This is likely due to satellite navigation systems providing this capability.

Qualitative effects of in-vehicle speed limits were a reported improvement in comfort and safety, however the impact on stress was questionable. Mean values for these impacts were assessed at 4.2-5.2 for comfort (on a scale from 1, strongly disagree to 7, strongly agree), and 5.2 for safety.

There were no reported impacts on modal shift.

5.13.3. Probe Vehicle Data (PVD)

Service Overview

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, road operators may use the data to improve traffic management.

Also known as Floating Car Data (FCD), probe vehicle data refers to the collection of data generated by vehicles. Information on a variety of vehicle parameters may be collected, including positional information, time stamp and direction of motion. Driver actions such as steering, braking, flat tyre, windscreen wiper status, air bag status, as well as weather and road surface conditions can also be transmitted and collated. This probe vehicle data is used to manage traffic flows, maintain roads and to alert users in hot spots, where the danger of accidents accumulates. This service is applicable to all road and vehicle types, although may be most useful on motorways. It has the potential to deliver safety, efficiency, vehicle operation and environmental benefits. It can be delivered via the presence of roadside units to aggregate and re-transmit the data, or via the use of cellular networks.

Impacts

The main data sources for the impacts of the probe vehicle data service were the EasyWay and eIMPACT projects. No other publically available studies that examine probe vehicle data specifically were identified.

<u>Traffic efficiency</u>

In TRT's ASTRA model, traffic efficiency impacts are only modelled on urban roads. The majority of the benefits of probe vehicle data are expected to be realised on motorways, therefore the impact of this service on traffic efficiency on urban roads was assumed to be zero.

<u>Fuel consumption and CO_2</u>

In the CODIA study, two services called speed adaptation due to accident and speed adaptation due to poor weather were assessed. If added together, these services have similar functionality to the probe vehicle data service described in this project. CODIA estimated the impact on carbon dioxide emissions to be as follows (at 100% penetration in EU-25 countries):

- Speed adaptation due to accident: 58.5 tonnes reduction
- Speed adaptation due to poor weather: 27,682 tonnes reduction
- Speed adaptation total: 27,741 tonnes reduction (EU-25)

The carbon dioxide emissions were scaled up to EU-27 level based on vehicle kilometre data from TRT's ASTRA and TRUST models, and then divided by the total EU carbon dioxide emissions stated in DRIVE C2X. This is equivalent to a **0.006% reduction in fuel consumption** in EU-27 countries.

Environmental and emissions impacts

Impacts on emissions were also given in the CODIA study for the dynamic speed adaptation service (includes speed limit advice given as a consequence of weather, obstacles and congestion). The results calculated in the study on an EU-25 level for a 100% penetration scenario are summarised below:

Impact on NO_x emissions:

- Speed adaptation due to accident: 0.7 tonnes reduction
- Speed adaptation due to poor weather: 490 tonnes reduction
- Speed adaptation total: 491. tonnes reduction

Impact on PM emissions:

- Speed adaptation due to accident: 0.015 tonnes reduction
- Speed adaptation due to poor weather: 5.13 tonnes reduction
- Speed adaptation total: 5.12 tonnes reduction

These values are equivalent to the following percentages at EU level:

- 0.003% reduction in NO_x emissions
- 0.001% reduction in PM emissions

As no further data was available, the same CO reduction was assumed as for fuel consumption (assuming a linear relationship between carbon content and emissions). For VOC emissions, the same percentage reduction as for fuel consumption (0.006%) was applied.

Safety

The safety impacts of probe vehicle data are primarily related to extended probe vehicle data, where the emphasis is on informing the driver about adverse road conditions ahead, for example adverse weather conditions. Safety impacts of probe vehicle data were reported in the EasyWay study (EasyWay, 2012). The following impacts were estimated (for EU-27, 100% penetration):

- Injury accidents and injuries: overall **2.8%** reduction (4.9% on motorways, 4.1% on interurban and rural roads, and 2.0% on urban roads)
- Fatal accidents and fatalities: overall **2.4%** reduction (3.3% on motorways, 2.8% on interurban and rural roads, and 1.6% on urban roads)

Other impacts

No data related to other impacts was identified in the reports reviewed.

5.13.4. Roadworks warning (RWW)

Service Overview

Roadworks warnings enable 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.

Roadside units are mounted on road works, enabling messages and instructions to be sent to approaching drivers, either directly via short-range communications, or via the cellular network. This service is applicable to all road and vehicle types.

Impacts

The main data source for the impacts of roadworks warning was the DRIVE C2X project (TNO, 2014) An overview of the general methodology is provided in Table 46. For roadworks warning, tests were carried out at test sites in Finland, Italy and Sweden. In DRIVE C2X, this service is evaluated in the same section as 'obstacle warning' and 'car breakdown warning', as the services perform a similar function, act via similar mechanisms and present information to drivers in a similar manner.

Another data source considered was the NordicWay project (Innamaa et al., 2017) which considered the safety impacts of roadworks warning, delivered by roadside systems. NordicWay deployed cooperative services via a cellular network along a corridor spanning Finland, Sweden, Denmark and Finland. 'NordicWay Coop' was a project along the Finnish part of the corridor that deployed safety related services. Data from this project has been examined for the roadworks warning service impacts.

No other publicly available studies that examine roadworks warning specifically were identified.

<u>Traffic efficiency</u>

The traffic efficiency impacts of the roadworks warning service are expected to be minimal as its purpose is to improve safety, rather than prevent traffic jams (TNO, 2014). No traffic efficiency impacts are expected when scaled up to EU level and it is not included as part of the model. This is confirmed by the DRIVE C2X study, which did not consider the effect on traffic efficiency for this service.

<u>Fuel consumption and CO_2</u>

Fuel efficiency impacts are expected to be negligible for this service when scaled up to an EU level. This is confirmed by the DRIVE C2X study, which did not consider the effect on fuel consumption for this service.

<u>Environmental and emissions impacts</u>

Impacts on vehicle emissions impacts are expected to be negligible for this service when scaled up to an EU level. This is confirmed by the DRIVE C2X study, which did not consider emissions impacts for this service.

Safety

The key objective of the roadworks warning service is to improve safety, which as described in the DRIVE C2X study can be achieved by reducing the likelihood of several different types of collisions. The types of collisions expected to be prevented the most by this service are side-by-side collisions, single vehicle collisions with obstacles and rear collisions (TNO, 2014). Specifically, the service is expected to:

- Warn drivers about upcoming roadworks (especially those outside of the field of vision) and therefore limit unsafe manoeuvres.
- Increase driver alertness.
- Help to avoid sudden braking or steering/swerving manoeuvres.
- Reduce speed in the proximity of roadworks, thus decreasing the severity of potential injuries.

DRIVE C2X scaled up safety impacts based on Swedish road safety statistics (TNO, 2014), which estimate that 2.3% of injuries and 3% of fatalities occur due to roadworks. The study assumes 100% infrastructure and vehicle penetration and assumes the following:

- Roadworks warning would only be effective for accidents caused due to inattention or lack of awareness (80-90% of accidents).
- Includes winter road maintenance work which does not take place in all parts of EU28. In those countries, the number of road works may be higher overall and may be made all year round (in Nordic countries, road works only take place in the summer).
- Effectiveness of the system was estimated to be 80-90% for rear collisions, single vehicle collisions with pedestrians and other obstacles. This high level of effectiveness is due to drivers expecting these types of hazards and has been based on previous naturalistic driving studies (Dingus, 2008).
- 80-90% system effectiveness was also assumed for 'other single vehicle accidents'. This category primarily includes driving off road during a panic manoeuvre, which would most likely be significantly reduced if roadworks warnings were operational.
- The effectiveness was estimated to be 70–80% for frontal collisions. This also represents panic manoeuvres.
- 60-70% effectiveness for other accident types. This lower effectiveness is due to the unexpected nature of these types of accident.

NordicWay also considered accidents at roadwork sites and in their influence area, which was assessed to be 1.5-2.2% of total road injury accidents. This value is taken from estimates of Danish roadwork related injury accidents. The following assumptions are also made:

- The main causal factor for roadworks related accidents is inattention around the critical moment/ location (Innamaa et al., 2017) and it is this factor that the warning system is attempting to influence.
- In general, the impact of roadworks warning was assumed to be less than for warnings of more surprising incidents such as accidents and obstacles on the road.
- The coverage of roadworks by the warning system is assumed to be 95-100%.
- A target year of 2030 is included in the analysis, which assumed penetration across the whole main road network in Finland (31-65% of total network).

In the DRIVE C2X high scenario, the overall safety impact for this service was calculated to be 209 prevented fatalities and 9,939 prevented injuries in EU-28 countries if the service was deployed in 100% of passenger cars (equivalent to a 76% fleet penetration). This is equivalent to a 1.9% decrease in fatalities and a 1.5% decrease in injuries.

The Drive C2X values were reduced by 30%, taking into consideration the lower safety impacts reported by NordicWay Coop. An average of the two project's values is not taken as the NordicWay values represent only a 31-65% penetration rate across Finland's road network. Furthermore, impacts on fatal accidents were assessed based on estimates of injury related accidents occurring at roadworks, which is lower than Swedish road safety statistics estimate for fatal accidents.

A **1.3% decrease in fatalities** and a **1.1% decrease in injuries** were used as inputs to the model. Impacts were assumed to be the same on all road types.

<u>Other impacts</u>

Subjective assessment carried out during the DRIVE C2X study using stakeholder input suggested that roadworks warning has limited usefulness, however the willingness to use the service remained rather high at 79%. Further assessment suggested that the impacts of the service on stress, comfort and feelings of uncertainty were minimal. There were no reported impacts on modal shift, or a change in travel patterns in the DRIVE C2X study.

5.13.5. Weather conditions (WTC)

Service Overview

The objective of this service is to increase safety through providing accurate and up-to-date local weather information. Drivers are informed about dangerous weather conditions ahead, especially where the danger is difficult to perceive visually, such as black ice or strong gusts of wind.

Vehicles are sent information from roadside units warning the driver of dangerous, or changeable weather conditions. Alternatively, the messages may be transmitted via the cellular network. This service is applicable to all roads and vehicle types.

Impacts

The main data source for the impacts of the weather conditions service was the DRIVE C2X project (TNO, 2014). An overview of the general methodology is provided in Table 46. FOTs took place in Finland and Spain as part of this project, with a total of 39 participants. In Finland, slippery road warnings were presented in winter conditions, while in Spain warnings about rainy conditions were shown.

Other studies that considered the impacts include eIMPACT (TNO, VTT, Movea, PTV, BASt, 2008), CODIA (VTT, TRL, 2008), eSafetyForum (eSafetyForum, 2010), EasyWay (EasyWay, 2012), SAFESPOT (SAFESPOT, 2010) and NordicWay (Innamaa et al., 2017). Much of the safety impacts data in these projects build on and the eIMPACT study. As the DRIVE C2X project incorporates FOT results into their estimates, values from this data source were used.

Traffic efficiency

The primary effect of the weather conditions warning is intended to be on safety, hence the traffic efficiency impacts are expected to be minimal.

The DRIVE C2X study did not assess the effect of this service on traffic efficiency, citing a lack of results to be able to qualitatively evaluate the service. CODIA assessed a "local danger warning due to poor weather" service, which led to an increase of 28,489 thousand hours on the road per year in EU25 at a 100% penetration rate. When converted to a percentage, the effect on time spent on the road is **less than 0.1%, applied to both cars and public transport on all road types in the modelling.**

Another service, 'speed adaptation due to poor weather' was also separately assessed in CODIA. The impacts associated with this service have not been included in this IA as the service definition for weather warning does not state that speed limit information will be provided to the driver.

Fuel consumption and CO_2

The primary effect of the weather conditions warning is intended to be on safety, hence the fuel consumption impacts are expected to be minimal on an EU level. The DRIVE C2X study did not assess the effect of this service on fuel consumption, however CODIA assessed a service called 'local danger warning due to poor weather'. At a 100% penetration level, a 47,407 tonnes per year reduction in carbon emissions at EU-25 level was calculated (VTT, TRL, 2008). This was scaled to EU-27 level based on vehicle kilometre data from TRT's TRUST and ASTRA models. The resulting value (48,444) was divided by the total annual EU CO_2 emissions stated in DRIVE C2X. This gives a **0.005% reduction in fuel consumption** at an EU-27 level**, which was applied to both cars and public transport on all road types in the modelling.**

Environmental and emissions impacts

Minor emissions benefits for the ‘local danger warning due to poor weather’ service were reported in CODIA. At a 100% penetration level, the following impacts on emissions were calculated by CODIA (VTT, TRL, 2008):

- 752.50 tonnes per year reduction in NO_x emissions at EU25 level
- 9.15 tonnes per year reduction in particulate matter emissions at EU25 level

These values are equivalent to the following percentages at EU level:

- 0.02% reduction in NO_x emissions
- 0.01% reduction in PM emissions

As further data was not available, the same CO reduction as for fuel consumption was assumed (assuming a linear relationship between carbon content and emissions). For VOC emissions, the same percentage reduction as for fuel consumption was applied. These values were applied **to cars and freight vehicles on all road types in the modelling.**

Safety

The objective of this service is to increase safety in adverse weather conditions such as ice, fog, rain, snow, sleet, hail and wind. The main impacts are expected to occur via direct in-vehicle modification of the driving task after drivers receive information about adverse weather conditions. Specifically, this service is expected to have a number of impacts:

- In conditions where the danger can easily be perceived (such as heavy rain), the notification serves as a reminder of the potential danger ahead, and increasing driver awareness.
- In situations where the danger cannot be easily be perceived (such as strong cross-winds, or black ice) drivers will receive valuable information regarding local weather conditions/hazards that they otherwise would not have known about.
- In both of the above situations, the driver will be more prepared for the hazard and will have the opportunity to adjust their speed accordingly, preventing sudden braking, accelerating, swerving or overtaking manoeuvres.

It is thought that any rebound effects from over-reliance on the system will be negligible. This is because the information used to deliver the service will come partially from other vehicles further ahead and therefore drivers cannot assume that there will always be suitably-equipped vehicles ahead (TNO, 2014).

DRIVE C2X scaled up safety impacts based on the impact on driver speeds, driver awareness and the headway between vehicles, using values from FOT data, expert estimates and estimates from the CODIA and eIMPACT projects. For the high scenario in 2030, this resulted in a projected **3.43% reduction in fatalities** and a **3.35% reduction in**

injuries, applied to cars and freight on all road types in the modelling. These values are supported by those reported in the NordicWay project.

Potential safety impacts of the weather conditions service are covered in many other studies, as summarised in Table 54. The values from DRIVE C2X are used as an input to the modelling in this project as they are based on FOT data and build on previous EU studies. A discussion of results from other studies is provided below for comparison.

Table 54: Summary of safety impacts of weather conditions services from EU studies

Study	Fatalities (reduction)	Injuries (reduction)	Scenario
DRIVE C2X	3.43%	3.35%	76% penetration, high safety impact estimate EU-28, 2030
NordicWay	3.5%	3.9%	100% penetration Finland, 2030
EasyWay	16.5% (average)	8.5% (average)	100% penetration EU-27, 2030
eIMPACT	4.5%	2.8%	100% penetration EU-25, 2020
SAFESPOT	1.6% (V2I) 16.4% (V2V)	0.7% (V2I) 8.6% (V2V)	100% penetration EU-25, 2020
eSafetyForum	2-4%	2-4%	Not stated

Estimations in the EasyWay project are based on the methodology from the CODIA project and state that if the base speed is 80km/h, there will be a 5% decrease in injury crash risk in adverse conditions, if low friction warnings are displayed, while a 12% decrease in injury collisions is expected for a fog warning. For a fatal crash risk, the percentage reductions are 10% for low friction warning and 23% for fog warnings. EasyWay averaged these figures to give overall impacts of 8.5% on injury crashes and 16.5% on fatal crashes.

eIMPACT evaluated a service called wireless location danger warning, one aspect of which is weather warning. A 4.5% reduction in fatalities and a 2.8% reduction in injuries was estimated, assuming 100% penetration on an EU-25 level. These values are slightly higher than those estimated by DRIVE C2X, however this is likely to be because eIMPACT also considered stationary vehicle warning to be part of this service.

SAFESPOT assesses the impact of two weather warning services: road departure (V2V) and hazard and incident warning (V2I). The road departure (V2V) use case informs the drivers of road conditions, such as a slippery road. SAFESPOT estimates an 8.6% reduction in injuries and a 16.4% reduction in fatalities, which is based on values obtained from the eIMPACT and CODIA projects. These figures are almost identical to EasyWay. The hazard and incident warning (V2I) use case includes weather conditions that result in reduced friction on the road or reduced visibility, such as ice, rain or fog and was shown to be significantly less effective than the V2V service. The estimation of impacts are again based on the eIMPACT and CODIA studies. SAFESPOT estimates a 1.6% reduction in fatalities and a 0.7% reduction in injuries at an EU-25 level, assuming 100% penetration in 2020 (SAFESPOT, 2010). These values are slightly lower than other reports reviewed in this section.

Finally, eSafetyForum reported that a weather conditions service could lead to a 2-4% reduction of fatalities/injuries. This is consistent with the DRIVE C2X figures.

Other impacts

A survey of drivers in the DRIVE C2X study indicated that 76% of drivers agreed that the weather conditions warning was useful, which is lower than the average for all services tested. This is likely due to the fact that drivers were more enthusiastic about particular types of weather warnings than others. For example, qualitative feedback provided by test drivers showed they were particularly receptive to warnings about potentially more serious hazards such as ice on the road, however they were less enthusiastic about receiving repetitive rainy conditions warnings while driving along a straight road. User acceptance is therefore likely to be dependent on the type of weather warning and how drivers value each type of weather warnings.

Further assessment showed that test drivers felt an increased sense of safety and comfort as a result of this service. On a scale of 1 (strongly disagree) to 7 (strongly agree), the mean value for increased feeling of comfort was 4.8 and for safety was 5.5.

There were no reported impacts on modal shift, or a change in travel patterns in the DRIVE C2X study.

5.13.6. Shockwave damping (SWD)

Service Overview

Shock wave damping aims to smooth the flow of traffic, by damping traffic shock waves.

Real-time traffic data is used to feed advisory speeds to cars to smooth out speed variations. This service is applicable to all vehicle types and is particularly relevant to motorways. Again, it could be delivered via roadside units, or the cellular network.

Impacts

The main data source for the impacts of shockwave damping was the CODIA project (VTT, TRL, 2008). No other publically available studies that specifically examine this service were identified. The majority of the benefits of shockwave damping are expected to be on motorways, therefore the impact of this service on urban roads and other interurban roads is assumed to be zero.

Traffic efficiency

CODIA assessed a dynamic speed adaptation due to congestion service that closely matches the shockwave damping service. As a consequence of this service, the authors estimated an increase of time spent on the road of 63.5 thousand vehicle hours per year in EU25 at 100% penetration rate. 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 was **assumed to be zero**.

Fuel consumption and CO_2

The dynamic speed adaptation due to congestion service assessed in CODIA estimates a reduction of 26,232 tonnes per year of carbon emissions at EU-25 level in a 100% penetration scenario (VTT, TRL, 2008). When calculated as a percentage, these effects are extremely small (**0.005% reduction**). It is assumed that all fuel consumption benefits will occur **on motorways** and that there will be zero impact on fuel consumption on other interurban roads, and urban roads.

Environmental and emissions impacts

The dynamic speed adaptation due to congestion service assessed in CODIA calculated the following impacts on vehicle emissions if the service is deployed at a 100% penetration level in EU-25 countries (VTT, TRL, 2008):

- 363 tonnes per year reduction in NO_x emissions at EU25 level
    - tonnes per year reduction in particulate matter emissions at EU25 level

When calculated as a percentage, these effects are extremely small (**less than 0.1%**).

Safety

One of the primary objectives of this service is to improve safety on high-speed roads. In CODIA, estimates of safety impacts were presented for the dynamic speed adaptation due to congestion/obstacles at a 100% penetration level (VTT, TRL, 2008). The study estimates a 13% reduction in fatalities and a 10.3% reduction in injuries on motorways.

The inclusion of obstacle warnings in the CODIA definition results in additional functionality to the shockwave damping service defined in this IA, therefore the safety impacts of the hazardous location service were subtracted from the figures reported in CODIA. This gave the following values, which were used in the modelling:

- Reduction in fatalities on motorways: 7.8%
- Reduction in injuries on motorways: 5.0%

Other impacts

No data related to other impacts was identified in the reports reviewed.

5.14. Bundle 5 - C-ITS V2I urban only applications

The impact data presented in this section are from the 2019 C-ITS impact assessment support study, which reviewed and updated the information that was collected for the 2016 C-ITS deployment study. In this second group of Bundle 5 V2I services, the services are more focused on intersection environments and include: Green Light Optimal Speed Advisory, Signal violation/Intersection safety, and Traffic signal priority request by designated vehicles. As with Bundle 4 and described in Section 5.12, safety impact overlap with the GSR is accounted for.

5.14.1. Green Light Optimal Speed Advisory (GLOSA) / Time to Green (TTG)

Service Overview

GLOSA 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. This is intended to provide traffic efficiency, vehicle operation (fuel saving) and environmental benefits by reducing unnecessary acceleration.

Traffic lights are connected to a roadside unit, which broadcasts information to nearby vehicles informing them of the traffic light phase schedule. This will enable vehicles to calculate optimal speed of approach. Time to green information may also be presented to drivers. It is applicable to all vehicle types and is particularly suitable in urban areas, where intersections are generally sited. Whilst it is expected to rely primarily on V2I direct short-range communication, a number of projects are looking to demonstrate its effectiveness using high-speed (e.g. 4G/5G) cellular networks.

Impacts

The main data source for the impacts of GLOSA was the DRIVE C2X project (TNO, 2014). An overview of the general methodology is provided in Table 46. For GLOSA, tests were carried out at test sites in Germany, Spain and Sweden. However, the number of events available after filtering in Sweden was too low to provide a good comparison of with and without-service behaviour. Similarly, the data from the Spanish test site was interpreted as a first order effect rather than an effect of GLOSA. Hence, pooling the GLOSA data was not straightforward due to the large differences in experimental set-up.

Other studies that considered the impacts include the Dutch ODYSA project and subsequent follow-ons; Beek et al. 2013 and van Katwijk et al. These studies were taken into account in the DRIVE C2X results and hence were not considered further here.

<u>Traffic efficiency</u>

In DRIVE C2X, traffic efficiency was assessed by naturalistic driving tests on urban roads and by simulations. The results were dependent on the level of traffic, with tests showing a slight overall increase in delay per traffic light, which was attributed to the slower speed of approach. The time spent stationary at traffic lights may be reduced by this service but the effects are not statistically significant. Results from the test site in Germany indicated that driver behaviour may become smoother and results from the literature surveyed by the authors of DRIVE C2X are inconclusive. The DRIVE C2X study team fed FOT data into a model, in order to calculate impacts. They reported an unexpected result of a 9% increase in delay for the implementation of GLOSA, however this was probably due to the way the yellow light was simulated in the model.

Overall, the effects on traffic efficiency are assumed to be small because (1) the system is not necessary when the driver arrives at a light that is already green; and (2) GLOSA has limited potential to affect the possibility of a driver arriving at a red light.

As the results currently stated in the literature are inconclusive, it is assumed that this service will **not have an impact on traffic efficiency** in urban areas.

Fuel consumption and CO_2

The primary effect of GLOSA is expected to be on fuel efficiency and environmental impacts due to reduced braking and acceleration while passing through traffic lights. The DRIVE C2X study shows that impacts are dependent on vehicle technology, with hybrids showing lower potential for improvement. The impact on motorways is assumed to be negligible, since GLOSA is only effective at traffic light controlled intersections. The study reported the following specific effects on urban roads, in the high penetration scenario:

- A reduction in fuel consumption of 3% when approaching an intersection. The authors scaled this impact to EU-27 level based on the number of approaching vehicles at signalised intersections in EU-27 countries. The number of approaching vehicles per year at signalised intersections in the EU-27 was estimated to be 1.708 trillion, concentrated on rural and urban roads (estimated to be 70% for urban and 30% for rural), as shown in Table 55. Although the amount of signalised intersections was known at the EU level, the number of approaching vehicles was estimated based on data from the Netherlands, as information for the EU was not available.

Table 55: Estimation of the number of vehicles approaching intersections in EU-27 countries per year (Source: DRIVE C2X)

Road type	Low demand (billions)	High demand (billions)
High speed roads	0	0
Rural roads	358.7	153.7
Urban roads	837.0	358.7

- An overall reduction in fuel consumption of 219,729 tonnes on rural roads and 512,702 on urban roads when scaled up to EU-27 level.
- This is equivalent to a **0.1% reduction in fuel consumption on rural roads and a 0.7% reduction in fuel consumption on urban roads**.

The DRIVE C2X values are lower than an earlier TNO study which estimated that traffic signal optimisation could lead to a 2% reduction in CO_2 emissions on an EU-27 level. The DRIVE C2X figures were used in the modelling as they are based on FOT data.

Environmental and emissions impacts

Only the DRIVE C2X study presented detailed results about the impact of GLOSA on vehicle emissions. Per intersection approach, the following effects were observed:

- Reductions in CO and HC emissions of 15.5% and 40.2%. The levels of changes to these pollutants are large because they are highly sensitive to acceleration and braking.
- Reduction in NO_x emissions of 3.2%

The authors scaled these figures up to EU-27 level by road type to give the impact on each pollutant in tonnes per year. These absolute emissions reductions were converted to percentages based on the annual pollutant emissions by road type from TRT's ASTRA and TRUST models. The following inputs were used in the model:

- CO: 0.3% reduction (other interurban roads), 0.8% (urban roads)
- NOx: 0.1% reduction (other interurban roads), 0.2% (urban roads)
- VOCs: 0.5% reduction (other interurban roads), 0.6% (urban roads)
- PM: 0.1% reduction (other interurban roads) , 0.0% (urban roads)

Safety

GLOSA was found to have minor safety benefits in the DRIVE C2X study (TNO, 2014), mainly as a consequence of the lower number of vehicles needing to stop at traffic lights. Since the primary objective of GLOSA is not safety-related, it is to be expected that the overall impacts are small.

Specifically, positive effects that were expected are:

- On average, drivers will need to stop at traffic lights less with GLOSA. The probability of a rear-end collision is therefore reduced.
- Smoother driving behaviour is expected on the approach to traffic lights, reducing both the risk and severity of a collision.
- Drivers will, on average, approach traffic lights at a lower speed with GLOSA.
- Abrupt and indecisive braking behaviour will be eliminated due to the information GLOSA provides to drivers. This will reduce the risk and impact of rear-end crashes, limit red light violations and reduce angle-crashes.

However, the study also suggests that GLOSA may be less effective and less reliable for adaptive or actuated traffic lights, as these are dependent on unpredictable traffic flows. The service may also distract drivers, resulting in decreased attention on the road ahead, due to focussing on the in-vehicle advisory system. This is expected to be minor and may be limited further by good design on the in-vehicle interface.

The effectiveness of GLOSA was found to be highly dependent on penetration rate and traffic intensity. Safety effects were presented as a percentage reduction in fatalities or injuries in 2030 for 100% infrastructure penetration. In the high scenario in 2030, the average **fatalities** prevented was estimated to be 0**.1% on both urban and rural roads**, while the average number of **injuries** prevented was estimated to be **0.1% on rural roads and 0.3% on urban roads**.

Other impacts

Stakeholder inputs during the DRIVE C2X project suggest that user acceptance for GLOSA is very high, with 86% of drivers rating the service as useful, while 50% claimed they would be willing to pay for use of the feature if it was available in their vehicle (VTT, TRL, 2008).

Qualitative effects of GLOSA were reported as improvements in terms of decreased stress and uncertainty, and an increased feeling of safety and comfort. The typical mean agreement values for comfort were 4.9-5.6 (on a scale from 1, strongly disagree to 7, strongly agree), for safety approximately 4.8 and for stress 4.7-5.2. Stress and uncertainty were also assessed on a scale from -3 to 3 (decrease-increase), and the typical mean values for those scales were approximately -0.5 for stress and from -1.0 to -0.2 for uncertainty.

There were no reported impacts on modal shift.

5.14.2. Signal violation/Intersection safety (SigV)

Service Overview

The primary objective of this service is to reduce the number and severity of collisions at signalised intersections.

This service, also known as the Red Light Violation Warning (RLVW), allows for drivers to be warned when they are in danger of violating a red light, or when it is probable that another vehicle is going to make a red light violation. It is applicable to all vehicle types and is particularly suitable in urban areas, where intersections are generally sited.

Impacts

The main data sources for the impacts of signal violation/intersection safety were the eIMPACT project (TNO, VTT, Movea, PTV, BASt, 2008) and SAFESPOT study. An overview of the general methodology for the eIMPACT study is provided in Table 47.

Traffic efficiency

The SAFESPOT study assumes that no traffic impacts are experienced but refers to the statement in the eIMPACT study that traffic effects are expected but have not been proven (SAFESPOT, 2010). As no quantitative estimates have been given in the literature, it is assumed that this service will not have an impact on traffic efficiency.

Fuel consumption and CO_2

No data was identified for this impact category in the reports reviewed. Fuel consumption impacts for this service are assumed to be zero.

Environmental and emissions impacts

No data was identified for this impact category in the reports reviewed. Impacts on vehicle emissions for this service are assumed to be zero.

Safety

The primary objective of this service is to improve safety at traffic intersections. A review of the reports covering this service revealed that the intersection safety service is defined differently depending on the study, with some studies including additional functionality such as GLOSA. A summary of the safety impacts stated in the studies reviewed is given in Table 56.

Table 56: Summary of safety impacts of the intersection safety service reported in other European studies

Study	Fatalities (reduction)	Injuries (reduction)	Scenario
eIMPACT	3.9% (includes GLOSA / TTG)	7.3% (includes GLOSA / TTG)	100% penetration EU-25, 2020
SAFESPOT	0.7% (V2V left-turn assist only) 3.1% (V2I red light violation, left and right turn assistance)	2.2% (V2V left-turn assist only) 4.8% (V2I red light violation, left and right turn assistance)	100% penetration EU-25, 2020
CODIA	3.7%	6.9%	100% penetration, assuming all vehicles were equipped, regardless of the year.

The eIMPACT study states 3.9% reduction in fatalities, 7.3% reduction in injuries, assuming 100% penetration in at EU-25 level in 2020. GLOSA/TTG functionality is also included in the eIMPACT definition of this service. If the safety impacts of GLOSA (the high scenario in the DRIVE C2X study estimates a 0.1% reduction in fatalities and a 0.3% reduction injuries) are subtracted from the impact predicted by eIMPACT, the impact would be a 3.8% reduction in fatalities and a 7.0% reduction in injuries. These are very similar to those suggested by CODIA (VTT, TRL, 2008).

The SAFESPOT study evaluated two intersection safety functions. The first function, a V2V service called "lateral collision – road intersection safety" assessed the impact of in-vehicle left-turn assistance (SAFESPOT, 2010). Assuming 100% penetration in the EU-25 in 2020, the estimated impact of this service is a 0.7% reduction in fatalities and a 2.2% reduction in injuries. These results are based on the PReVAL project, which follows the same methodological approach implemented by the eIMPACT study. Another intersection safety function evaluated by SAFESPOT was the "Intelligent Cooperative Intersection Safety system – IRIS" service, which is based on V2I communication. This service primarily aims to prevent red light violations, although also includes left and right turn assistance. The estimated impact of this service, assuming 100% penetration, is a 3.1% reduction in fatalities and a 4.8% reduction in injuries at EU-25 level (SAFESPOT, 2010). These results are based on the findings of the eIMPACT and CODIA projects. If the impacts of the two SAFESPOT intersection safety services are added together, a 3.8% reduction in fatalities and a 7.0% reduction in injuries is found.

The CODIA study also assessed the impact of cooperative intersection collision warning. This report estimated a 3.7% reduction in fatalities and a 6.9% reduction in injuries at a 100% penetration rate, providing the system is used in all intersections in the EU (VTT, TRL, 2008).

Based on the above, the most appropriate figure was selected as the eIMPACT estimation (with GLOSA impacts subtracted). A **3.8% reduction in fatalities and a 7.0% reduction in injuries on urban roads, and other interurban roads** were used as inputs to the modelling. These percentages were applied to **all vehicle types** and are very similar to those stated by the SAFESPOT and CODIA studies.

Other impacts

No data related to other impacts was identified in the reports reviewed.

5.14.3. Traffic signal priority request by designated vehicles (TSP)

Service Overview

The traffic signal priority request by designated vehicles allows drivers of priority vehicles (for example emergency vehicles, public transport, HGVs) to be given priority at signalised junctions.

This service works by either extending or terminating the current traffic light phase, to ensure that the required phase is displayed. Different levels of priority can be applied, depending on the vehicle type. For example, emergency vehicles may be given the highest priority, whereas the appropriate level of green priority for a public transport vehicle may be dependent on its current status, i.e. whether it is on-time or behind schedule. This has the potential to deliver a variety of benefits. Safety benefits may be gained by extending the phase for emergency vehicles travelling at speed, efficiency benefits for public transport and environmental benefits gained when reducing the need for vehicles to repeatedly brake and accelerate through signalised intersections. This service is most suitable for urban environments and is applicable for all vehicle types except passenger cars. Whilst it is expected to rely primarily on V2I ITS-G5 communication, a number of projects are looking to demonstrate its effectiveness using high-speed (e.g. 4G/5G) cellular networks.

Impacts

The main data sources for the impacts of the traffic signal priority request by designated vehicles service were the eSafetyForum Intelligent Infrastructure Working Group's Final

Report and the COMeSafety project. An overview of the general methodology of the eSafetyForum report is provided in Table 51.

Despite several European FOTs trialling this service, no other publically available studies that specifically examine traffic signal priority request by designated vehicles as a C-ITS service were identified.

The limited information from the above two reports was therefore supplemented by additional desk research into traffic signal priority systems – this yielded one particularly useful source of information, namely a study by the UITP Working Group (TfL, TRL, University of Southampton, 2009) on the interaction of buses and signals at road crossings. This study analysed a number of European city bus priority projects, summarising travel time reduction data for buses equipped with a variety of bus priority systems allowing them to interact with traffic lights to smooth their passage through signalised intersections. One such example is the SCOOT system currently being trialled by Transport for London. Whilst not using the ITS-G5 protocols discussed in this study, some of the systems discussed in this study could loosely fall within the definition of C-ITS services and operate through very similar mechanisms to the C-ITS service discussed here. It was therefore deemed appropriate to use input data from this study to estimate impacts data from first principles.

Traffic efficiency

Traffic signal priority request will only be available to certain vehicles on other interurban roads and urban roads. For the purposes of the modelling, it is assumed that this service will only apply to public transport and not passenger cars or freight vehicles. In most situations, there will also be secondary effects on non-bus users. This is captured in the modal shift element of TRT's ASTRA model.

The eSafetyForum literature review suggests that requesting green/signal priorities can lead to a 1-2% reduction in congestion, however this cannot be easily translated into an impact on urban travel speed, which is the required input for the modelling.

In the absence of data from specific C-ITS studies, data from the UITP Working Group report was therefore used as an input to the model. Quantitative estimates of travel time savings for bus priority systems were given for trials in the following cities: Aalborg, Cardiff, Genoa, Gothenburg, Helsinki, Prague, Stockholm, Stuttgart, Toulouse and Turin. The average saving was a **9.2% reduction in travel time for buses** equipped with some form of traffic signal priority system.

Fuel consumption and CO_2

Reduced fuel consumption is one of the main objectives of this service. The eSafetyForum report suggests that requesting green/signal priorities can lead to a 1-3% impact reduction in carbon dioxide emissions, while results of the FREILOT project show that HGVs equipped with this service reported reductions in fuel consumption of up to 20% (ERTICO, 2012). The FREILOT project was a FOT based on 11 intersections, with 7 trucks equipped with a number of services, including traffic signal priority, energy efficient driving (which provided speed advice and indicated when to shift up or down in order to save energy) and remote parking spot booking for loading and unloading. However given the lack of references in the eSafetyForum output and the difficulty in separating traffic signal priority from other services in the FREILOT project, it was decided to estimate fuel consumption and CO_2 savings using the results of the UITP Working Group study referenced above.

To this end, the average speed of buses without any traffic signal priority service installed was estimated from the UITP Working Group study at 15.3 kph, alongside the improved speed (9.2% reduction in time spent travelling) of 17.2 kph. This difference in speed was used as an input to Ricardo Energy and Environment's speed-emissions curve model, which is able to estimate the impact on CO_2/fuel consumption, NO_x and PM_{10} emissions.

The total improvement in fuel consumption and CO_2 emissions was therefore estimated as **8.28% across all buses in urban environments**.

Environmental and emissions impacts

NO_x and PM emissions were estimated using the same speed-emissions curve model as for fuel consumption/CO_2. Total improvement in **NO_x and PM** emissions were estimated at **8.04% and 8.17% respectively across all buses in urban environments**.

For **CO and VOC emissions**, these were assumed to be proportional to fuel consumption savings, and therefore estimated at an **8.28% reduction for urban buses**.

Safety

No data was identified for this impact category in the reports reviewed and given that this service will most likely only be available to a limited number of vehicles, it is assumed that the impact on safety at an EU-level will be negligible for this service and it is not included in the model.

Other impacts

No data related to other impacts was identified in the reports reviewed.

5.15. Bundle 6 - Vulnerable road user protection – pedestrians and cyclists (VRU)

Service Overview

This is a safety focussed service, which is intended to protect vulnerable road users. In this vase vulnerable road users are considered to be pedestrians and cyclists only.

This service is designed to increase safety by alerting drivers of the presence of vulnerable road users (those outside the vehicle such as pedestrians, cyclists). This may be achieved via communication with a smartphone, or in the case of cyclists, via communication with a C-ITS device fitted on the bike. In the case that installing direct short-range capability is not practical within smartphones, this service could be based on a cellular technology, provided it offers sufficiently low latency. Vulnerable road user protection is applicable to all vehicle types and is expected to bring safety benefits to all road types, however the majority of benefits are expected to be on urban roads.

Impacts

The eIMPACT project evaluated a non-cooperative intelligent transport service called "pre-crash protection of vulnerable road users". This is similar to the vulnerable road user protection service evaluated in this IA, however in eIMPACT it was not considered to be a cooperative system and was assumed to operate by detecting vulnerable road users via sensors. The two services are likely to present information to the driver in a similar manner and safety impacts will occur via similar mechanisms, therefore the data presented can be applied to the cooperative service.

Traffic efficiency

No data was identified for this impact category in the reports reviewed. It is assumed that this service will not have an impact on traffic efficiency at an EU level.

Fuel consumption and CO_2

No data was identified for this impact category in the reports reviewed. It is assumed that this service will not have an impact on fuel consumption at an EU level.

Environmental and emissions impacts

No data was identified for this impact category in the reports reviewed. It is assumed that this service will not have an impact on vehicle emissions at an EU level.

Safety

Due to the absence of other data, data from the eIMPACT project for the "pre-crash protection of vulnerable road users" was referenced. This was not considered to be a cooperative system, however the results provide a good indication of the expected impacts of a similar cooperative service, as both services are expected to display similar information to the driver.

Assuming a 100% penetration in EU-25 countries, the eIMPACT study estimated a 1.8% reduction in fatalities and a 1.9% reduction in injuries for the pre-crash protection of vulnerable road users (TNO, VTT, Movea, PTV, BASt, 2008). Discussions with experts confirmed that the majority of benefits of this service will be seen in urban areas. **A 1.8% reduction in fatalities and a 1.9% reduction in injuries has therefore been used for other interurban roads, and urban roads**, **applied to all vehicle types**. This service was assumed to have no impact on safety on motorways in the modelling.

Other impacts

No data related to other impacts was identified in the reports reviewed.

5.16. Bundle 6 – Cooperative Adaptive Cruise Control

Service Overview

Impacts

A study carried out by TNO looking at the environmental benefits of C-V2X (TNO, 2020) conducted a number of field tests on Dutch rural roads with vehicles equipped with CACC. Platoons of 3 and 7 vehicles equipped with CACC and data logging systems drove in regular traffic on a 2 lane rural road with controlled intersections. The logged data was used to assess the CO_2 emissions of the vehicles.

Traffic efficiency

No data was identified for this impact category in the report reviewed. It is assumed that this service will not have an impact on traffic efficiency at an EU level.

Fuel consumption and CO_2

The average reduction in CO_2 emissions per vehicle was 6.0% for passenger vehicles. The study noted that the field test produced varying impacts from just 1.8% reduction to 10.5% reduction. For freight vehicles, the impact is around 20% higher than passenger cars, resulting in a CO_2 reduction of 7.2%. In absence of any further data, the same impacts have been applied across all road types.

Environmental and emissions impacts

No data was identified for this impact category in the report reviewed. It is assumed that this service will not have an impact on vehicle emissions at an EU level.

Safety

No data was identified for this impact category in the report reviewed. It is assumed that this service will not have an impact on safety at an EU level.

5.17. Bundle 6 – Other

We recognise that Bundle 6 includes other critical services such as C-ITS cooperative perception services and other services leading to higher levels of automation. However, due to the early level of development of such services, there are no concrete studies that have investigated the impacts under consideration in this IA and therefore these services cannot be accurately represented in the model. This was confirmed during discussions with stakeholders during the workshops, who agreed that there were no reliable sources, and stated that the focus of the ITS Directive should be on increasing the deployment of services with a higher level of maturity, rather than Bundle 6 services that are more forward looking.

6. Overlap between services

A number of ITS services covered in this assessment have similar functionality, therefore the impact of certain services is likely to overlap. For example, a driver could be alerted to an obstacle in the road through variable message signs using SRTI or through the vehicle interface using V2V. Therefore, in practice, when two or more similar services are deployed, certain impacts may not be additional and any further benefits may only be a fraction of the services individual impact. It is therefore important to capture the interaction between services, to avoid overestimating the benefits. Another consideration relates to overlaps between other legislation outside the ITS Directive framework, that play a role in the deployment of ITS solutions, and the impacts arising from the services considered in this assessment.

To this end, service overlap was accounted for in the assessment using a service weighting matrix, as shown in Table 58. This matrix applies a percentage weighting from 0-100% to each service, based on which services would be deployed before it in the progression of the policy options. Weightings were applied in increments of 25%, in an attempt to account for different amounts of overlap between different services. These were developed in the context of the impact assessment support study and shared with stakeholders for consultation. Within the C-ITS service bundles, the overlap between individual services under each service type has already been accounted for using the values originally developed in working groups under the C-ITS platform for the 2016 C-ITS Deployment Study.

The full list of overlaps is described below:

- **Multimodal travel information service:** It is assumed that 100% of the impacts would be eliminated due to MaaS on the basis that MaaS platforms include a travel information service with the addition of a booking/reselling service.
- **Travel information service:** It is assumed that 75% of the impacts would be eliminated due to RTTI on the basis that RTTI incorporates most aspects of travel information services.
- **Parking and pricing information:** It is assumed that 25% of the impacts would be eliminated due to RTTI on the basis that some navigation providers will already be collecting this data as part of their service.
- **Re-charging/re-fuelling location and pricing information:** It is assumed that 50% of the impacts will be eliminated due to the provisions of AFIR in making data available.
- **Mobility management services:** It is assumed that 75% of the fuel consumption, emissions and traffic efficiency and 100% of safety impacts would be eliminated due to traffic network management systems as the mobility management services provide similar services but to the mobility system as a whole (rather than just the road network).
- **Road safety-related minimum universal traffic information service:** It is assumed that 50% of the impacts would be eliminated due to C-ITS services on the basis that around half of the use cases utilise the same type of data (e.g. hazardous location notification).
- **S&S truck parking location information system:** It is assumed that 100% of the impacts would be eliminated due to S&S truck parking location reservation system as the reservation system will incorporate all location information in the service.

- **All C-ITS service types (V2V, V2I motorway, V2I urban)**: It is assumed that 25% of the safety impacts would be eliminated due to traffic network management systems on the basis that similar services are delivered to the end user through different means. In the case of traffic network management systems it is through VMS, and for C-ITS the service is delivered through in-vehicle systems.

Table 57: Service type and reference code

Service type	Reference code
Multimodal travel information service (including linking between modes)	1_MMTIS-1
Multimodal travel information and booking/re-selling service (MaaS)	2_MaaS-1
Travel information service / Road traffic information & navigation services	3_Tinfo-1
Real-time traffic information service	4_RTTI-1
Parking (and pricing) information	5_Pinfo-1
Re-charging/re-fuelling location and pricing information	6_iFuel-1
(Enhanced) Traffic network and incident management systems	7_Tmang-2
Mobility management services	8_Mmang-2
Road safety-related minimum universal traffic information service	9_SRTI-3
S&S truck parking location information system	10_HDVPinfo-3
S&S truck parking location reservation system	11_HDVPres-3
C-ITS safety-based V2V services:	12_V2V-4
C-ITS V2I motorway focused applications:	13_V2Ihwy-5
C-ITS V2I urban only applications:	14_V2Iurb-5

Table 58: Service overlaps in percentages

Impact	1_MMTIS-1	2_MaaS-1	3_Tinfo-1	4_RTTI-1	5_Pinfo-1	6_iFuel-1	7_Tmang-2	8_Mmang-2	9_SRTI-3	10_HDVPinfo-3	11_HDVPres-3	12_V2V-4	13_V2Ihwy-5	14_V2Iurb-5
Fuel consumption	0	100	25	100	75	50	100	25	50	0	100	100	100	100
CO	0	100	25	100	75	50	100	25	50	0	100	100	100	100
NOx	0	100	25	100	75	50	100	25	50	0	100	100	100	100
VOC	0	100	25	100	75	50	100	25	50	0	100	100	100	100
PM	0	100	25	100	75	50	100	25	50	0	100	100	100	100
Fatalities	0	100	25	100	75	50	100	0	50	0	100	75	75	75
Serious injuries	0	100	25	100	75	50	100	0	50	0	100	75	75	75
Light injuries	0	100	25	100	75	50	100	0	50	0	100	75	75	75
Material damages	0	100	25	100	75	50	100	0	50	0	100	75	75	75
Average speed	0	100	25	100	75	50	100	25	50	0	100	100	100	100