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The needs for and prioritization of Cooperative ITS (C-ITS) services in Finland

Risto Kulmala, Ilkka Kotilainen, Timo Majala, Ville Isoranta and Tomi Laine

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Abstract
This study provided information of the user and society needs for Cooperative ITS or C-ITS services as well as identified the services, which should be deployed in the first phase in Finland. The inventory of society and user needs was carried out via transport system statistics, relevant literature, and interviews of specific user groups. The study included all C-ITS services specified by the European C-Roads Platform complemented by services specified in the EU's C-ITS Platform.
The selection of the first phase deployment services utilised multicriteria decision analysis (MCDA). In MCDA, each C-ITS service was assessed according to how well its impacts contributed to society or user needs (13 user groups), what is its techno-economical feasibility, and how well it serves the EU and Finnish national deployment strategies. Specific weights were assigned to each criteria, separately for interurban/rural roads and city streets. The prioritisation also took into account the magnitude of the public sector investment as well as the added value of C-ITS with regard to the novelty and quality of the information provided by the C-ITS service.
The study results indicate hazardous location notifications, roadworks warnings, and in-vehicle signage as the priority C-ITS services for deployment in Finland. The factor common to all these services is that the information to be provided by the services exists or will do so in the near future. In addition, event information provision, railway grade crossing warnings and traffic information & smart routing had high priorities on all road types. On streets, the signalised intersection C-ITS services had high priority.
The deployment should commence with traffic sign information and roadworks warning on both interurban/rural roads and city streets. Next services to be deployed should be hazardous location and railway grade crossing warnings on roads as well as event information provision, signalised intersection and other city-specific priority C-ITS services on city streets.

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Tekijät
Risto Kulmala, Ilkka Kotilainen, Timo Majala, Ville Isoranta, Tomi Laine

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Tiivistelmä
Tässä työssä tuotettiin tietoa tieliikenteen vuorovaikutteisiin älyliikennepalveluihin eli C-ITS-palveluihin liittyvistä käyttäjien ja yhteiskunnan tarpeista sekä tunnistettiin palvelut, jotka kannattaisi toteuttaa ensi vaiheessa Suomessa. Yhteiskunnan ja käyttäjien tarpeet kartoitettiin liikennejärjestelmän nykytilan, kirjallisuuden ja eri käyttäjäryhmiin kohdistettujen haastattelujen avulla. Tarkasteluun valittiin kaikki eurooppalaisten tieoperaattoreiden C-Roads Platform -yhteistyöryhmässä määrittelemät C-ITS-palvelut sekä niitä täydentävät EU:n C-ITS Platformin määrittelemät palvelut.
Ensimmäisessä vaiheessa toteutettavien palvelujen valinnassa hyödynnettiin multikriteeripäätösanalyysia (engl. multicriteria decision analysis). Menetelmässä arvioitiin kukin C-ITS-palvelu sen perusteella, kuinka hyvin sen vaikutukset edistävät yhteiskunnan tai käyttäjien tarpeita (kolmetoista eri käyttäjäryhmää), mikä on sen teknistaloudellinen toteutettavuus ja miten se tukee EU:n sekä Suomen toteutusstrategioita. Kullekin kriteerille annettiin erikseen painoarvot. Lisäksi arvioitiin erikseen palveluiden toteutukset maanteillä ja kaduilla. Priorisoinnissa otettiin huomioon julkisen investoinnin suuruusluokka ja C-ITS:n tuoma lisäarvo tiedon uutuuteen ja laatuun.
Tulosten mukaan C-ITS-palveluiden toteutuksessa Suomessa tulisi priorisoida kolmea eri palvelutyyppiä: vaaranpaikkavaroituksia, tietyövaroituksia ja liikennemerkkitietoa.
Kaikkia näitä palveluja yhdistää se, että niissä tarvittavaa tietopohjaa on jo tai on pian olemassa. Lisäksi korkean prioriteetin palveluita sekä maanteillä että kaduilla olivat tapahtumatiedon tuottaminen, tasoristeysvaroitukset ja älykäs reittiopastus. Kaduilla liittymien valo-ohjauksen palvelut saivat korkeahkon prioriteetin.
Toteutus kannattaa aloittaa liikennemerkkitiedoista ja tietyövaroituksista sekä maanteillä että kaduilla. Toteutusta kannattaa jatkaa vaaranpaikka- ja tasoristeysvaroituksilla maanteillä sekä tapahtumatiedon tuottamisella, liikennevalo- ja muilla kaupunkiseutujen tärkeinä pitämillä C-ITS-palveluilla kaduilla

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Sammandrag
I detta arbete producerades information om användarnas och samhällets behov i anslutning till interaktiva intelligenta transporttjänster för vägtrafiken, dvs. C-ITS-tjänster. Dessutom identifierades de tjänster som bör genomföras i Finland i första skedet. Samhällets och användarnas behov undersöktes med hjälp av transportsystemets nuläge, litteratur och intervjuer med olika användargrupper. Granskningen omfattade alla C-ITS-tjänster som de europeiska vägoperatörerna fastställt i samarbetsgruppen C-Roads Platform samt de tjänster som EU:s C-ITS Platform fastställt som kompletterande tjänster.
Vid valet av tjänster som ska genomföras i första skedet användes multikriteriebeslutsanalys (eng. multicriteria decision analysis). Metoden innebar att varje C-ITS-tjänst bedömdes utifrån hur väl dess verkan främjar samhällets eller användarnas behov (tretton olika användargrupper), tjänstens teknisk-ekonomiska genomförbarhet och hur den stöder EU:s och Finlands strategier för genomförandet. Betydelsen av varje kriterium bedömdes separat. Dessutom bedömdes separat hur tjänsterna genomförs på landsvägar och gator. I prioriteringen beaktades storleksklassen på den offentliga investeringen och det mervärde som C-ITS innebär för informationens nyhet och kvalitet.
Enligt resultaten borde tre olika typer av tjänster prioriteras när C-ITS-tjänsterna genomförs i Finland: varningar för farliga platser, varningar för vägarbete och information om vägmärken.
Gemensamt för alla dessa tjänster är att det kunskapsunderlag som behövs för dem redan är tillgängligt eller snart kommer att vara tillgängligt. Tjänster med hög prioritet på både landsvägar och gator var dessutom produktion av händelseinformation, varningar för plankorsningar och intelligent vägvisning. På gatorna fick signalregleringstjänsterna i korsningar relativt hög prioritet.
Det är klokt att börja genomförandet med information om vägmärken och varningar för vägarbete både på landsvägar och gator. Dessa kan åtföljas av varningar för farliga platser och plankorsningar på landsvägar samt produktion av händelseinformation, trafikljustjänster och andra C-ITS-tjänster som stadsregionerna anser vara viktiga på gatorna.

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Foreword

In the next few years, Finland and other countries in Europe will be widely introducing Cooperative ITS (C-ITS) services for road transport. In Finland, the aim is to implement services that meet users' needs and promote key development targets of the national transport system. This study produced information on the needs of users and society related to C-ITS and identified services that should be deployed in the first phase in Finland. The study was produced as a consultant and expert assignment, and its proposals do not represent the official views of the Finnish Transport and Communications Agency, the Finnish Transport Infrastructure Agency or other authorities involved in the study.

The steering group of the study included Anna Schirokoff, Mikko Räsänen and Risto Öörni from the Finnish Transport and Communications Agency, Petri Antola and Jari Myllärinen from the Finnish Transport Infrastructure Agency, Mika Ahvenainen from Fintraffic Ltd and Olli Rossi from Fintraffic Road Ltd, Antti Paasilehto from the Ministry of Transport and Communications, Mika Kulmala from the City of Tampere and Niko Kynsijärvi from the City of Helsinki. The study was carried out by Risto Kulmala, Ilkka Kotilainen, Tomi Laine and Ville Isoranta from Traficon Oy and Timo Majala from Nodeon Finland Oy.

Members of the C-ITS Expert Group of the European reference countries supporting the study were Eric Kenis (BE), Benno Nager (CH), Lone Dörge (DK), David Laoide-Kemp (IE), Henk Schuurman and Onno Tool (NL), Knut Evensen (NO) and Per-Olof Svensk (SE).

This report is a translation of the Finnish-language report *Vuorovaikutteisten älykkäiden liikennejärjestelmien (C-ITS) palveluiden tarve ja priorisointi Suomessa* (Traficom Research Reports 19/2025), excluding a few annexes relevant only to Finland.

The work was part of the European C-Roads Extended project, which received financial support from the Connecting Europe Facility (CEF) in the years 2024–2027.

Helsinki, 23 May 2025

Anna Schirokoff

Chief adviser

Finnish Transport and Communications Agency Traficom

Alkusanat

Suomessa ja muualla Euroopassa ollaan lähivuosina ottamassa laajalti käyttöön tieliikenteen vuorovaikutteisia älyliikennepalveluita eli C-ITS (Cooperative ITS) -palveluita. Kansallisesti tavoitteena on toteuttaa etenkin sellaisia palveluja, jotka täyttävät käyttäjien tarpeita ja edistävät liikennejärjestelmän keskeisiä kehityskohteita Suomessa. Tässä työssä tuotettiin tietoa C-ITS-palveluihin liittyvistä käyttäjien ja yhteiskunnan tarpeista sekä tunnistettiin palvelut, jotka kannattaisi toteuttaa ensi vaiheessa Suomessa. Työ on toteutettu konsultti- ja asiantuntijatyönä, eivätkä sen ehdotukset ole Liikenne- ja viestintäviraston, Väyläviraston tai muiden työssä mukana olleiden viranomaistoimijoiden virallisia näkemyksiä.

Työn ohjausryhmässä toimivat Anna Schirokoff, Mikko Räsänen ja Risto Öörni Liikenne- ja viestintävirastosta, Petri Antola ja Jari Myllärinen Väylävirastosta, Mika Ahvenainen Fintraffic Oy:stä ja Olli Rossi Fintraffic Tie Oy:stä, Antti Paasilehto liikenne- ja viestintäministeriöstä, Mika Kulmala Tampereen kaupungilta ja Niko Kynsijärvi Helsingin kaupungilta. Työn tekivät Risto Kulmala, Ilkka Kotilainen, Tomi Laine ja Ville Isoranta Traficon Oy:stä sekä Timo Majala Nodeon Finland Oy:stä.

Työtä tukevan Euroopan verrokkimaiden C-ITS-asiantuntijaryhmän jäseninä toimivat Eric Kenis (BE), Benno Nager (CH), Lone Dörge (DK), David Laoide-Kemp (IE), Henk Schuurman ja Onno Tool (NL), Knut Evensen (NO) ja Per-Olof Svensk (SE).

Tämä raportti on käännös suomenkielisestä raportista Vuorovaikutteisten älykkäiden liikennejärjestelmien (C-ITS) palveluiden tarve ja priorisointi Suomessa (Traficomin tutkimuksia ja selvityksiä 19/2025) lukuun ottamatta muutamaa vain Suomelle relevanttia liitettä.

Työ oli osa eurooppalaista C-Roads Extended -hanketta, joka sai Verkkojen Eurooppa -ohjelman (CEF, Connecting Europe Facility) rahoitustukea vuosina 2024–2027.

Helsingissä, 23. toukokuuta 2025

Anna Schirokoff

Johtava asiantuntija

Liikenne- ja viestintävirasto Traficom

Förord

I Finland och på andra håll i Europa kommer interaktiva intelligenta transporttjänster för vägtrafiken, dvs. C-ITS-tjänster (Cooperative ITS), att införas i stor utsträckning under de närmaste åren. På nationell nivå är målet att genomföra i synnerhet sådana tjänster som tillgodoser användarnas behov och främjar viktiga utvecklingsobjekt i transportsystemet Finland. I detta arbete producerades information om användarnas och samhällets behov i anslutning till C-ITS-tjänster och de tjänster som bör genomföras i Finland i första skedet identifierades. Arbetet har genomförts som konsult- och expertarbete. De förslag som arbetet resulterat i utgör inte officiella ståndpunkter från Transport- och kommunikationsverket, Trafikledsverket eller andra myndighetsaktörer som deltagit i arbetet.

I styrgruppen för arbetet deltog Anna Schirokoff, Mikko Räsänen och Risto Öörni från Transport- och kommunikationsverket, Petri Antola och Jari Myllärinen från Trafikledsverket, Mika Ahvenainen från Fintraffic Ab och Olli Rossi från Fintraffic Väg Ab, Antti Paasilehto från kommunikationsministeriet, Mika Kulmala från Tammerfors stad och Niko Kynsijärvi från Helsingfors stad. Arbetet utfördes av Risto Kulmala, Ilkka Kotilainen, Tomi Laine och Ville Isoranta från Traficon Ab samt Timo Majala från Nodeon Finland Oy.

Medlemmar i de europeiska jämförelseländernas C-ITS-expertgrupp som stödde arbetet var Eric Kenis (BE), Benno Nager (CH), Lone Dörge (DK), David Laoide-Kemp (IE), Henk Schuurman och Onno Tool (NL), Knut Evensen (NO) och Per-Olof Svensk (SE).

Denna rapport är en översättning av den finskspråkiga rapporten *Behov och prioritering av tjänster inom interaktiva intelligenta transportsystem (C-ITS) i Finland* (Traficoms undersökningar och utredningar 19/2025), med undantag för några bilagor som endast är relevanta för Finland.

Arbetet var en del av det europeiska projektet C-Roads Extended som under 2024–2027 fick finansiering från Fonden för ett sammanlänkat Europa (CEF, Connecting Europe Facility).

Helsingfors den 23 maj 2025

Anna Schirokoff

Ledande sakkunnig

Transport- och kommunikationsverket Traficom

Contents

1 Introduction

Promoting safe, sustainable, smooth and connected transport lies at the core of the European transport policy (European Union 2024). In traffic safety, the European Union's goal is to reach a situation where there will be zero fatalities in road traffic by 2050 (European Commission 2022b). In Finland, road traffic emissions have a significant impact on total national emissions; in 2023, road transport accounted for around 95% of the greenhouse gas emissions from domestic transport and around 22% of Finland's total greenhouse gas emissions. Congestion complicates road traffic, resulting in the slowing down of the flow of travel and transport. European transport policy also supports the economy and the emergence of new innovations. New innovations and technological development include services for automated driving systems and road traffic automation.

In 2016, the European Commission presented a strategy towards the coordinated and rapid deployment of cooperative, connected and automated vehicles in road transport (European Commission 2016). A Government resolution published in 2021 defined Finland as one of the forerunners of road transport automation (Ministry of Transport and Communications 2021). With the resolution, the Government steers sustainable and safe automation development towards meeting people's needs. The resolution is based on the Action plan on legislation and key measures of transport automation of the Ministry of Transport and Communications. Its background review also recognised the importance of the real-time (dynamic) information sharing infrastructure of the Cooperative Intelligent Transport Systems (C-ITS) necessary for data utilisation and road transport automation.

Intelligent Transport Systems (*ITS*) combine information and communication technologies in the transport system. *Cooperative Intelligent Transport System C-ITS*) services can automatically alert road users to a hazardous situation or circumstance, such as an obstacle on the road or a slippery road, in the right place and at the right time. The services may also provide information aimed at improving the flow of traffic and making mobility easier in other ways, for example by providing information on a suitable driving speed when approaching a traffic light. The aforementioned service may also contribute to reducing traffic emissions, as well as services that enable the platooning of heavy vehicles.

C-ITS services also contribute to enabling automation in road transport. *An automated vehicle* can perform at least part of a driving task without driver input in that the vehicle may use services that rely on wireless communication technology (as a so-called *connected vehicle*), such as C-ITS, to support the driving task. The concept of an *automated vehicle* is used when the vehicle performs a driving task without a driver and is not connected to other vehicles or the infrastructure with wireless communication technology.

Two objectives were set for the work and are summarised below.

Objective 1: to produce information about the needs of users and society related to C-ITS services

As part of identifying the needs of users and society, it was necessary to investigate the road traffic problems in Finland that can potentially be solved with the C-ITS and other road transport-related needs of users and society.

Objective 2: to prepare a proposal for C-ITS services deployed in Finland in the first phase and prioritise the services in relation to each other

The primary limitation of the examination was the list of C-ITS services and the use cases included in them drawn up in the European C-Roads cooperation, but based on the needs identified in the work, other C-ITS services and the use cases included in them could also be covered in the examination. The C-ITS services had to be prioritised, taking into account traffic safety, flow of traffic and the environmental impacts of traffic in Finland as well as the foreseeable needs of road transport automation in Finland's conditions.

The structure and chapters of the research report consist of three parts: background research, multicriteria analysis and conclusions. The structure of the report is described in Figure 1. The background study consists of Chapters 2–4. Chapters 5–6 concern the multicriteria decision analysis and consist of the prioritisation criteria for C-ITS services and the prioritisation of services. The final Chapter 7 presents the conclusions drawn from the results.

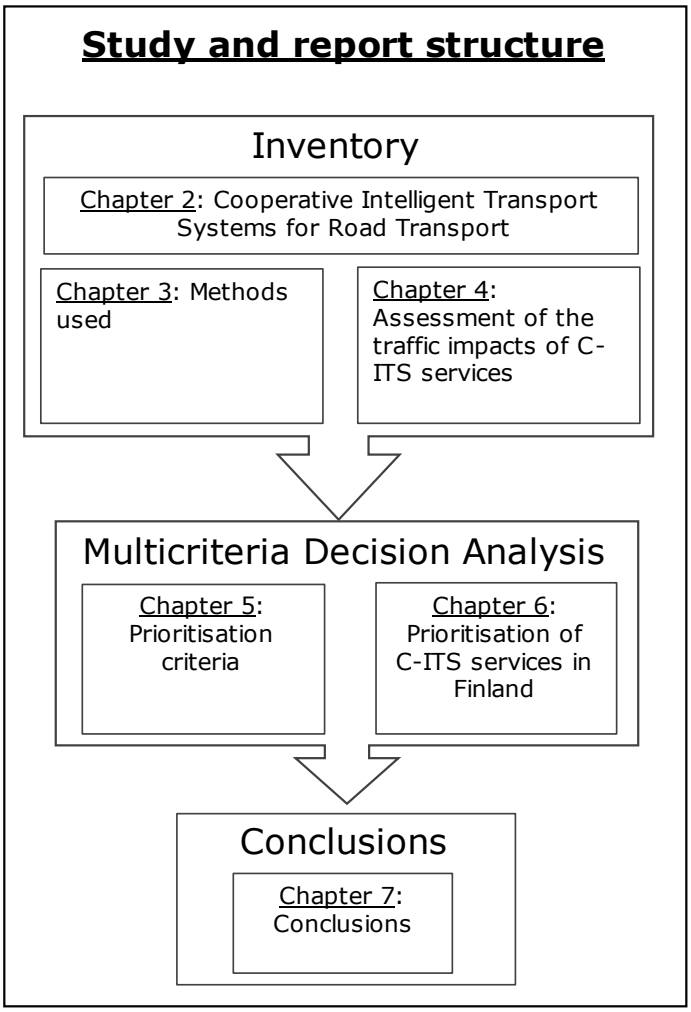

Figure 1. The structure and chapters of the research report consist of three parts: background research, multicriteria analysis and conclusions.

2 Cooperative Intelligent Transport Systems for Road Transport (C-ITS)

2.1 C-ITS technologies and standards

In Europe, Cooperative Intelligent Transport System (C-ITS) services for road transport refer to intelligent transport services provided through Cooperative Intelligent Transport Systems that exchange real-time C-ITS messages with vehicles, other road users, infrastructure or other parts of the environment in accordance with the EU C-ITS trust model. These messages can be used for purposes such as warning drivers in advance of a danger ahead, such as a slippery road surface or an accident site.

The C-ITS trust model is based on the Public Key Infrastructure (PKI) and is part of the EU C-ITS Security Credential Management System (EU CCMS).

Cooperative Intelligent Transport Systems (C-ITS) technologies include implementations utilising a short-range ad-hoc wireless network and a long-range IP (Internet Protocol). The two aforementioned implementations are collectively referred to as hybrid communication. Long-range communications utilise mobile network technologies, such as 4G/LTE (Uu interface) and 5G (NR Uu interface), and Internet Protocol (IP) and protocols used by cloud services. The following technologies are most commonly used in the 5.9 GHz frequency band for short-range networks: IEEE WLAN (802.11p) technology, also known as ITS-G5 and DSRC (Dedicated Short-Range Communications), and 5G C-V2X Direct and LTE-V2X (PC5 interface) technologies based on mobile network technologies and 3GPP standards (Garcia et al. 2021).

The combination of hardware and software components used to exchange secure and reliable C-ITS messages is also referred to as C-ITS stations or, in the context of standardisation, also as ITS stations (ETSI EN 302 665, ISO 21217). C-ITS station types include vehicle ITS station, roadside ITS station and central ITS station, as well as personal ITS station, which is carried by individual users. Vehicle ITS stations may include vehicle-integrated stations and devices installed in special vehicles, such as emergency vehicles.

Based on the ETSI and ISO standards, European road administration authorities in the C-Roads Platform cooperation group and industry in the CAR 2 CAR Communication Consortium (C2C-CC) have defined specifications and content of C-ITS messages that enable the interoperability of messages between Member States and different manufacturers. C-ITS messages are signed messages that are exchanged between C-ITS stations. (C-Roads WG TF2 2022, ETSI TS 103 301 2018)

2.2 Cooperative Intelligent Transport System (C-ITS) services

This report assessed European C-ITS services. The services were selected based on an examination of European and Finnish studies, strategies, specifications, legislation and implemented service experiments.

2.2.1 European cooperation and strategy

In the period 2014–2016, the European Commission funded the C-ITS Deployment Platform cooperation, whose aim was to implement a shared European vision for the implementation of interoperable C-ITS services. Its members included national authorities, the private sector and the European Commission. The European C-ITS strategy published by the European Commission in 2016 was based on recommendations created in the C-ITS Platform cooperation. The recommendations included the priorities for the deployment of C-ITS services, i.e. selecting a group of services that would be interoperable and widely available across Member States. Services were assessed based on their cost benefits, maturity and usefulness. Based on the assessment, a set of services which should be implemented in the first phase was recommended and named Day 1 services. The set of services recommended to be implemented in the second phase was named Day 1.5 services. (European Commission 2021a, C-ITS Platform, C-ITS Platform phase II, European Commission 2016, Table 1, Annex 2)

2.2.2 Specifications

The *C-Roads Platform* cooperation group was established by European Member States and road operators in 2015 with co-funding from the European Union's Connecting Europe Facility. The aim of the cooperation was to implement the testing and deployment of cross-border C-ITS services for European road users. The C-Roads Steering Committee is composed of representatives of the European Member States who approve the common European specifications and ensure compliance with them. C-Roads is primarily focused on communication between infrastructure and the vehicle (I2V or V2I). Finland is involved in the C-Roads Platform cooperation as a core member.

The *CAR 2 CAR Communication Consortium (C2C-CC)* examines and implements C-ITS solutions. Its members include vehicle manufacturers, equipment suppliers, research institutes and road operators. C2C-CC implements development and standardisation in European and international cooperation. The C2C-CC specifications include both vehicle-to-infrastructure communications (V2I) as well as vehicle-to-vehicle communications (V2V). (Table 1, Appendices 4 and 5)

2.2.3 Legislation

At the time of writing this report, there was no direct legislation on C-ITS services in Europe, as explained in section 2.4. Legislation. The 2019 proposed regulation, which was subsequently rejected, did not set any requirements for the locations of implemented C-ITS stations or which services should be implemented.

However, the Commission Delegated Regulations of the ITS Directive (see section 2.4 Legislation) on road-safety related traffic information (EU No 886/2013) and real-time information (EU 2022/670) contain data types similar to those communicated by C-ITS services. Below is a summarised list of the data types included in the regulations.

Road safety-related minimum universal traffic information (EU No 886/2013):

a) temporary slippery road
b) animals, people, obstacles, debris on the road
c) unprotected accident zone
d) short-term road works
e) reduced visibility
f) wrong-way driver
g) unmanaged blockage of a road
h) exceptional weather conditions.

with regard to the provision of EU-wide real-time traffic information services (EU 2022/670), at least the following data types correspond to C-ITS services:

- static and dynamic traffic regulations, where applicable
- road closures
- lane closures
- road works
- accidents and incidents
- weather conditions affecting the road surface and visibility
- traffic volume and speed
- location and length of traffic queues.

2.2.4 Experiments in Finland and elsewhere in Europe

Cooperative Intelligent Transport System (C-ITS) services have been developed and tested in Finland and Europe for several decades.

Finland participated in the pan-Nordic NordicWay projects between 2015 and 2023. These projects included piloting Transboundary and interoperable C-ITS services in accordance with the specifications of the C-Roads Platform cooperation group. Table 1 below presented the C-ITS services tested in the NordicWay 2 project. (NordicWay 2023)

Table 1. C-ITS services piloted by Nordic countries in the NordicWay 2 project.

	C-ROADS SERVICES	NORDICWAY 2 USE CASES	FI	NO	SE
Day-1 services	IVS	In-vehicle speed limit	x	x	-
	Hazardous location notifications (HLN)	Weather and road condition	x	x	-
		Slow or stationary vehicle	x	x	-
		Emergency vehicle approaching	-	-	x
		Traffic ahead warning	x	x	-
		Emergency brake light	-	x	-
		Cooperative collision warning	-	x	-
	Road works warning (RWW)	Road and lane closure	x	x	-
		Mobile roadworks	-	x	x
	Signalised intersections (SI)	Signal violation / intersection safety	-	x	-
		Time to green	-	-	x
		Green light optimal speed advisory (GLOSA)	-	x	x
		Traffic signal priority request	-	-	x
	PVD	Single vehicle data	x	x	-
Day-1.5 services	Traffic management	Traffic information & smart routing	x	x	-
		On-street parking information and management	-	x	-
		Information on alternative fuel vehicle fuelling & charging stations	-	x	-
	CAD	Data collection for mapping of infrastructure readiness	-	x	-
	CCN in and out of the city	Dynamic access control of designated infrastructure	-	-	x
	Dynamically controlled zones	Dynamic environmental zone	-	-	x

The following services were among the joint Nordic flagship services in the NordicWay 3 project that ended in 2023 (NordicWay 2023):

- Traffic signals
- Dynamic zones
- Emergency vehicle warnings
- Road works warning.

As a part of the NordicWay projects, the City of Tampere implemented C-ITS pilots for traffic signal services in its street network.

There are numerous services available in Finland that involve vehicles or smartphones exchanging warning messages between different service providers about road traffic conditions and disruptions. However, they do not use EU CCMS certificates or standard C-ITS messages and are therefore not C-ITS services.

2.2.5 Summary of the C-ITS services assessed in this report

The C-ITS services assessed in this report are listed in Table 2 below. The table shows the number of the appendix to the report that contains a list of the C-ITS services included in the publication.

Table 2. European publications listing C-ITS services.

Appendix	Publisher	Publication name, year and version
1	C-Roads Platform	C-ITS Service and Use Case Definitions (2024) Version 2.2.1
2	C-ITS Platform	Phase II Final report (2017)
3	5GAA Automotive Association	C-V2X Use Cases (2023)
4	CAR 2 CAR Communication Consortium	Basic System Profile Use Cases (2015)
5	CAR 2 CAR Communication Consortium	Beyond Release 1 Use Cases
6	ETSI ITS Vehicular Communication Basic Set of Applications	*ETSI TR 102 638 v2.2.1 (2024-04);* Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Release 2. *ETSI TS 103 324 V2.1.1 (2023-06)* Intelligent Transport System (ITS); Vehicular Communications; Basic Set of Applications; Collective Perception Service; Release 2.

2.3 Parties and roles

C-ITS systems involve several parties, roles and tasks that, regarding public and private actors, cover areas such as the implementation, maintenance and supervision of the software and infrastructure required by services. In its report, C-Roads Platform WG1 presented the high-level roles described in C-ITS standardisation, which are shown in Figure 2.

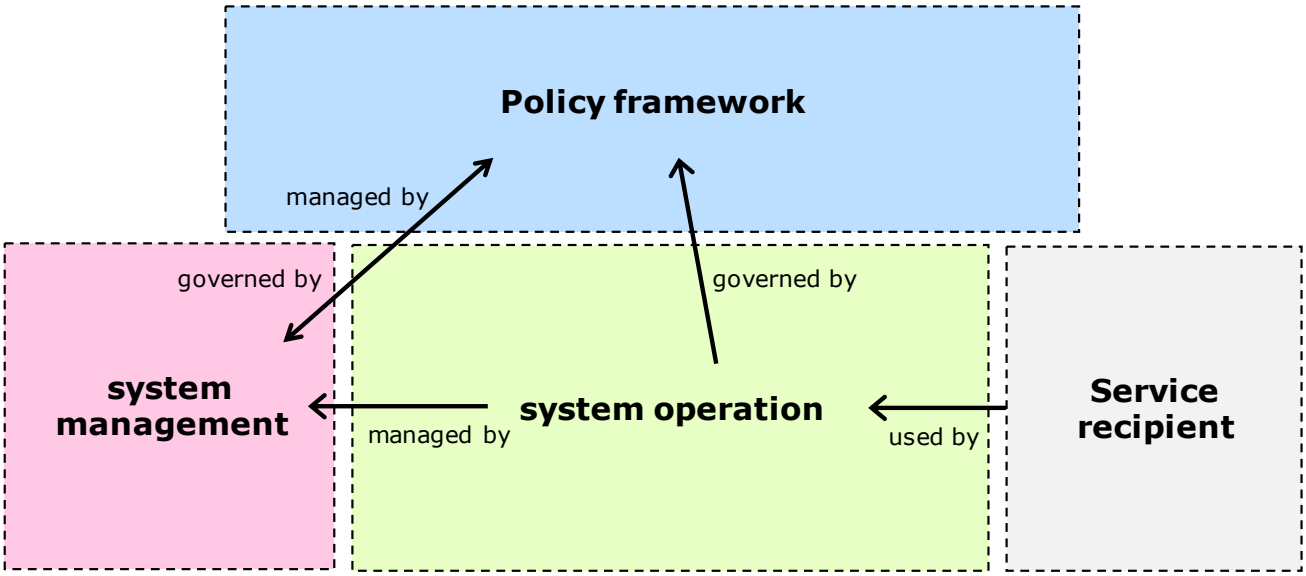

Figure 2. The image according to ISO TS 17427 shows four high-level C-ITS roles. (Kotilainen et al. 2024)

Operational level C-ITS actors include:

- authority
- European Commission
- infrastructure owners and operators
- component and equipment manufacturers
- automotive industry
- mobile network operators
- service providers
- C-ITS service operator
- National Access Point and the designated bodies.

More information on the parties, roles and tasks related to C-ITS systems is available in the Finnish Transport and Communications Agency Traficom publication 23/2023 "Viranomaisten roolit vuorovaikutteisten älykkäiden liikennejärjestelmien (C-ITS) palveluiden käyttöönotossa ja operatiivisessa käytössä" ("The roles of the authorities in the implementation and operational use of Cooperative Intelligent Transport Systems (C-ITS) services"; Kotilainen et al. 2024).

2.4 Legislation

At the time of writing this report, there was no direct legislation on C-ITS systems in place in Europe. The Intelligent Transport Systems (ITS) Directive serves as a framework directive for the coordinated deployment of transboundary intelligent transport in Europe. The ITS Directive empowers the European Commission to adopt delegated regulations in its priority sectors. (EU 2023/2661)

The proposed Delegated Regulation on C-ITS was published in 2019. The proposed regulation was prepared in cooperation between the European Commission and the Member States in the period 2017–2019. However, the proposed regulation was rejected in the final vote and was thus not adopted. As a result of the amendment of the current revised ITS Directive, the European Commission has the competence to continue the preparation of the regulation. (European Commission 2019)

More information on the legislation related to C-ITS systems is available in the Finnish Transport and Communications Agency Traficom publication 23/2023 "Viranomaisten roolit vuorovaikutteisten älykkäiden liikennejärjestelmien (C-ITS) palveluiden käyttöönotossa ja operatiivisessa käytössä" ("The roles of the authorities in the implementation and operational use of Cooperative Intelligent Transport Systems (C-ITS) services", (Kotilainen et al. 2024)

2.5 C-ITS services examined in this report

Table 3 lists the services originally selected for the report, which include not only the services covered by the C-Roads specifications (Appendix 1) but also the C-ITS Platform services (Appendix 2). The services are classified into the following categories, depending on the parties involved in the exchange of information:

- I2V, i.e. infrastructure to vehicle
- V2I, i.e. vehicle to infrastructure
- Verv2V, i.e. emergency or rescue/recovery vehicle to vehicle
- Vpt2V, i.e. public transport vehicle to vehicle
- Vru2V, i.e. vulnerable road user to vehicle
- Vro2V, i.e. road operator vehicle to vehicle.

Table 3. Services examined in the report (C-Roads Specifications version 2.2.1, C-ITS Platform Final Report 2017).

C-ITS services and use cases	Data ex-change	Source
In-vehicle signage (IVS)		
Traffic signs (IVS-TS)	I2V	C-Roads
In-vehicle speed limit (VSPD)	I2V	C-ITS Platf.
Free text (IVS-FT)	I2V	C-Roads
Smart routing (IVS-SM)	I2V	C-Roads
Hazardous locations notification (HLN)		
Accident zone (HLN-AZ)	I2V	C-Roads
Emergency electronic brakelight (EBL)	V2V	C-ITS Platf.
Traffic jam ahead (HLN-TJA)	I2V	C-Roads
Stationary vehicle (HLN - SV)	I2V	C-Roads
Weather condition warning (HLN-WCW)	I2V	C-Roads
Temporarily slippery road (HLN-TSR)	I2V	C-Roads
Animal or person on the road (HLN-APR)	I2V	C-Roads
Obstacle on the road (HLN-OR)	I2V	C-Roads
Emergency or rescue/recovery vehicle in intervention (HLN-ERVI)	Verv2V	C-Roads
Emergency or prioritized vehicle approaching (HLN-EPVA)	Verv2V	C-Roads
Railway level crossing (HLN-RLX)	I2V	C-Roads
Unsecured blockage of a Road (HLN-UBR)	I2V	C-Roads
Alert wrong way driving (HLN-AWWD)	I2V	C-Roads
Shockwave damping (SWD)	I2V	C-ITS Platf.
Public transport vehicle crossing (HLN-PTVC)	Vpt2V	C-Roads
Public transport vehicle at a stop (HLN-PTVS)	Vpt2V	C-Roads
Collision warnings		
Cooperative collision risk warning	I2V	C-ITS Platf.
Vulnerable road user protection (pedestrians and cyclists)	V2V, vru2V	C-ITS Platf.
Motorcycle approaching indication	V2V, vru2V	C-ITS Platf.
Road work warnings (RWW)		
Lane closure (and other restrictions) (RWW-LC)	I2V	C-Roads
Road closure (RWW – RC)	I2V	C-Roads
Road works mobile (RWW-RM)	I2V	C-Roads
Winter maintenance (RWW-WM)	Vro2V	C-Roads
Signalized intersections (SI)		
Signal phase and timing information (SI-SPTI)	I2V	C-Roads
Green light optimal speed advisory (SI-GLOSA)	I2V	C-Roads
Imminent Signal Violation Warning (SI-ISVW)	I2V	C-Roads
Traffic light prioritisation (SI-TLP)	I2V, V2I	C-Roads
Emergency vehicle priority (SI-EVP)	I2V, V2I	C-Roads
Toll station crossing (SI-TSC)	I2V	C-Roads

C-ITS services and use cases	Data ex-change	Source
Information and management		
Information on alternative fuelled vehicle charging and fuelling stations (iFuel)	I2V	C-ITS Platf.
Park & ride information (P&Ride)	I2V	C-ITS Platf.
Traffic information & smart routing (SmartR)	I2V	C-ITS Platf.
Loading zone management (LZM)	V2I, I2V	C-ITS Platf.
Zone access control management (ZACM)	I2V	C-ITS Platf.
Automated vehicle guidance (AVG)		
SAE level guidance (AVG-SAELG)	I2V	C-Roads
Platoon support information (AVG-PSI)	I2V	C-Roads
Topology information		
Toll Station Approaching (TI-TSA)	I2V	C-Roads
Points of interest		
Parking availability (POI-PA)	I2V	C-Roads
Collective perception		
Collective perception on motorways (CP-MW)	I2V	C-Roads
Collective perception on urban/interurban intersections (CP-UI)	I2V	C-Roads
Probe vehicle data (PVD)		
Vehicle data collection (PVD-VDC)	V2I	C-Roads
Event data collection (PVD-EDC)	V2I	C-Roads

3 Methods used

3.1 Determining the needs of users and society

The needs of users and society were examined qualitatively and quantitatively by analysing statistics and conducting a literature review, interviews, a workshop and expert assessments.

The analysis of statistics and literature review were carried out using information available from public sources on road safety, the environmental impacts of traffic and satisfaction with the transport system and traffic flow. The aim was to provide background information for the assessment of the problems and needs of the transport system as part of the assessment of C-ITS services.

The *interviews* were mainly carried out as group theme interviews, whose participants were Finnish experts and road users. The results of the interviews are reported in Chapter 5 User needs.

All of the interviews were conducted as remote interviews, and the participants had an opportunity to use a video connection during them. The group of service providers and manufacturers also included foreign experts as representatives of companies. Table 3 below presents the interview groups and the organisations that participated in the groups. Interview invitations were sent to 62 organisations, of which ultimately thirty-one (n = 31) organisations (50%) participated in the interviews and provided feedback. If the organisation was willing to participate but was prevented from participating in a group interview, they were offered an opportunity for an individual interview or could submit their responses in writing: three individual interviews were conducted remotely and, additionally, one organisation submitted their responses in writing.

The expertise of the steering group for this study and the parties and roles in the C-ITS value chain identified in the European C-Roads group's work presented in Chapter 2 (Table 4), were utilised in defining the interview groups and determining the group compositions. All interviewed groups and organisations were also offered the opportunity to submit feedback and materials in writing. After the interviews, written feedback was also received from three organisations.

Table 4. Six expert groups and participating organisations.

#	Group	Organisations
1	Public transport	Helsinki Region Transport (HSL), Koiviston Auto, Linja-autoliitto ry (Finnish Bus and Coach Operators' Association), Matkahuolto, Finnish Taxi Owners' Federation
2	Municipalities	ITS Factory (Tampere), Association of Finnish Local and Regional Authorities, City of Tampere, City of Vantaa
3	Logistics	Logistiikkayritysten liitto (Finnish Federation of Logistics Companies), Metsäteho, Posti, Finnish Transport and Logistics SKAL, Tietorahti
4	Service providers, manufacturers and groups representing them	5G Automotive Association (5GAA), Aebi Schmidt Group, CAR 2 CAR Communication Consortium (C2C-CC), Conveqs, DNA, Elisa, ITS-Finland, Kapsch, Manifesto (Kapsch as a partial representative), Nodeon Finland, Sitowise, Swarco, Telia, Volkswagen (VW), Yhteinen Toimialaliitto ry (YTL)
5	Maintenance/weather management	Destia, Finnish Transport Infrastructure Agency, Teconer, Roadscanners, Finnish Meteorological Institute, YIT
6	Road users	Enemmistö ry, Finnish Association of People with Physical Disabilities, Finnish Road Safety Council, Finnish Cyclists' Federation, Suomen Motoristit ry (SMOTO)

The maximum duration of the group theme interviews was two hours. First, the interviews began by presenting the background and objectives of the work, including a summary of the Cooperative Intelligent Transport System (C-ITS) services to the participants. Second, a summary of the preliminary results of a problem analysis of road traffic in Finland was presented. Third, the interviewees were presented with the following two themes and related questions for discussion:

- What problems and needs related to Finland's street and road network do you have?
- Which of the problems and needs are priorities? A summary of the problems and needs discussed and their order of priority; which of the problems are the worst? Which of them are the most significant?

In addition to discussions, the group interviews with service providers, manufacturers and groups representing them utilised a working platform that enabled the participants to give anonymous feedback on notes. This platform made it possible for the members of the largest group to provide feedback as a part of the discussion, possibly lowering the threshold for giving feedback on a topic that could otherwise be considered sensitive for the company. This feedback obtained through the work platform was analysed qualitatively and quantitatively.

The aim of the *workshop* was to validate the criteria used in the study, their weights, and the scored and prioritised C-ITS services. An invitation to the workshop was sent to 62 organisations that were the same as the ones

that had previously participated in the group interviews. Ultimately, thirty-eight of the organisations participated in the workshop (n = 38).

The workshop was carried out in a structured format, which involved the participants responding to pre-planned questions and surveys in four parts. In connection with the questions, the participants were presented a list of C-ITS services and the assessment criteria and assessed scores for the question as well as the order of priority of the services. The four parts of the workshop and their questions were as follows:

1. Criteria weights
    i. A structured survey on the weights.
    ii. Do you think the weights are correct?
    iii. The weights given to the lower levels of roads and streets?
2. Part 1 - Criteria values and costs
    i. Societal, techno-economic and user needs, each of which also included the following questions:
        1. Do you have any comments on the list?
        2. Should the list include some other service?
        3. Please explain your views.
    ii. Questions about the investment costs to public actors:
        1. Do you have any comments on the costs?
        2. Are some of the numbers too low or too high?
        3. Please explain your views.
3. Part 2 – Service prioritisation
    i. The needs of society and users;
        1. Do you have any comments on the list?
        2. Should the list include some other service?
        3. Please explain your views.
4. Starting points for forming the operational programme
    i. A structured questionnaire on the formation of an operational programme.
    ii. What would be the best way to proceed, or a combination of the proposed services?
    iii. What other grounds could work?

In the workshop, the participants commented on the questions using an interactive tool in an online service, which enabled each participant to write their comments and questions using a notes feature. The participants were also given an opportunity to ask for permission to comment.

Expret assessments on the needs of users and society were also obtained from the organisations represented in the steering group of the study, which were the Finnish Transport and Communications Agency, the Finnish Transport Infrastructure Agency, Fintraffic Ltd's subsidiary of road traffic

management and management Fintraffic Tie Oy, the Ministry of Transport and Communications, and the cities of Tampere and Helsinki.

In addition, a group of experts from Finland's reference countries, including representatives of the authorities from Belgium, the Netherlands, Ireland, Norway, Sweden, Switzerland and Denmark, was consulted on the needs.

3.2 Selection of C-ITS services

The C-ITS services discussed/analysed in the report were selected in the following three phases, which were repeated (iterated) whenever this was considered necessary for examining the needs:

- The first phase included compiling the C-ITS services identified in the literature and their specifications, which were presented in section 2.2 and in the appendices to this report.
- In the second phase, the development of services in Europe and the requirements valid in Europe were assessed by means of a literature review, group interviews and expert assessments.
- In the third phase, the needs for useful services were assessed based on the needs of users and society.

Section 2.5 C-ITS services examined in this report presented the services originally selected after the 1st–3rd assessment rounds of the first phases. The final prioritised services and service clusters are presented in Chapter 7 of this report.

3.3 Assessment of C-ITS services

The assessment of services focused on the impacts of services on traffic safety, flow of traffic, greenhouse gas emissions and accessibility. The key indicator for road safety was the number of people killed and injured in traffic, the key indicator for the flow of traffic was the travel time spent in traffic, and the key indicator for greenhouse gas emissions was the amount of carbon dioxide emissions. Accessibility was assessed as the qualitative accessibility of services, as the general main indicator of accessibility, travel time (Finnish Transport Infrastructure Agency 2020), is already used as an indicator of the flow of traffic.

The assessment of each service began as an impact chain analysis, which described the behavioural changes in different actors caused by the service and the changes likely to arise from this in different impact areas. This phase also involved identifying which part of the transport network the impacts mostly affect, for example motorways, roads, urban areas, etc.

Next, information on the estimated impacts of different services was examined using the literature. The most important sources were the NordicWay 2 Evaluation Report (Innamaa et al. 2021) and an assessment report (Asselin-Miller et al. 2016) related to the Final Report on the C-ITS Platform (C-ITS Platform 2016), in which the assessments were described using a network relevant to each service, assuming that the service would be used in all vehicles. In addition, recent assessment summaries from the C-Roads Platform (2024) and pilots carried out in the United States (Balke et al. 2023) were utilised. The NordicWay 2 assessments were utilised in their original form, but the results of other assessments were modified to correspond to Finland's traffic conditions as an expert assessment. The figures depict a situation in which all users are using the service as opposed to a situation where the service or any similar solution is not used.

If no assessment of the entire relevant network was available for the services, an approximate assessment was produced by extending point- or transaction-specific estimates to the network level with basic information on the transport system. This was done as an expert assessment.

The assessments were reviewed by consulting an international expert group from the reference countries and the steering group of the study.

3.4 Establishment of prioritisation criteria

The services were prioritised using multicriteria analysis and, specifically, the multicriteria decision analysis method (Government Analysis Function 2024). In the method, the values of the criteria reflect how well the examined service corresponds to the optimal value of the criterion. The criteria were divided into four main criteria areas as shown in Table 5.

Assessments of the impacts on user needs were made based on expert interviews and literature. In other criteria areas, qualitative assessments were produced as expert assessments by the authors of this report based on literature and experience.

The costs of implementing and providing the service were also used as one of the criteria, but these were partly excluded from the actual multicriteria calculation. This was due to also using the costs in comparing the weighted sums and costs of other criteria as a prioritisation criterion for different services. The criteria can be formed based on a single factor mentioned above or a combination of several factors. When forming the criteria and planning the prioritisation in general, a consultation group comprising public sector experts in Finland's reference countries was utilised.

Table 5. Prioritisation criteria and the establishment of their values.

Criterion	Formation method
Impacts promoting the needs of society	
Improving traffic safety	Quantitative impact assessment
Improving the flow of traffic	
Reducing CO_2 emissions from transport	
Improved accessibility of services	Qualitative assessment
Impacts promoting the needs of users	
Meeting the needs of motorists	Qualitative assessment
Meeting the needs of people using active modes of transport	
Meeting the needs of public transport users	
Meeting the needs of public transport operators	
Meeting the needs of emergency vehicle users	
Meeting the mobility needs of special groups	
Meeting the needs of companies providing transport services (incl. taxis)	
Meeting road and street maintenance needs (planning, construction, maintenance, service)	
Meeting road traffic management needs	
Meeting the needs of municipalities with the street network	
Improving logistics efficiency	
Meeting the needs of transport companies	
Improving the operation of automated driving systems	
Techno-economic feasibility	
Technical feasibility, i.e. the existence of the required digital infrastructure, telecommunications infrastructure and competence, ease of technical feasibility and maintenance of information security	Qualitative assessment
Existence of effective business models	
Existence of an ecosystem for service implementation	
Development of business and its competitiveness	
Added value provided by C-ITS in data production	
Strategic and legal framework	
Existence of C-Roads service specification	Qualitative assessment
Data type in the SRTI or RTTI Regulation of the ITS Directive	

3.5 Prioritisation of C-ITS services

Multi-Criteria Decision Analysis (MCDA) was used for the prioritisation of services. The method allows decision-makers to choose between options when there are many factors affecting a decision and the factors cannot be compared in a commensurate way, for example, because some of the factors are quantitative and some are qualitative. Many different versions of MCDA methods are available. This study used a procedure recommended by the public sector in the United Kingdom, where a numerical value is produced for all comparison criteria. This enables clearly indicating the mutual preferability of each individual assessment criterion. The high preferability

of an individual option in view of one criterion may compensate for its low preferability regarding another criterion. (Government Analysis Function 2024)

For each criterion, the most successful service was scored 100 and the least successful 0. For quantitative variables, i.e. the impacts on safety, flow of traffic and carbon dioxide emissions of a service indicated as a percentage, the highest impact percentage produced a value of 100 and the other values were calculated by multiplying the percentage estimates by 100/(highest impact percentage).

For the qualitative criteria, the most successful service was first given the value of 100 and the worst 0. The values assigned to the other services were positioned between these reference points so that the differences in their values reflected their relative difference with respect to the criterion. In other words, this is an interval scale where, in addition to the order of the values, the distance (difference) between the points on the scale has a relevant interpretation.

The method makes it easy to calculate the most recommended service on the basis of several criteria using a weighted average. If there are n criteria to be examined, the preferability of the individual service S is calculated using the equation:

$$S_{total} = (P_1S_1 + P_2S_2 + P_3S_3 + \ldots + P_{n-1}S_{n-1} + P_nS_n)/n,$$

where P_k describes the weight of criterion k in the comparison. The sum of the weights $P_1 + P_2 + P_3 + \ldots + P_{n-1} + P_n = 1$, which means that the maximum value of term S_{total} is 100, if the service value for each criterion is 100.

The authors determined the values and weights of the criteria based on their experience and expertise as well as data available. The values and weights were reviewed both in the expert group of the reference countries and in the steering group. The steering group made the ultimate decision on the values used in the study. The weights used in the study for different criteria were as presented in Table 6.

Table 6. The weights of different criteria in the calculation on roads and streets. The main level describes the differences in weighting between criteria areas when different criteria groups are used in the calculation at the same time.

Criterion	Main level	Roads	Streets
Impacts promoting the needs of society			
Improving traffic safety	0.3	0.3	0.29
Improving the flow of traffic		0.3	0.29
Reducing CO_2 emissions from transport		0.3	0.33
Improving the accessibility of services		0.1	0.09
Impacts promoting the needs of users			
Meeting the needs of motorists	0.3	0.1	0.08
Meeting the needs of emergency vehicle users		0.025	0.025
Meeting the mobility needs of special groups		0.025	0.025
Meeting the needs of people using active modes of transport		0.1	0.12
Meeting the needs of public transport users		0.05	0.06
Meeting the needs of public transport operators		0.05	0.06
Meeting the needs of companies providing transport services (incl. taxis)		0.1	0.08
Meeting road and street maintenance needs (planning, construction, maintenance, service)		0.125	0.075
Meeting road traffic management needs		0.125	0.075
Meeting the needs of municipalities with the street network		0	0.15
Improving logistics efficiency		0.1	0.075
Meeting the needs of transport companies		0.1	0.075
Improving the operation of automated driving systems		0.1	0.1
Techno-economic feasibility			
Existence of the required digital infrastructure	0.3	0.6	0.6
Existence of the required telecommunications infrastructure			
Existence of required competence			
Ease of technical feasibility			
Existence of effective business models		0.1	0.1
Existence of an ecosystem for service implementation		0.05	0.05
Development of business and its competitiveness		0.15	0.15
Added value provided by C-ITS in data production		0.1	0.1
Strategic and legal framework			
Existence of C-Roads service specification	0.1	0.5	0.5
Data type in the SRTI or RTTI Regulation of the ITS Directive		0.5	0.5

4 Assessment of the traffic impacts of C-ITS services

The traffic impacts are discussed below, one service at a time. First, a description of what information is shared and with whom is provided. Subsequently, there is an examination of the mechanisms through which the information influences the behaviour of road users and, consequently, traffic. Finally, the available impact data and their suitability for Finnish conditions are examined.

4.1 In-vehicle signage

The in-vehicle signage service provides information on stationary and changing traffic signage on the side of the road and possibly also their significance for the expected behaviour of the road user. The service is expected to increase road users' awareness of the traffic signs and rules currently in force, even when the signs are difficult to observe. (C-Roads Platform 2024)

The service is likely to increase compliance with traffic signs and thus traffic rules and improve adaptation to the prevailing conditions, which reduces the risk of collisions and injuries.

The impact assessment study on the C-ITS Platform (Asselin-Miller et al. 2016) estimated that data on traffic signage other than speed limits would reduce accidents resulting in personal injury in Europe by 0.7%, but would have little impact on traffic flow or travel time emissions. C-Roads (2024) estimates that the service will slightly reduce carbon dioxide emissions.

Speed limit data is expected to have a significant impact on traffic accidents. It is estimated to reduce personal injury accidents by 3% and carbon dioxide emissions by 0.2% in Nordic conditions (Innamaa et al. 2020). Despite an increase of in-vehicle signage information visible in vehicles, the mandatory use of ISA (Intelligent Speed Assistance) in new cars (European Commission 2021b) will probably keep the impacts at the aforementioned level. The service will probably increase travel times, but this is mainly due to a reduction in speeding, which is not considered a disadvantage in socio-economic assessments.

Assessments of the impacts of textual signage information are not available, but the impacts were estimated to be somewhat lower than other in-vehicle signage.

In a specialised smart routing service, travel times to airports or similar destinations, possibly using alternative routes, provided in traffic signs, are produced for the road user's device. While the service is not expected to affect traffic safety or carbon emissions, it is projected to reduce travel times by 0.2% (Innamaa et al. 2020).

4.2 Hazardous location notifications

Hazardous location notifications are warning messages about conditions and situations on the road involving risk. The notifications indicate the type, location and potential duration of the risk situation. The aim of the services is to alert road users while also providing recommendations on speed or the lane to be used. The services are expected to increase road users' alertness to minimise collision risks, which is expected to reduce the number of collisions and related injuries or fatalities. (C-Roads Platform 2024)

The safety impacts of different warning services are described below. All services that reduce the risk and number of collisions also reduce travel times and CO2 emissions. This is due to a reduction in the number of traffic jams caused by collisions. This indirect effect is greater the more the risk of collision is reduced. Warning services have been estimated to have a very minor direct impact on travel times and carbon dioxide emissions (Asselin-Miller et al. 2016, Innamaa et al. 2020).

In the CODIA project (Kulmala et al. 2008), an Accident Zone warning was estimated to reduce collisions on the European road network by 0.7%, but the decrease in the Finnish road network is currently likely to be significantly smaller, perhaps 0.3%, due to the general improvement in traffic safety.

The Emergency Electronic Brakelight alerts drivers to sudden braking in vehicles ahead, which is especially useful in fast-moving but congested traffic. The service based on vehicle-to-vehicle communication has been estimated to reduce collisions by 3% in Nordic conditions (Innamaa et al. 2020).

Both the Traffic Jam Ahead warning and the Stationary Vehicle warning have been estimated to reduce collisions by 1% in Nordic conditions (Innnamaa et al. 2020).

The NordicWay2 project (Innamaa et al. 2020) estimated that warnings related to road weather and road conditions (Weather Condition Warning, Temporary Slippery Road) would reduce collisions by 0.1% in Nordic conditions where road users are already offered similar warnings through several channels.

An Animal or Person on the Road warning is estimated to reduce collisions by around 2%. The estimate is based on the fact that road accidents involving cervids and collisions with people using active modes of travel account for about 15% of all accidents involving personal injury. According to a study on the impacts of a Porokello warning system (Kotituomi et al. 2019), a similar warning reduced reindeer–vehicle collisions by 15%. The impact of the collisions with people using active modes of travel is roughly

the same (0.15 x 0.15 = 0.0225 or 2.3%) while moose– and deer–vehicle collisions may be less than half (1.15%).

Warnings alerting motorists of an obstacle on the road and an unsecured blockage of a road have been assessed (Innamaa et al. 2020) to reduce collisions by 1% in Nordic conditions.

The NordicWay2 project (Innamaa et al. 2020) estimated that warnings alerting motorists of an emergency or rescue/recovery vehicle in intervention and emergency or prioritized vehicle approaching would reduce accidents involving personal injury by 0.03%. The low percentage for all accident types is due to the low number of accidents involving emergency vehicles, although the service has a significant impact on them.

Level crossing warnings (Öörni et al. 2011) have been estimated to reduce accidents involving personal injury by 0.6%. As level crossings are currently mainly located on roads with considerably low traffic, the positive impact on safety of these warnings was not estimated to involve a reduction in travel times or CO2 emissions.

An alert of wrong way driving, which warns the motorist of a vehicle driving against traffic, is typically aimed at dual-carriageway roads. Due to their small number and the small number of related collisions, the impact of these alerts, albeit considered effective, on the number of collisions in Finland has been estimated to be around 0.05% (Innamaa et al. 2020).

Shockwaves, i.e. the phenomena that a shockwave damping service targets, are also not particularly common in Finland’s conditions. At the annual level, the impact of the service in reducing collisions in Finland, a country characterised by low traffic flows, is roughly 0.01%; by contrast, the impact at the EU level, for example, is estimated to be as high as 5% (Asselin-Miller 2016).

In the Czech Republic, public transport vehicle crossing or public transport vehicle at a stop warnings were estimated to reduce collisions by 0.2% (C-Roads 2024). In Finland’s conditions, the impact of the service warning motorists of a public transport vehicle at a stop was estimated to be approximately 0.1%, as Finland has very clear traffic rules and arrangements for related interactive situations.

4.3 Collision warnings

Collision warnings inform the service user of other road users nearby at a given time. The message allows the driver or traveller receiving the message to take these users into account and thus makes them aware of the likelihood of collision, allowing for an evasive manoeuvre or braking if necessary. While the direct impact of collision warnings mainly concerns

safety, the warnings also indirectly reduce travel times and carbon emissions using the same logic as hazardous location notification.

A cooperative collision risk warning has been assessed at the EU level to have a high impact on services, reducing collisions by up to 8% (Asselin-Miller 2016). In Finland’s conditions, the impact is estimated to be reduced by half due to lower traffic volumes and density.

Vulnerable road user protection not only warns the driver but also performs emergency braking if necessary to avoid a collision. The service is estimated to reduce collision risk by 1.9% (Asselin-Miller 2016). This figure is also probably the right magnitude on the streets of Finland. On interurban and rural roads, the service is estimated to have barely any effect.

Based on EU-level estimates, motorcycle approaching indication alerts reduce the risk of collision in urban areas by 4.8%. In Finland's conditions, the impact is estimated to be around 1% due to the lower share of the total number of kilometres driven with motorcycles compared to the EU average.

4.4 Road works warnings

Road work warnings apply to stationary road construction sites, slow-moving paving sites or painting, mowing and other similar vehicles as well as maintenance vehicles moving in traffic flows. The warnings are expected to increase the safety of both road workers and other road users in connection with road work. The improvement of safety also has an indirect impact on traffic flow and carbon emissions in the case of these warnings.

The aim is to ensure that road users pay good attention and follow proactive driving practices when approaching and bypassing road works by providing them with road work information (precise location, possible lane arrangements, traffic arrangements and restrictions). This prevents sudden braking and evasive manoeuvres that may lead to collisions. At the same time, the flow of traffic will improve in connection with road work. (C-Roads Platform 2024)

It has been estimated that warnings of lane closures and other road restrictions or road closures will reduce collisions by 0.5% in Finland's conditions (Innamaa et al. 2020).

Warnings of mobile road works (Road Works Mobile) were estimated to reduce the number of collisions (Innamaa et al. 2010) by 0.25%. Winter maintenance warnings are probably equally effective.

4.5 Signalised intersections

These services produce information for road users and vehicle information for traffic light systems to secure and streamline traffic in signalised intersections. The aim is to drive more attentively in signalised intersections using vehicle information, speed recommendations and signal priority, which leads to higher energy efficiency and traffic safety. (C-Roads Platform 2024)

Signal phase and timing information has been estimated (Innamaa et al. 2020) to reduce collisions in urban areas by 0.15% and to slightly reduce travel times and carbon dioxide emissions.

Green Light Optimal Speed Advisory (GLOSA) reduces collisions in urban areas by 0.35% in Finland's conditions. According to C-Roads (2024) assessments, the service balances traffic flows, reduces stops and affects travel times mainly in time-controlled traffic lights. The reduction in travel time in urban areas was estimated at 0.006%. GLOSA affects carbon dioxide emissions, especially for heavy-duty vehicles, as their energy consumption increases significantly in traffic that involves frequent stopping (C-Roads 2024). At the EU level, the impact on emissions is estimated to be between -0.3% and -0.8% (Asselin-Miller et al. 2016). The impact is estimated to be -0.3% in Finnish cities.

Imminent signal violation warnings mainly affect safety. At the EU level, the service was estimated to reduce collisions in signalised intersections by 7% (Asselin-Miller 2016). The impact on street traffic in Finland is approximately -0.4% (Innamaa et al. 2020). The service has indirect impacts on travel time and carbon emissions due to reduced congestion caused by collisions.

Traffic light prioritisation for public transport and other heavy vehicles does not have a significant impact on traffic safety. The impacts on travel times depend on local conditions and, in particular, the traffic flows at the intersection. If most traffic approaches the intersection from the same streets as the prioritised vehicles, travel times will be reduced. In an opposite situation, travel times will be extended. As a result, the service is assumed to have very minor impacts on travel time. On the other hand, emissions from heavy goods vehicle traffic are reduced, which reduces emissions from all traffic (C-Roads 2024). At the EU level, carbon dioxide emissions from buses were estimated to decrease by 8% (Asselin-Miller et al. 2016). The service may reduce carbon dioxide emissions from Finnish street traffic by approximately 0.1%, as 7% of buses are already electric and buses account for about 1% of the total number of kilometres driven.

Emergency vehicle priority mostly affects safety. While its impact on the number of accidents is expected to be minor in Nordic conditions, the

estimated impact on fatalities was 4% (Innamaa et al. 2020). Consequently, accidents involving personal injury were estimated to decrease by 1%.

Finland is not expected to introduce road toll stations in the next few years, and as a result, the toll station crossing service is not expected to have an influence in Finland's conditions in the next few years.

4.6 Information and management

These services guide road users to find refuelling, parking or loading sites or other destinations they are looking for. The services therefore mainly affect travel times and traffic emissions by reducing the distance travelled and the time spent to reach the destination. The information service also affects the accessibility of information services. The impacts on road safety have been assessed to be very small. (Asselin-Miller et al. 2016, Innamaa et al. 2020)

Information on alternative fuelled vehicle charging and fuelling stations (Innnamaa et al. 2020) has been estimated to reduce travel times by 0.1% and carbon dioxide emissions by 0.1% in Finland's conditions.

The impact of Park & Ride information is estimated to be around -0.1%. At the EU level, this service has been estimated to reduce carbon dioxide emissions from transport in urban areas by approximately 0.3% (Asselin-Miller 2016), but the impact in Finnish conditions is likely to be at most half of this, at 0.15%.

Traffic information & smart routing (SmartR) reduces travel times and transport-related carbon dioxide emissions, especially in urban areas (Asselin-Miller et al. 2016). The reductions are probably roughly 0.2% in Finland's conditions (Innamaa et al. 2020).

The loading zone management service has minor impacts on travel times, but the service reduces emissions from heavy traffic. As a result, emissions from all transport have been estimated (Asselin-Miller 2016) to reduce carbon dioxide emissions from transport by 0.3% at the EU level. In Finland's conditions, the impact is likely to be at most half, or 0.15%.

4.7 Automated vehicle guidance

SAE Level Guidance is a service that provides instructions for a SAE level 3 or 4 autonomous driving system related to the automation level used. The aim is to improve traffic safety in situations where the autonomous driving capability of a car is considered to pose risks to the flow and safety of traffic. (C-Roads Platform 2024). According to studies, vehicle fleet operators are responsible for the guidance of self-driving cars based on their own

data sources (Vreeswijk et al. 2023). Therefore, the influence of the road operator and traffic centres on guidance is relatively limited. Guidance on the level of automation provided by road operators and traffic centres is estimated to reduce the risk of collisions by 0.1% and, indirectly, the travel times and carbon dioxide emissions to some extent.

The purpose of the Platoon Support Information service is to inform platoon users of road sections that are not suitable for platooning. As platooning will probably not be very common in Finland in the next few years, the impacts of the service on traffic safety and travel time will be minimal. As the most significant traffic impact of platooning is the reduction of energy consumption and thus carbon emissions, it is assumed that carbon dioxide emissions can be reduced by about 0.001%.

4.8 Topology information

As Finland is not expected to introduce road toll stations in the next few years, toll station approaching information is not expected to affect drivers in Finland's conditions.

4.9 Points of interest

A parking availability service provides information on parking places, garages and spaces nearby. The service is expected to make it easier for users to find the parking spaces they need and therefore shorten journeys as well as reduce travel times and energy consumption. (C-Roads Platform 2024).

Parking availability information is not expected to have a significant impact on traffic safety (Asselin-Miller et al. 2016, Innamaa et al. 2020). The carbon dioxide emissions from travel times and transport (Innamaa et al. 2020) are estimated to decrease by 0.01% in Finnish conditions. The reduction is supported by slightly higher reduction estimates at the EU level (Asselin-Miller et al. 2016, C-Roads 2024).

4.10 Collective perception

In a collective perception service, sensors in the road environment and vehicles produce information on the observed locations and movements of road users and obstacles on the roadway for all road users. As a result, collective perception messages improve road users’ awareness of their environments despite visibility obstructions and shortcomings in perception capacity. In the use cases of the C-Roads Platform (2024), only information produced by sensors in the road environment is shared with cars in specific situations:

- Collective Perception on Motorways, either at tunnel openings or entry ramps, and
- mainly in Collective Perception on Urban/Interurban Intersections, focusing on unprotected road users.

As accidents related to use cases are rare on motorways, the impact on the collision risk is around -0.05%. Motorway entry is likely to become a little easier, but the impact on carbon emissions is negligible. In urban areas, the intersection use case can be expected to have a similar impact to a vulnerable road user protection service, though around one third lower, as the former also includes emergency braking to avoid a collision. As a result, the impact of the collective perception service on the collision risk would be -1.27%. The impacts on travel time and carbon emissions are minimal.

4.11 Probe vehicle data

The probe vehicle data service differs from other services in that vehicles containing a C-ITS device produce data that is subsequently used in various information and other services provided by road operators, traffic centres and other service providers. The impacts on traffic safety, traffic flow and carbon emissions are indirect, and it is very difficult to attribute them to the probe vehicle data service. C-Roads has defined two different use cases: Vehicle data collection and event data collection.

At the EU level, probe vehicle services were estimated to reduce collisions by 3% (Asselin-Miller et al. 2016), but not to affect travel times or carbon dioxide emissions. In this study, the impact on the number of accidents involving personal injury, travel time and carbon dioxide emissions from transport was estimated to be -0.2%, -0.1% and -0.1% for vehicle data, and -0.3%, -0.15% and -0.15% for event data.

5 Prioritisation criteria

The establishment of the values for the prioritisation criteria is described by the criteria group. The impacts on the needs of society are discussed first, after which the impacts on the needs of users, techno-economic feasibility and compliance with strategies are addressed. The principles of prioritising different criteria for each group are presented, and the criteria values given to each service are reviewed.

Finally, estimates of the magnitudes are presented for the service-specific investment costs of different C-ITS services. Costs are not used as criteria or a component in the MCDA prioritisation calculation, but they are used in assessing whether the prioritised services should be included in the recommended implementation programme.

5.1 Impacts on the needs of society

Impacts on the number of accidents involving personal injury, travel times and carbon dioxide emissions were assessed quantitatively. The impacts were converted to corresponding criteria values using the equation

criterion value = 100 * impact percentage/(maximum impact percentage),

where the greatest impact percentage was -4% for accidents involving personal injury, -0.2% for travel times and -0.2% for carbon dioxide emissions on roads and -0.3% on streets. The best service in relation to the criterion thus received the value of 100 and the worst was given the value of 0.

The accessibility of transport services can also be defined from the perspective of transport services as the accessibility of information and services for road users. The main quantitative indicator of the accessibility of the service is the number of users or its change. This enables examining either a site or area (e.g. village, tourist destination) or a transport service (e.g. service line). (Finnish Transport Infrastructure Agency 2020)

For the accessibility of services criterion, a qualitative assessment was used, as it was not possible to apply the number of users or another comparable quantitative measure. Traffic Information & Smart Routing received the best criterion value of 100. It was followed by Parking Availability, Information on Alternative Fuelled Vehicle Charging and Fuelling Station and Park & Ride Information, which all received the value of 80. The Loading Zone Management service received the value of 50. Smart Routing, Road Closure warning, Winter Maintenance warning, Traffic Light Prioritisation and Event Data Collection were given the criterion value of 20. Traffic Jam Ahead, Weather Condition Warning, Temporarily Slippery Road, Lane Closure and Other Restrictions and Vehicle Data Collection received the value

of 10. Free Text, Emergency Vehicle Priority, SAE Level Guidance and Platoon Support Information received the value of 5.

Table 7 presents a summary of the values of the criteria.

Table 7. Values for different C-ITS services examined on roads and streets in the "impacts on the needs of society" criteria group. 0 stands for the lowest impact and 100 for the highest impact in each column.

Criteria	Traffic safety		Traffic flow		Carbon emissions		Accessibility
C-ITS services and use cases	roads	streets	roads	streets	roads	streets	all
In-Vehicle Signage (IVS)							
Traffic Signs (IVS-TS)	18	18	6	6	5	3	5
In-Vehicle Speed Limit (VSPD)	75	75	0	0	100	67	0
Free Text (IVS-FT)	13	13	4	4	4	3	5
Smart Routing (IVS-SM)	0	0	0	0	0	0	20
Hazardous Locations Notification (HLN)							
Accident Zone (HLN-AZ)	8	8	3	3	1	1	0
Emergency Electronic Brakelight (EBL)	75	0	24	0	12	0	0
Traffic Jam Ahead (HLN-TJA)	25	0	10	0	5	0	10
Stationary vehicle (HLN - SV)	25	0	10	0	5	0	0
Weather Condition Warning (HLN-WCW)	3	3	1	1	1	0	10
Temporarily slippery road (HLN-TSR)							
Animal or person on the road (HLN-APR)	50	0	16	0	8	0	0
Obstacle on the road (HLN-OR)	25	0	10	0	5	0	0
Unsecured Blockage of a Road (HLN-UBR)							
Emergency or Rescue/Recovery Vehicle in Intervention	1	0	0	0	0	0	0
Emergency or Prioritized Vehicle Approaching (HLN-EPVA)							
Railway Level Crossing (HLN-RLX)	15	15	0	0	0	0	0
Alert Wrong Way Driving (HLN-AWWD)	0	0	0	0	0	0	0
Shockwave Damping (SWD)	0	0	0	0	0	0	0
Public Transport Vehicle Crossing (HLN-PTVC)	0	5	0	5	0	5	0
Public Transport Vehicle at a Stop (HLN-PTVS)	0	3	0	3	0	3	0
Collision Warnings							
Cooperative collision risk warning	100	100	32	32	16	11	0
Vulnerable road user protection (pedestrians and cyclists)	0	48	0	15	0	5	0
Motorcycle approaching indication	25	25	10	10	5	3	0
Road Works Warning (RWW)							
Lane closure (and other restrictions) (RWW-LC)	13	13	4	4	2	1	10
Road Closure (RWW – RC)							20
Road Works Mobile (RWW-RM)	6	6	2	2	1	1	0
Winter Maintenance (RWW-WM)	6	6	2	2	1	1	20
Signalized Intersections (SI)							
Signal Phase and Timing Information (SI-SPTI)	0	4	0	2	0	1	0
Green Light Optimal Speed Advisory (SI-GLOSA)	0	9	0	3	8	100	0
Imminent Signal Violation Warning (SI-ISVW)	0	10	0	3	0	1	0
Traffic Light Prioritisation (SI-TLP)	0	0	0	0	2	33	20
Emergency Vehicle Priority (SI-EVP)	0	25	0	0	0	0	5
Toll Station Crossing (SI-TSC)	0	0	0	0	0	0	0
Loading zone management (LZM)	0	0	5	5	3	50	50
Information and management							
Information on alternative fuelled vehicle charging and fuelling stations (iFuel)	0	0	5	5	5	3	80
Park & Ride information (P&Ride)	0	0	5	5	0	50	80
Traffic information & Smart routing (SmartR)	0	0	100	100	5	67	100
Loading zone management (LZM)	0	0	5	5	3	50	50

Criteria	Traffic safety		Traffic flow		Carbon emissions		Accessibility
C-ITS services and use cases	roads	streets	roads	streets	roads	streets	all
Automated Vehicle Guidance (AVG)							
SAE Level Guidance (AVG-SAELG)	3	3	1	1	0	0	5
Platoon Support Information (AVG-PSI)	0	0	0	0	1	0	5
Topology Information (TI)							
Toll Station Approaching (TI-TSA)	0	0	0	0	0	0	0
Point of Interest (POI)							
Parking Availablity (POI-PA)	0	0	5	5	5	3	80
Collective Perception (CP)							
Collective Perception on Motorways (CP-MW)	1	0	1	0	0	0	0
Collective Perception on Urban/Interurban Intersections	0	32	0	0	0	0	0
Probe Vehicle Data (PVD)							
Vehicle Data Collection (PVD-VDC)	5	5	50	50	50	33	10
Event Data Collection (PVD-EDC)	8	8	75	75	75	50	20

5.2 User groups, needs and possible services

Impacts on meeting users' needs were assessed qualitatively based on interviews and a literature review by assessing which C-ITS services would meet those needs. The fulfilment of user needs was assessed according to the following criteria:

- Meeting the needs of car users
- Meeting the needs of people using active modes of transport
- Meeting the needs of public transport users
- Meeting the needs of emergency vehicle users
- Meeting the needs of special groups
- Meeting road and street maintenance needs
- Meeting road traffic management needs
- Meeting the needs of municipalities with the street network
- Improving logistics efficiency
- Meeting the needs of transport companies
- Meeting the needs of public transport operators
- Meeting the needs of companies providing transport services
- Improving the operation of automated driving systems.

Each of the above criteria is presented and evaluated in the following order:

- Definition of the criterion
- The source material for the criterion such as interviewed users and literature. (Chapter 3 Methods used and section 4.4 User needs)
- An assessment, including assumptions and justifications, of C-ITS services that would be responsible for meeting user needs based on the source material. Up to fifteen of the most important services identified in the evaluation are proposed.

Toll-related services received no points for any criteria, as they were not used in Finland during the implementation of the study.

Table 8 presents a summary of the C-ITS services and the criteria values for the criteria group "Impacts on meeting user needs".

Table 8. Values for different examined C-ITS services in the "impacts on meeting user needs" criteria group.

Criteria / **C-ITS services**	Motorists	Active modes of transport	Public transport passengers	Emergency vehicle users	Special groups	Road and street maintenance	Road traffic management	Municipal street network	Logistics efficiency	Transport companies	Public transport operators	Companies providing transport services	Automated driving system operation
In-Vehicle Signage (IVS)													
Traffic Signs (IVS-TS)	60	90	60	60	60	90	80	70	85	90	60	0	100
In-Vehicle Speed Limit (VSPD)	60	90	60	60	60	90	80	70	60	60	60	0	100
Free Text (IVS-FT)	60	70	60	60	60	90	80	70	60	60	60	0	90
Smart Routing (IVS-SM)	45	60	75	80	85	85	85	80	90	95	20	0	100
Hazardous Locations Notification (HLN)													
Accident Zone (HLN-AZ)	100	90	80	100	100	100	100	100	100	100	100	100	100
Emergency Electronic Brakelight (EBL)	70	85	90	70	91	75	75	75	75	75	75	0	75
Traffic Jam Ahead (HLN-TJA)	65	30	70	65	65	50	50	60	70	70	60	0	100
Stationary vehicle (HLN - SV)	63	0	70	65	63	90	80	75	65	65	75	0	100
Weather Condition & Slippery road (HLN-WCW + TSR)	55	90	70	55	55	95	90	75	85	85	90	100	100
Animal or person on the road (HLN-APR)	75	80	70	75	75	75	100	60	75	75	80	100	100
Obstacle or Unsecured Blockage of Road (HLN-OR & UBR)	95	60	90	95	95	95	100	90	95	95	95	100	88
Emergency vehicle warnings (HLN-ERVI & EPVA)	80	35	80	100	80	60	80	90	70	70	75	0	88
Railway Level Crossing (HLN-RLX)	75	0	75	75	75	75	75	75	75	75	60	0	75
Alert Wrong Way Driving (HLN-AWWD)	75	0	75	75	75	75	75	75	75	75	75	0	75
Shockwave Damping (SWD)	15	0	60	0	15	40	50	40	60	60	30	0	60
Public Transport Vehicle Crossing & at Stop (HLN-PTVC & PTVS)	50	30	100	75	50	75	70	70	40	40	90	0	75
Collision Warnings													
Cooperative collision risk warning	75	0	95	90	91	80	90	75	75	80	80	0	80
Vulnerable road user protection (pedestrians and cyclists)	75	100	95	90	91	90	90	95	80	85	80	0	75
Motorcycle approaching indication	75	0	75	75	75	75	75	75	75	75	75	0	75
Road Works Warning (RWW)													
Lane and road closure (and other restr.) (RWW-LC & RC)	90	60	90	75	90	100	85	85	90	90	75	100	100
Road Works Mobile (RWW-RM)	30	60	70	75	30	100	85	85	90	90	75	100	100
Winter Maintenance (RWW-WM)	30	70	70	75	30	100	80	75	85	85	90	100	100
Signalized Intersections (SI)													
All SI use cases (SPTI + GLOSA + ISVW + TLP + EVP)	35	30	85	88	42	66	78	86	73	78	90	0	76
Signal Phase and Timing Information (SI-SPTI)	20	20	60	70	20	70	70	80	70	80	80	0	75
Green Light Optimal Speed Advisory (SI-GLOSA)	20	20	60	70	20	70	70	80	70	80	80	0	75
Imminent Signal Violation Warning (SI-ISVW)	57	90	70	100	91	70	90	90	75	75	75	0	80
Traffic Light Prioritisation (SI-TLP)	0	0	100	100	0	60	70	90	80	85	95	0	75
Emergency Vehicle Priority (SI-EVP)	80	20	80	100	80	60	90	90	70	70	75	0	75
Toll Station Crossing (SI-TSC)	0	0	0	0	0	0	0	0	0	0	0	0	0
Loading zone management (LZM)	10	0	0	0	10	0	50	70	95	95	0	50	10

Criteria / C-ITS services	Motorists	Active modes of transport	Public transport passengers	Emergency vehicle users	Special groups	Road and street maintenance	Road traffic management	Municipal street network	Logistics efficiency	Transport companies	Public transport operators	Companies providing transport services	Automated driving system operation
Information and management													
Info on alt. fuelled vehicle charging & fuelling stations (iFuel)	15	0	0	10	15	0	10	50	85	85	2	0	40
Park & Ride information (P&Ride)	35	50	65	0	90	0	65	80	85	85	0	60	20
Traffic information & Smart routing (SmartR)	50	60	75	80	85	85	85	80	90	95	20	0	100
Loading zone management (LZM)	10	0	0	0	10	0	50	70	95	95	0	50	10
Automated Vehicle Guidance (AVG)													
SAE Level Guidance (AVG-SAELG)	10	0	0	0	90	0	20	10	50	50	20	0	70
Platoon Support Information (AVG-PSI)	10	0	0	0	10	0	20	0	50	50	0	0	70
Topology Information (TI)													
Toll Station Approaching (TI-TSA)	0	0	0	0	0	0	0	0	0	0	0	0	0
Point of Interest (POI)													
Parking Availablity (POI-PA)	35	60	65	0	90	0	65	80	85	85	0	0	20
Collective Perception (CP)													
Collective Perception on Motorways (CP-MW)	75	0	75	90	91	90	90	80	75	85	80	0	100
Collective Perception on Urban/Interurban Intersections (CP-UI)	75	100	90	90	91	90	90	95	75	90	95	0	100
Probe Vehicle Data (PVD)													
Vehicle Data Collection (PVD-VDC)	10	0	70	10	10	80	85	80	75	75	60	50	100
Event Data Collection (PVD-EDC)	50	0	70	10	10	80	85	80	75	75	80	100	100

The needs of **car users** or those using cars for mobility primarily refer to passenger car drivers, but also car passengers. Other vehicles, such as trucks or buses, were also considered to belong to the same group. Many other criteria groups also use cars, including public transport, emergency vehicles and logistics; therefore, the results of the criteria group using a car are also reflected in these other groups. The needs of car users were assessed based on literature and interviews.

The main source for the assessment of meeting the needs of car users was the impact assessment report of the NordicWay 2 project presented in section 8.4.3. The report presented the survey results of more than 4,000 Nordic respondents on the most important information content on journeys made on motorways, main roads or the street network. Based on the survey results, the most important information content for users was obstacles on motorways and main roads, such as accidents, road closures or animals. In the street network, the most important information content included emergency or prioritized vehicle approaching, accidents ahead and road or lane closures. Outside the survey, for example, based on interviews, car users were also estimated to have a need for information content and services that warn them about road safety events in advance.

Table 9 shows the C-ITS services that scored the highest based on the assessment of user needs.

Table 9. C-ITS services considered to best meet user needs.

#	C-ITS services: Meeting the needs of car users	Score 0–100
1	Accident Zone (HLN-AZ)	100
2	Obstacle or Unsecured Blockage of Road (HLN-OR & UBR)	95
3	Lane and road closure (and other restr.) (RWW-LC & RC)	90
4	Emergency vehicle warnings (HLN-ERVI & EPVA)	80
5	Emergency Vehicle Priority (SI-EVP)	80
6	Animal or person on the road (HLN-APR)	75
7	Railway Level Crossing (HLN-RLX)	75
8	Alert Wrong Way Driving (HLN-AWWD)	75
9	Cooperative collision risk warning	75
10	Vulnerable road user protection (pedestrians and cyclists)	75
11	Motorcycle approaching indication	75
12	Collective Perception on Motorways (CP-MW)	75
13	Collective Perception on Urban/Interurban Intersections (CP-UI)	75
14	Emergency Electronic Brakelight (EBL)	70
15	Traffic Jam Ahead (HLN-TJA)	65

People using active modes of transport refer to pedestrians and cyclists whose needs and problems were assessed based on interviews in this study.

The assessment of the fulfilment of the needs of people using active modes of transport assumed that the users would not send messages in line with the services, but could receive the messages as a part of map and navigation applications and benefit from messages exchanged between vehicles and infrastructure (e.g. C-V2X communication between mobile phone and vehicle). For example, people using active modes of transport can use the information provided by the services in route planning, but were less likely to actively keep up with updates during their journey.

C-ITS services, such as traffic light prioritisation or refuelling station locations, which did not apply to users of active modes of transport but rather to vehicles, were not scored. Based on the interviews, the needs of pedestrians, cyclists and special groups in intersections in urban transport were given priority. Based on the examination, the needs were best met by Vulnerable Road User Protection (VRU) and Collective Perception on Urban/Interurban services, which received the perfect score. Information related to weather conditions, such as slippery road conditions, was also considered important. Traffic sign and speed limit information, especially when improving the attention of drivers, was also assessed to indirectly improve the safety of pedestrians and cyclists. Information that warns vehicles of an accident zone can protect pedestrians or cyclists moving in the area.

Table 10 shows the C-ITS services that scored the highest in the assessment from the perspective of meeting the needs of people using active modes of transport.

Table 10. C-ITS services considered to best meet the needs of people using active modes of transport.

#	C-ITS services: Meeting the needs of people using active modes of transport	Score 0–100
1	Vulnerable road user protection (pedestrians and cyclists)	100
2	Collective Perception on Urban/Interurban Intersections (CP-UI)	100
3	Traffic Signs (IVS-TS)	90
4	In-Vehicle Speed Limit (VSPD)	90
5	Accident Zone (HLN-AZ)	90
6	Weather Condition & Slippery road (HLN-WCW + TSR)	90
7	Imminent Signal Violation Warning (SI-ISVW)	90
8	Emergency Electronic Brakelight (EBL)	85
9	Animal or person on the road (HLN-APR)	80
10	Free Text (IVS-FT)	70
11	Winter Maintenance (RWW-WM)	70
12	Smart Routing (IVS-SM)	60
13	Obstacle or Unsecured Blockage of Road (HLN-OR & UBR)	60
14	Lane and road closure (and other restr.) (RWW-LC & RC)	60
15	Road Works Mobile (RWW-RM)	60

Public transport users refer to users riding a bus or a tram on the road or street network and may thus benefit from C-ITS services used by the vehicle during their journey. The problems and needs of public transport passengers were assessed based on interviews and expert assessments.

The assessment of meeting the needs of public transport passengers emphasised not only the safety of transport but also particularly prioritisation involving public transport that improves the flow of transportation, such as Traffic Light Prioritisation. Public Transport Vehicle Crossing, Public Transport Vehicle at a Stop and Traffic Light Prioritisation were considered the most necessary services, which were considered to improve the flow and safety of public transport, and therefore also travel, in transit stop and intersection areas. Other similar services that increase the safety of pedestrians and passengers while driving were also considered important. Indirect impacts can also be achieved by, for example, the Smart Routing of other vehicles, which utilises public transport, and parking information, such as for Park & Ride purposes.

Table 11 shows the C-ITS services that scored the highest in the assessment from the perspective of meeting the needs of public transport users.

Table 11. C-ITS services considered to best meet the needs of public transport users.

#	C-ITS services: Meeting the needs of public transport users	Score 0–100
1	Public Transport Vehicle Crossing & at Stop (HLN-PTVC & PTVS)	100
2	Traffic Light Prioritisation (SI-TLP)	100
3	Cooperative collision risk warning	95
4	Vulnerable road user protection (pedestrians and cyclists)	95
5	Emergency Electronic Brakelight (EBL)	90
6	Obstacle or Unsecured Blockage of Road (HLN-OR & UBR)	90
7	Lane and road closure (and other restr.) (RWW-LC & RC)	90
8	Collective Perception on Urban/Interurban Intersections (CP-UI)	90
9	All SI use cases (SPTI + GLOSA + ISVW + TLP + EVP)	85
10	Accident Zone (HLN-AZ)	80
11	Emergency vehicle warnings (HLN-ERVI & EPVA)	80
12	Emergency Vehicle Priority (SI-EVP)	80
13	Smart Routing (IVS-SM)	75
14	Railway Level Crossing (HLN-RLX)	75
15	Alert Wrong Way Driving (HLN-AWWD)	75

Emergency vehicle users refer to the driver and passengers of an emergency vehicle, as well as any patient being transported and treated during transit. Passengers may include police and rescue workers, and a family member of the care recipient. Expert assessments were carried out to assess possible problems and whether the users' needs were met.

The needs of emergency vehicles were considered to be very similar to those of motorists. Services related to traffic safety, such as Accident Zone and Obstacles on the Road, were particularly important. Services that warn other vehicles of emergency vehicles as well as Emergency Vehicle Priority and related warnings, were also considered among the most important services. Services warning the vehicle of pedestrians and cyclists, which can increase safety, especially in urban and built-up areas, were also considered important.

Table 12 shows the C-ITS services that scored the highest in the assessment for meeting the needs of emergency vehicle users.

Table 12. C-ITS services considered to best meet the needs of emergency vehicle users.

#	C-ITS services: Meeting the needs of emergency vehicle users	Score 0–100
1	Accident Zone (HLN-AZ)	100
2	Emergency vehicle warnings (HLN-ERVI & EPVA)	100
3	Imminent Signal Violation Warning (SI-ISVW)	100
4	Traffic Light Prioritisation (SI-TLP)	100
5	Emergency Vehicle Priority (SI-EVP)	100
6	Obstacle or Unsecured Blockage of Road (HLN-OR & UBR)	95
7	Cooperative collision risk warning	90
8	Vulnerable road user protection (pedestrians and cyclists)	90
9	Collective Perception on Motorways (CP-MW)	90
10	Collective Perception on Urban/Interurban Intersections (CP-UI)	90
11	All SI use cases (SPTI + GLOSA + ISVW + TLP + EVP)	88
12	Smart Routing (IVS-SM)	80
13	Traffic information & Smart routing (SmartR)	80
14	Animal or person on the road (HLN-APR)	75
15	Railway Level Crossing (HLN-RLX)	75

Special groups include older persons, persons with disabilities or persons with reduced mobility who benefit from support or need special support in using services. The problems and needs of special groups were examined based on interviews.

The needs of special groups were generally considered to correspond to those of car users. The services used by all car users may even bring particular benefits to special groups, as the services provide more detailed information as a support service and thus enable the driver to better anticipate events on the road or on the street. In addition, C-ITS services that specifically serve special groups were estimated to support operative and tactical driving performance, i.e. support services for driving performance and e.g. routing; such services include Collective Perception and Cooperative Collision Risk as well as services that warn car users of pedestrians and cyclists. In addition, Park & Ride Information may support people with reduced mobility in finding a parking space, which is already one of the attributes included in the European C-Roads specifications for this information. Road transport automation support services can also be important, as they enable the use of an automated driving system and thus reduce the driver's workload while driving.

Table 13 shows the C-ITS services that scored the highest in the assessment for meeting the needs of special groups.

Table 13. C-ITS services considered to best meet the needs of special groups.

#	C-ITS services: meeting the needs of special groups	Score 0–100
1	Accident Zone (HLN-AZ)	100
2	Obstacle or Unsecured Blockage of Road (HLN-OR & UBR)	95
3	Emergency Electronic Brakelight (EBL)	91
4	Cooperative collision risk warning	91
5	Vulnerable road user protection (pedestrians and cyclists)	91
6	Imminent Signal Violation Warning (SI-ISVW)	91
7	Collective Perception on Motorways (CP-MW)	91
8	Collective Perception on Urban/Interurban Intersections (CP-UI)	91
9	Lane and road closure (and other restr.) (RWW-LC & RC)	90
10	Park & Ride information (P&Ride)	90
11	SAE Level Guidance (AVG-SAELG)	90
12	Parking Availablity (POI-PA)	90
13	Smart Routing (IVS-SM)	85
14	Traffic information & Smart routing (SmartR)	85
15	Emergency vehicle warnings (HLN-ERVI & EPVA)	80

Road and street maintenance refers to the maintenance of motorways, main roads and the street network of cities, which may include road works and winter maintenance. The problems and needs related to this task were examined on the basis of interviews and expert assessments.

It was estimated that road and street maintenance needs could be met, in particular, by road works services, such as a Lane and Road Closure, Road Works Mobile, Winter Maintenance and Obstacle on the Road or Accident Zone. Services related to exceptional weather conditions, such as slippery roads, were also considered useful. Up-to-date traffic sign information may also contain information relevant to road and street maintenance. In addition, Collective Perception, Stationary Vehicle, Vulnerable Road User, Routing (e.g. exceptional routes) and Vehicle Data (V2I traffic flow and events) services were considered to be particularly useful to maintenance, for example, due to the benefits they offer to improve the safety and flow of road traffic.

Table 14 shows the C-ITS services that scored the highest in the assessment for meeting the needs of road and street maintenance.

Table 14. C-ITS services considered to best meet the needs of road and street maintenance. groups.

#	C-ITS services: Meeting road and street maintenance needs	Score 0–100
1	Accident Zone (HLN-AZ)	100
2	Lane and road closure (and other restr.) (RWW-LC & RC)	100
3	Road Works Mobile (RWW-RM)	100
4	Winter Maintenance (RWW-WM)	100
5	Weather Condition & Slippery road (HLN-WCW + TSR)	95
6	Obstacle or Unsecured Blockage of Road (HLN-OR & UBR)	95
7	Traffic Signs (IVS-TS)	90
8	In-Vehicle Speed Limit (VSPD)	90
9	Free Text (IVS-FT)	90
10	Stationary vehicle (HLN - SV)	90
11	Vulnerable road user protection (pedestrians and cyclists)	90
12	Collective Perception on Motorways (CP-MW)	90
13	Collective Perception on Urban/Interurban Intersections (CP-UI)	90
14	Smart Routing (IVS-SM)	85
15	Traffic information & Smart routing (SmartR)	85

Road traffic management refers to the control and management of traffic in the road and street network, in which traffic centres serve as operational command centres using traffic management information systems that can transmit or receive data from services. Interviews and expert assessments were carried out to assess possible problems and needs fulfilment.

In meeting the needs of road traffic management, warnings concerning dangerous road sections, such as accident zones or other obstacles and animals and people on the road, were emphasised. More than any of the other groups, road traffic management was estimated to benefit from a large number of services, or even most of them, as the majority of the services support traffic management and traffic safety and flow. Nearly thirty services were considered important. Traffic light services mainly concern the street network area in cities. Although Collective Perception services are related to operational driving performance, they directly support the problems and needs of road traffic management related to safe and smooth traffic.

Table 15 shows the C-ITS services that scored the highest in the assessment for meeting the needs of road traffic management.

Table 15. C-ITS services considered to best meet the needs of road traffic management.

#	C-ITS services: Meeting the needs of road traffic management	Score 0–100
1	Accident Zone (HLN-AZ)	100
2	Animal or person on the road (HLN-APR)	100
3	Obstacle or Unsecured Blockage of Road (HLN-OR & UBR)	100
4	Weather Condition & Slippery road (HLN-WCW + TSR)	90
5	Cooperative collision risk warning	90
6	Vulnerable road user protection (pedestrians and cyclists)	90
7	Imminent Signal Violation Warning (SI-ISVW)	90
8	Emergency Vehicle Priority (SI-EVP)	90
9	Collective Perception on Motorways (CP-MW)	90
10	Collective Perception on Urban/Interurban Intersections (CP-UI)	90
11	Smart Routing (IVS-SM)	85
12	Lane and road closure (and other restr.) (RWW-LC & RC)	85
13	Road Works Mobile (RWW-RM)	85
14	Traffic information & Smart routing (SmartR)	85
15	Vehicle Data Collection (PVD-VDC)	85

The fulfilment of the needs of **municipalities** in the street network was assessed using interviews and expert assessments.

For municipalities, the key areas include the provision of information on accidents and the introduction of services that would improve the safety of vulnerable road users, especially in intersection areas. Services concerning emergency vehicles and providing other disruption information, as well as traffic light services, were also highlighted as they improved the safety of users and the flow of traffic. Information about parking spaces and smart routing in the municipality was also considered to potentially improve traffic flow and environmental friendliness.

Table 16 shows the C-ITS services that scored the highest in the assessment for meeting the needs of municipalities.

Table 16. C-ITS services considered to best meet the needs of municipalities.

#	C-ITS services: Meeting the needs of municipalities	Score 0–100
1	Accident Zone (HLN-AZ)	100
2	Vulnerable road user protection (pedestrians and cyclists)	95
3	Collective Perception on Urban/Interurban Intersections (CP-UI)	95
4	Obstacle or Unsecured Blockage of Road (HLN-OR & UBR)	90
5	Emergency vehicle warnings (HLN-ERVI & EPVA)	90
6	Imminent Signal Violation Warning (SI-ISVW)	90
7	Traffic Light Prioritisation (SI-TLP)	90
8	Emergency Vehicle Priority (SI-EVP)	90
9	All SI use cases (SPTI + GLOSA + ISVW + TLP + EVP)	86
10	Lane and road closure (and other restr.) (RWW-LC & RC)	85
11	Road Works Mobile (RWW-RM)	85
12	Smart Routing (IVS-SM)	80
13	Signal Phase and Timing Information (SI-SPTI)	80
14	Green Light Optimal Speed Advisory (SI-GLOSA)	80
15	Park & Ride information (P&Ride)	80

Logistics efficiency refers to the efficiency of the logistics sector, i.e. the commission and implementation of the carriage of goods, which has societal impacts. The improvement in logistics efficiency was mainly assessed through interviews.

The services emerging as the most important in the assessment were similar to those for car users, i.e. information about disruptions such as accidents, obstacles and roadworks. Road condition information was also considered important, especially with regard to winter maintenance. Based on the interviews, it is currently difficult to predict travel times, as there is not enough information available on traffic disruptions and maintenance. Parking and loading area information gains importance in urban areas. Based on the interviews, information on refuelling stations was also considered important, and there was particularly a need for more detailed information on the charging network infrastructure. For example, logistics benefits from up-to-date and high-quality traffic sign data, such as restrictions on bridges and tunnels, which are used in the planning of driving routes.

Table 17 shows the C-ITS services that scored the highest in the assessment for improving logistics efficiency.

Table 17. C-ITS services considered to best respond to improving logistics efficiency.

#	C-ITS services: Improving logistics efficiency	Score 0–100
1	Accident Zone (HLN-AZ)	100
2	Obstacle or Unsecured Blockage of Road (HLN-OR & UBR)	95
3	Loading zone management (LZM)	95
4	Smart Routing (IVS-SM)	90
5	Lane and road closure (and other restr.) (RWW-LC & RC)	90
6	Road Works Mobile (RWW-RM)	90
7	Traffic information & Smart routing (SmartR)	90
8	Traffic Signs (IVS-TS)	85
9	Weather Condition & Slippery road (HLN-WCW + TSR)	85
10	Winter Maintenance (RWW-WM)	85
11	Information on alternative fuelled vehicle charging and fuelling stations (iFuel)	85
12	Park & Ride information (P&Ride)	85
13	Parking Availablity (POI-PA)	85
14	Vulnerable road user protection (pedestrians and cyclists)	80
15	Traffic Light Prioritisation (SI-TLP)	80

Transport companies refer to undertakings offering transportation and their drivers. The needs of transport companies were assessed using literature and interviews. The source of literature was a publication by Lauhkonen & Lehtonen (2021), Acceptance and need of real-time traffic information services in the transport industry.

Areas relevant to meeting the needs of transport companies included information about disruptions, such as obstacles and accidents on the road network. There was also agreement on the needs related to logistics efficiency, which were discussed above. In addition to the above, however, the needs of companies and professional drivers were considered to be slightly broader, i.e. more services, such as Smart Routing, Road Works Information, Park & Ride Information (especially municipalities), make use of transport. Information and warnings about weather and driving conditions were also considered important. In addition, in traffic lights, in some cases, prioritisation could benefit heavy goods vehicles, e.g. when driving uphill in slippery conditions. Services related to the automation of road transport, such as information related to platooning, may bring benefits in the longer term. Transport companies were estimated to differ from the logistics sector in their need for information about restrictions (e.g. tunnels and bridges), vulnerable road users (e.g. blind spots for a large vehicle at an intersection), traffic light signal data and collision warnings.

Table 18 shows the C-ITS services that scored the highest in the assessment for meeting the needs of transport companies.

Table 18. C-ITS services considered to best meet the needs of transport companies.

#	C-ITS services: Meeting the needs of transport companies	Score 0–100
1	Accident Zone (HLN-AZ)	100
2		95
3	Obstacle or Unsecured Blockage of Road (HLN-OR & UBR)	95
4	Traffic information & Smart routing (SmartR)	95
5	Loading zone management (LZM)	95
6	Traffic Signs (IVS-TS)	90
7	Lane and road closure (and other restr.) (RWW-LC & RC)	90
8	Road Works Mobile (RWW-RM)	90
9	Collective Perception on Urban/Interurban Intersections (CP-UI)	90
10	Weather Condition & Slippery road (HLN-WCW + TSR)	85
11	Vulnerable road user protection (pedestrians and cyclists)	85
12	Winter Maintenance (RWW-WM)	85
13	Traffic Light Prioritisation (SI-TLP)	85
14	Information on alternative fuelled vehicle charging and fuelling stations (iFuel)	85
15	Park & Ride information (P&Ride)	85

Public transport operators refer to parties such as companies operating buses, whose needs and problems were mainly investigated through interviews.

With regard to meeting the needs of public transport operators, the problems identified in the interviews were particularly related to challenges in the smooth flow of travel chains and traffic, as well as the predictability of the traffic situation. These include traffic disruptions, such as roadworks, obstacles on the road, accident sites or road conditions. Special services that apply to public transport include traffic light prioritisation, which emerged as an important area in the interviews and priorities. In addition, public transport vehicles crossing intersection areas and the location of public transport vehicles at a transit stop were considered important special public transport services. Public transport vehicles can also benefit from the additional visibility provided by Collective Perception services, especially for vulnerable road user protection in urban areas. Traffic signal status information, such as the timing of when the light will turn green, may streamline and enable more environmentally friendly driving as a part of traffic light prioritisation, if this information is suitable for use and depending on the responsiveness of the signal priority system to grant traffic light prioritisation.

Table 19 shows the C-ITS services that scored the highest in the assessment from the perspective of meeting the needs of public transport operators.

Table 19. C-ITS services considered to best meet the needs of public transport operators.

#	C-ITS services: Meeting the needs of public transport operators	Score 0–100
1	Accident Zone (HLN-AZ)	100
2	Obstacle or Unsecured Blockage of Road (HLN-OR & UBR)	95
3	Traffic Light Prioritisation (SI-TLP)	95
4	Collective Perception on Urban/Interurban Intersections (CP-UI)	95
5	Weather Condition & Slippery road (HLN-WCW + TSR)	90
6	Public Transport Vehicle Crossing & at Stop (HLN-PTVC & PTVS)	90
7	Winter Maintenance (RWW-WM)	90
8	All SI use cases (SPTI + GLOSA + ISVW + TLP + EVP)	90
9	Animal or person on the road (HLN-APR)	80
10	Cooperative collision risk warning	80
11	Vulnerable road user protection (pedestrians and cyclists)	80
12	Signal Phase and Timing Information (SI-SPTI)	80
13	Green Light Optimal Speed Advisory (SI-GLOSA)	80
14	Collective Perception on Motorways (CP-MW)	80
15	Event Data Collection (PVD-EDC)	80

Companies providing transport services refer to companies that are either manufacturers or service providers producing or utilising C-ITS services. The needs of the companies were assessed on the basis of literature, interviews and expert assessments.

The interviews carried out in the study produced hardly any precise data type-specific assessments of the needs of transport service providers. In addition, the companies themselves provide highly different services, and as a result, their priorities may concern selected services in line with their respective business objectives. In this case, disqualification issues should also be taken into account, for example, if the company rated a service they produce as the most important one.

The needs assessment mainly used the statistical data provided by the Finnish National Access Point Digitraffic.fi on the historical frequency of use of data types, which reflects well the service providers' and developers' needs related to the use of data (Ahvenainen 2025). In this data, there is an emphasis on accident and disruption information as well as information related to road conditions and roadwork.

It was also noted in the interviews that in developing services, there may also be cooperation between several Member States in areas such as the winter conditions in the Nordic countries and passing over railway level crossings. Road Works Warnings were considered the most common European service at the time of the interviews. The priorities are service-specific and vary from local urban conditions to roads.

Table 20 shows the C-ITS services that scored the highest in the assessment from the perspective of meeting the needs of companies providing transport services.

Table 20. C-ITS services considered to best meet the needs of companies providing transport services.

#	C-ITS services: Meeting the needs of companies providing transport services	Score 0–100
1	Accident Zone (HLN-AZ)	100
2	Weather Condition & Slippery road (HLN-WCW + TSR)	100
3	Animal or person on the road (HLN-APR)	100
4	Obstacle or Unsecured Blockage of Road (HLN-OR & UBR)	100
5	Lane and road closure (and other restr.) (RWW-LC & RC)	100
6	Road Works Mobile (RWW-RM)	100
7	Winter Maintenance (RWW-WM)	100
8	Event Data Collection (PVD-EDC)	100
9	Park & Ride information (P&Ride)	60
10	Loading zone management (LZM)	50
11	Vehicle Data Collection (PVD-VDC)	50

Improving the operation of automated driving systems refers to the information systems or programs responsible for the functionality of vehicle automation. The capabilities of these systems or programs, such as observation capability, can be improved by means of C-ITS services. The assessment was mainly carried out on the basis of the literature.

The needs were considered to be similar to those of motorists but also more extensive, as just as in traffic management, many services can utilise the performance of the automated driving system depending on the driving situation. The assessment made use of the research results of the TM4CAD (Traffic Management for Connected and Automated Driving) project, for which European vehicle manufacturers and service providers had been interviewed on the information needs of their automated driving systems (Kulmala et al. 2023). The responses of representatives of the industrial sector in the TM4CAD project emphasised traffic disruptions, obstacles, traffic flow information, weather conditions, roadworks and traffic sign information. In addition, routing information, which improves the planning of transport routes, was found to be important in the assessment.

Table 21 shows the C-ITS services that scored the highest in the assessment from the perspective of meeting the needs of the improvement of the operation of automated driving systems.

Table 21. C-ITS services considered to best meet the needs of the improvement of the operation of automated driving systems.

#	C-ITS services: Improving the operation of automated driving systems	Score 0–100
1	Traffic Signs (IVS-TS)	100
2	In-Vehicle Speed Limit (VSPD)	100
3	Smart Routing (IVS-SM)	100
4	Accident Zone (HLN-AZ)	100
5	Traffic Jam Ahead (HLN-TJA)	100
6	Stationary vehicle (HLN - SV)	100
7	Weather Condition & Slippery road (HLN-WCW + TSR)	100
8	Animal or person on the road (HLN-APR)	100
9	Lane and road closure (and other restr.) (RWW-LC & RC)	100
10	Road Works Mobile (RWW-RM)	100
11	Winter Maintenance (RWW-WM)	100
12	Traffic information & Smart routing (SmartR)	100
13	Collective Perception on Motorways (CP-MW)	100
14	Collective Perception on Urban/Interurban Intersections (CP-UI)	100
15	Vehicle Data Collection (PVD-VDC)	100

5.3 Techno-economic feasibility

The techno-economic analysis of C-ITS services includes an assessment of the technical feasibility and costs of the deployment of the services, the business opportunities related to the deployment of C-ITS services, existing business capabilities and the added value of the information produced by C-ITS services. The analysis also takes into account the broader perspective of digitalisation and the development of automation in road transport highlighted in the objectives of this study. New national business opportunities will be identified in this context.

A key report on the development of transport automation and digitalisation in Finland is the Action plan on legislation and key measures of transport automation implemented by the Ministry of Transport and Communications in 2021. In accordance with the study and the related resolution, Finland aims to be one of the forerunners of transport automation. Key opportunities for this development that the study highlights include new innovations in Finnish companies, the competitiveness of companies, the positive development of exports and, consequently, the improvement of social well-being. (Miettinen et al. 2021)

Scope of the analysis

The examination focused on C-ITS services related to the interaction between infrastructure and vehicles (I2V, V2I). The introduction of vehicle-to-

vehicle (V2V) C-ITS services was not examined in the techno-economic analysis referred to in this chapter.

The analysis emphasised the use of long-range communication solutions in the implementation architecture of C-ITS services, as this has been a strong starting point for the deployment of C-ITS services in Finland.

The analysis assumes that the national and city-specific background services necessary for the implementation of C-ITS services in compliance with European Commission and C-Roads requirements, such as the C-ITS central stations, the interchange server and the national root certificate service needed for forming C-ITS messages and providing the services have been implemented. The background services support all vehicle-to-infrastructure and infrastructure-to-vehicle C-ITS services implemented with long-range technologies.

The techno-economic analysis assumed that real-time and safety-related traffic information (RTTI and SRTI) is available through the National Access Point (NAP) to facilitate the deployment of several C-ITS services. The SRTI and RTTI regulations related to the collection and distribution of this information (EU 2022/670, EU 886/2013) and the timetables for the adoption of the new ITS Directive (EU/2023/2661) have been discussed in more detail in a report published by Traficom in 2024 (Laine & Kotilainen 2024).

As an important observation related to the limitations of the examination, it should be noted that the assessment of the ease of technical feasibility of the services does not comment on the current quality level of the initial data needed to implement the services. The analysis rather assesses whether there are clear existing or future structures for obtaining source data (e.g. NAP, location data for public transport via city interfaces, etc.) that enable implementing the services.

Examined techno-economic criteria

The deployment of C-ITS was examined based on the following technical and economic criteria:

- Ease of technical feasibility
- Improvement of business opportunities and competitiveness
- Existence of effective business models
- Existence of functioning ecosystems
- The added value of the information produced by C-ITS services, particularly in cases in which the same information or activity has already been implemented in other ways.

The following section describes the issues related to the evaluation of each criterion and the prioritisation of C-ITS services based on the evaluation.

Ease of technical feasibility

The ease of technical feasibility was clearly emphasised the most in the techno-economic analysis. The weight of this criterion was 60% of the overall score of the techno-economic analysis.

The technical feasibility analysis assessed the linearity of the implementation of C-ITS services. The availability of source data needed for the implementation of C-ITS services or the level of challenge involved in forming such data played a particularly important role in the evaluation. This is key to the implementation of C-ITS services, especially when the background architecture services for C-ITS services mentioned in the assumptions of the analysis have been implemented (C-ITS central stations, interchange server, root certificate services). Other criteria for assessing technical feasibility included the suitability of existing telecommunications networks and, in particular, a solution based on long-range communications for the implementation of C-ITS services, consideration of cybersecurity issues and the challenging nature of the technical implementation. In practice, the ease of technical feasibility also strongly affects the cost-effectiveness of the deployment of C-ITS services.

Below is a list of assumptions related to the assessment of the ease of technical feasibility:

- The examination favours C-ITS services, which can be implemented very successfully through long-range communications and mobile networks.
- In the review, the highest scores were received by services that can be implemented in a straightforward manner through a National Access Point (NAP) with the necessary information in accordance with the SRTI and RTTI Regulations.
- The above criterion also assumes that data under the European Data for Road Safety development programme for the distribution of traffic safety data will also be available through the National Access Point (NAP).
- Services for which the source data necessary for implementation is readily available but which are not necessarily available through a National Access Point (NAP) also scored well in the analysis.
- The analysis favours services whose implementation does not require heavy instrumentation of roadsides or kerbsides or the development of heavy back-end systems.

In the technical feasibility analysis, the full score was given to the road work warning services Road Closure, Lane Closure and Road Works Mobile, i.e. hazardous location notifications whose information will be provided through a NAP and produced as a result of the Data for Road Safety development programme. In addition to these, the production of traffic sign data

for road users (In-Vehicle Speed Limit, Traffic Signs) also scored full points. Services that did poorly in the assessment of C-ITS services in accordance with this criterion included those whose implementation required separate instrumentation of the road or curbside with identification equipment or the development of back-end systems that utilise data from several sources of information and involve demanding computational processes. Such services included SmartRouting and Shockwave Damping, which require demanding development of back-end systems, and Collective Perception, which requires road and street network instrumentation. The traffic light services familiar from C-ITS pilot projects, such as Signal Phase and Timing, were ranked around the middle in the analysis, as their introduction requires equipping all traffic light control units with data transfer capabilities to transmit status and forecast data to C-ITS central stations.

Improvement of business opportunities and competitiveness

In line with the limitations previously proposed to the techno-economic analysis, the assessment of this criterion does not take into account the back-end systems (national C-ITS central station or interchange server) implemented in connection with the deployment of C-ITS services or any business opportunities associated with them. The analysis only considered the new business opportunities that emerge due to the implementation of C-ITS services.

In the assessment of business opportunities, business opportunities with higher added value, i.e. the manufacturing of Finnish products, services or equipment, were valued higher than the sales of expert services or the import and resale of foreign products on the domestic market. This choice was based on the better scalability of a product and service-based business, which provides companies offering products and services with better conditions for international, export-driven business growth. Perspectives related to the development of the transport system, such as the benefits resulting from improved safety, traffic flow and environmental friendliness, were not taken into account in this analysis, even though they produce better national competitiveness in many respects.

The following assumptions were associated with the analysis of improved business opportunities and competitiveness:

- The end-users of C-ITS services are not expected to pay for the services.
- Versatile services that involve several business models and, in particular, business models with higher added value (products, services, domestic equipment manufacturing) receive high scores in the assessment.
- The export potential identified in relation to the implementation of C-ITS services raises the scores.

- Services based solely on imports or services with sales potential limited to the national expert services market do not score very high on this criterion.

In the assessment of this criterion, it is worth noting that it gave rise to almost reverse criteria compared to the ease of technical implementation discussed above. C-ITS services produced based on data collected from the NAP in a linear manner provide few new business opportunities. On the other hand, if the deployment of the C-ITS service is challenging, it is very likely that it requires extensive development and possibly data collection and analysis solutions, which will enable the development of scalable product solutions also suitable for international markets.

The services that were successful in the assessment of C-ITS services, in accordance with this criterion, were ones that involved the development of back-end systems or road and street instrumentation, such as Smart Routing, Shockwave Damping or Collective Perception. The services that performed well in the assessment based on the ease of technical implementation did not score well in this analysis.

Existence of effective business models

When services were assessed from the perspective of effective business models, the most central assessment criterion was the solutions, operating environments and competence that may already exist in Finland and the related established business models that have emerged over time. The assessment aimed to identify private sector solutions, such as Finnish device manufacturing or product and service business activities, and specialist services related to the topic provided in the private sector. The assessment also identified solutions owned by the public sector. However, these were not valued as highly, as, from a business model perspective, they did not involve the versatile utilisation of different business models; instead, they were nearly exclusively concerned with the provision of expert services for public administration.

From the perspective of the existence of effective business models, the assessment included the following assumptions:

- High scores will be awarded to a C-ITS service whose deployment involves the broad and varied application of different business models at the national level (product solutions, services, equipment manufacturing, equipment sales, expert competence and its sales).
- The service is afforded value if it is identified as including long-term business activities that have already been established.
- The existence of national expertise and business models is valued in connection with the service.

When assessing the existence of business models, those C-ITS services that concern areas in which Finland has strong expertise or a long history of using technologies related to the services did particularly well. The best scores is the assessment were given to the Winter Maintenance and Weather Condition Warning services and the Traffic Light Prioritisation service. C-ITS services located in traffic light environments also scored good points, as these technologies have been used in Finland for a long time, and there are related effective business models. Services related to traffic light environments lost some points because they only involve business operations related to importing and representing foreign product and equipment solutions.

Existence of functioning ecosystems

The assessment of C-ITS services in accordance with this criterion aimed to identify Finnish business ecosystems that would support the deployment of the services. The assessment identified the following four different levels of business ecosystems. In the scoring of the assessment in accordance with this criterion, the ecosystems are presented from the least valuable to the most valuable.

1) The lowest-level ecosystem was identified to consist of innovation ecosystems whose contribution still strongly occurs in research and development activities. For example, they may include Business Finland or EU-funded research projects in which a number of parties in the private and public sectors and research institutes conduct research and develop new solutions around a certain theme.
2) Entrepreneurship and start-up ecosystems usually include "accelerator activities" for developing business ideas, which involve strong networking and cooperation between participants. The participating early-stage companies may also receive development support from investors, financial institutions and large companies.
3) Growth ecosystems refer to value networks consisting of a new product or solution that is already growing strongly on the market. In these ecosystems, a strong group of actors support the conditions for the success of the solution with their own expertise and simultaneously increases the business of all those involved in the growth ecosystem.
4) Ecosystems operating at the highest level are known as actual business ecosystems, which can be considered the objective of the above ecosystems. A business ecosystem is usually built on a single, robust actor, surrounded by a lot of cooperation between the actors and subcontracting chains. These ecosystems resemble traditional industrial clusters in terms of their structure and operating methods.

With regard to this analysis criterion, those C-ITS services whose implementation involves the need for special weather and condition information, winter maintenance and slippery road management succeeded the best in

the assessment. In these areas, Finland has significant structures that may even resemble industrial clusters. The introduction of C-ITS services related to the traffic light services, often demonstrated in many innovation ecosystems, also fared well in this analysis, as in addition to innovation ecosystems, the traffic light sector already has equipment representatives and supplier networks that have become established in Finland over the long term. However, it should be noted that the established business area of traffic lights does not currently involve actual Finnish product innovations that would generate export activities.

Added value of information provided by the C-ITS service

The examination in accordance with this criterion assessed the individuality and unique nature of the data produced by C-ITS services in the market. If it was identified that the C-ITS service clearly produces new information for the market, it improved the valuation of said product in the assessment of the service according to this category. Those C-ITS services that produced information that is already widely available fared poorly in the assessment.

Nearly all Road Works Warning services and Hazardous Location Notification services providing information that is not currently comprehensively available succeeded well in the analysis in accordance with the criterion. The service generating anticipatory information about traffic light status and phase change (SI - Signal Phase and Timing) and the production of information about park-and-ride areas (Park & Ride Information) also scored full points in this assessment. Services receiving poor scores in this assessment included traffic light prioritisation services and the Weather Condition Warning service, which warns of poor weather conditions, as this information is already widely available.

Table 22 summarises the values of the techno-economic criteria for the different C-ITS services.

Table 22. Techno-economic criteria for different C-ITS services. The figures presented on their own are values concerning both roads and streets, while a pair of numbers separated by a "/" symbol represents the values for roads/streets.

Criteria C-ITS services and use cases	Ease of technical feasibility	Development of business	Business models	Ecosystems	C-ITS added value
In-Vehicle Signage (IVS)					
Traffic Signs (IVS-TS)	100	25	75	50	75
In-Vehicle Speed Limit (VSPD)	100	25	75	50	50
Free Text (IVS-FT)	75	50	10	25	25
Smart Routing (IVS-SM)	25	75/100	50	50	50

C-ITS services and use cases	Ease of technical feasibility	Development of business	Business models	Ecosystems	C-ITS added value
Hazardous Locations Notification (HLN)					
Accident Zone (HLN-AZ)	100	50	50	25	50
Emergency Electronic Brakelight (EBL)	5	5	5	25	100
Traffic Jam Ahead (HLN-TJA)	25	75	75	25	50
Stationary vehicle (HLN - SV)	25	50	50	50	100
Weather Condition & Slippery road (HLN-WCW + TSR)	87/75	63	63	88	25
Animal or person on the road (HLN-APR)	100	25	40	75	75
Obstacle or Unsecured Blockage of Road (HLN-OR & UBR)	100	25	40	50	88
Emergency vehicle warnings (HLN-ERVI & EPVA)	75	25	25	75	63
Railway Level Crossing (HLN-RLX)	100	50	75	25	100
Alert Wrong Way Driving (HLN-AWWD)	100	25	25	50	75
Shockwave Damping (SWD)	25/0	75/0	100/0	25/0	75/0
Public Transport Vehicle Crossing & at Stop (HLN-PTVC & PTVS)	20/40	25/50	25/50	50	25/90
Collision Warnings					
Cooperative collision risk warning	5	5	5	25	100
Vulnerable road user protection (pedestrians and cyclists)	0/50	0/75	0/75	0/50	0/100
Motorcycle approaching indication	5	5	5	25	100
Road Works Warning (RWW)					
Lane and road closure (and other restr.) (RWW-LC & RC)	100	50	75	25	75
Road Works Mobile (RWW-RM)	100	50	75	25	100
Winter Maintenance (RWW-WM)	50	25	25	100	100
Signalized Intersections (SI)					
All SI use cases (SPTI + GLOSA + ISVW + TLP + EVP)	45	50	13	65	30
Signal Phase and Timing Information (SI-SPTI)	50	50	15	75	100
Green Light Optimal Speed Advisory (SI-GLOSA)	25	50	15	50	25
Imminent Signal Violation Warning (SI-ISVW)	50	50	5	50	25
Traffic Light Prioritisation (SI-TLP)	50	50	15	75	0
Emergency Vehicle Priority (SI-EVP)	50	50	15	75	0
Toll Station Crossing (SI-TSC)	0	0	0	0	0
Information and management					
Information on alternative fuelled vehicle charging and fuelling stations (iFuel)	75	25	5	25	25
Park & Ride information (P&Ride)	75	25	5	25	100
Traffic information & Smart routing (SmartR)	25	75/100	100	50	90
Loading zone management (LZM)	0/100	0/25	0	0/25	0/50
Automated Vehicle Guidance (AVG)					
SAE Level Guidance (AVG-SAELG)	50	50/0	0	25	100
Platoon Support Information (AVG-PSI)	25/0	25/0	5/0	25	100
Topology Information (TI)					
Toll Station Approaching (TI-TSA)	0	0	0	0	0
Point of Interest (POI)					
Parking Availablity (POI-PA)	0/50	0/75	0/90	0/75	75
Collective Perception (CP)					
Collective Perception on Motorways (CP-MW)	50/0	75/0	90/0	75/0	100/0
Collective Perception on Urban/Interurban Intersections (CP-UI)	0/50	0/75	0/50	0/75	0/100
Probe Vehicle Data (PVD)					
Vehicle Data Collection (PVD-VDC)	5	5	0	25	50
Event Data Collection (PVD-EDC)	25/10	50	25	25	50

5.4 Strategic and legal framework

National legislation does not prioritise between different C-ITS services. Differences in prioritisation can be identified in European regulation. First, the C-Roads Platform, supported by the European Commission, supports the implementation of C-ITS services in Europe. The C-Roads service specifications, according to which the implemented services are cooperative in Europe, are a key tool for supporting the implementation. Therefore, the existence of a service specification gives an indication that the service falls within the scope of EU priorities.

In addition, through its Commission Delegated Regulations on road traffic information (European Commission 2013 and 2022a), the EU has allocated some of the data types to special stations by laying down provisions on their production for road users on European road networks. In addition, the Delegated Regulation on Intelligent Speed Assistance Systems (ISA) (European Commission 2021b) emphasises speed limit information, albeit this is also a data type emphasised by the RTTI Regulation.

The service received a value of 100 for the strategy and regulatory framework criterion if the service has C-Roads specifications (C-Roads Platform 2024) and the data type it transmits is mentioned as being offered either in the Safety Related Traffic Information (SRTI, European Commission 2013) or in the Real-time Traffic Information Regulation (RTTI, European Commission 2022a). The criterion receives the value 50 if the service has either C-Roads specifications or the data type required by the Commission Delegated Regulation, but not both. The criterion scores 0 if it also lacks a C-Roads specification. The criteria values received by the different services are shown in Table 23.

Table 23. Criteria values for strategies and regulatory frameworks for different C-ITS services.

C-ITS services and use cases	C-Roads service specification	SRTI Regulation (2013)	RTTI Regulation (2022)	Strategy criterion total
In-Vehicle Signage (IVS)				
Traffic Signs (IVS-TS)	100		100	**100**
In-Vehicle Speed Limit (VSPD)	100		100	**100**
Free Text (IVS-FT)	100		100	**100**
Smart Routing (IVS-SM)	100			**50**

C-ITS services and use cases	C-Roads service specifi-cation	SRTI Regula-tion (2013)	RTTI Regula-tion (2022)	Strategy criterion total
Hazardous Locations Notification (HLN)				
Accident Zone (HLN-AZ)	100	100	100	**100**
Emergency Electronic Brakelight (EBL)	100			**50**
Traffic Jam Ahead (HLN-TJA)	100		100	**100**
Stationary vehicle (HLN - SV)	100			**50**
Weather Condition Warning (HLN-WCW)	100	100	100	**100**
Temporarily slippery road (HLN-TSR)	100	100	100	**100**
Animal or person on the road (HLN-APR)	100	100		**100**
Obstacle on the road (HLN-OR)	100			**50**
Unsecured Blockage of a Road (HLN-UBR)	100	100		**100**
Emergency or Rescue/Recovery Vehicle in Intev.	100			**50**
Emergency or Prioritized Vehicle Approaching	100			**50**
Railway Level Crossing (HLN-RLX)	100			**50**
Alert Wrong Way Driving (HLN-AWWD)	100	100		**100**
Shockwave Damping (SWD)	0			**0**
Public Transport Vehicle Crossing (HLN-PTVC)	100			**50**
Public Transport Vehicle at a Stop (HLN-PTVS)	100			**50**
Collision Warnings				
Cooperative collision risk warning	0			**0**
Vulnerable road user protection (pedestrians and cyclists)	0			**0**
Motorcycle approaching indication	0			**0**
Road Works Warning (RWW)				
Lane closure (and other restrictions) (RWW-LC)	100	100	100	**100**
Road Closure (RWW – RC)	100	100	100	**100**
Road Works Mobile (RWW-RM)	100	100	100	**100**
Winter Maintenance (RWW-WM)	100	100	100	**100**
Signalized Intersections (SI)				
Signal Phase and Timing Information (SI-SPTI)	100			**50**
Green Light Optimal Speed Advisory (SI-GLOSA)	100			**50**
Imminent Signal Violation Warning (SI-ISVW)	100			**50**
Traffic Light Prioritisation (SI-TLP)	100			**50**
Emergency Vehicle Priority (SI-EVP)	100			**50**
Toll Station Crossing (SI-TSC)	100			**50**
Information and management				
Information on alternative fuelled vehicle charging and fuelling st.	0		100	**50**
Park & Ride information (P&Ride)	0			**0**
Traffic information & Smart routing (SmartR)	0			**0**
Loading zone management (LZM)	0		100	**50**
Automated Vehicle Guidance (AVG)				
SAE Level Guidance (AVG-SAELG)	100			**50**
Platoon Support Information (AVG-PSI)	100			**50**
Topology Information (TI)				
Toll Station Approaching (TI-TSA)	100			**50**
Point of Interest (POI)				
Parking Availablity (POI-PA)	100			**50**
Collective Perception (CP)				
Collective Perception on Motorways (CP-MW)	100			**50**
Collective Perception on Urban/Interurban Inter-sections (CP-UI)	100			**50**
Probe Vehicle Data (PVD)				
Vehicle Data Collection (PVD-VDC)	100		100	**100**
Event Data Collection (PVD-EDC)	100			**50**

5.5 Costs

The costs were not separately examined in this study, but the magnitude of the approximate investment costs required from public sector actors was estimated by the experts (Table 24). The main public sector investors would be the Finnish Transport Infrastructure Agency, Fintraffic, cities and emergency response centres.

Table 24. The magnitude of the investment costs of public sector actors required by the likely implementation of C-ITS services.

C-ITS services and use cases	Road environment	Public investment, magnitude (EUR million)
In-Vehicle Signage (IVS)		
Traffic Signs (IVS-TS)	All	1
In-Vehicle Speed Limit (VSPD)	All	1
Free Text (IVS-FT)	All	1
Smart Routing (IVS-SM)	Main roads & streets	3
In-Vehicle Signage (IVS)		
Traffic Signs (IVS-TS)	All	1
In-Vehicle Speed Limit (VSPD)	All	1
Free Text (IVS-FT)	All	1
Smart Routing (IVS-SM)	Main roads & streets	3
Hazardous Locations Notification (HLN)		
Accident Zone (HLN-AZ)	All	0.5
Emergency Electronic Brakelight (EBL)	Road	0
Traffic Jam Ahead (HLN-TJA)	Road	0.5
Stationary vehicle (HLN - SV)	Road	0.5
Weather Condition Warning (HLN-WCW)	All	0
Temporarily slippery road (HLN-TSR)	All	2
Animal or person on the road (HLN-APR)	Road	1
Obstacle on the road (HLN-OR)	Road	
Unsecured Blockage of a Road (HLN-UBR)	Road	0.5
Emergency or Rescue/Recovery Vehicle in Intervention (HLN-ERVI)	Road	1
Emergency or Prioritized Vehicle Approaching (HLN-EPVA)	All	
Railway Level Crossing (HLN-RLX)	Not motorway	1
Alert Wrong Way Driving (HLN-AWWD)	Motorway	3
Shockwave Damping (SWD)	Motorway	10
Public Transport Vehicle Crossing (HLN-PTVC)	Urban area	
Public Transport Vehicle at a Stop (HLN-PTVS)	Urban area	15
Collision Warnings		
Cooperative collision risk warning	All	100
Vulnerable road user protection (pedestrians and cyclists)	Urban area	100
Motorcycle approaching indication	All	0
Road Works Warning (RWW)		
Lane closure (and other restrictions) (RWW-LC)	All	
Road Closure (RWW – RC)	All	3
Road Works Mobile (RWW-RM)	All	10
Winter Maintenance (RWW-WM)	All	10
Signalized Intersections (SI)		
Signal Phase and Timing Information (SI-SPTI)	Intersection	
Green Light Optimal Speed Advisory (SI-GLOSA)	Intersection	
Imminent Signal Violation Warning (SI-ISVW)	Intersection	15
Traffic Light Prioritisation (SI-TLP)	Intersection	
Emergency Vehicle Priority (SI-EVP)	Intersection	
Toll Station Crossing (SI-TSC)	Motorway	0

C-ITS services and use cases	Road environment	Public investment, magnitude (EUR million)
Information and management		
Information on alternative fuelled vehicle charging and fuelling st.	All	1
Park & Ride information (P&Ride)	All	2
Traffic information & Smart routing (SmartR)	All	10
Loading zone management (LZM)	All	2
Automated Vehicle Guidance (AVG)		
SAE Level Guidance (AVG-SAELG)	All	1
Platoon Support Information (AVG-PSI)	Motorway	1
Topology Information (TI)		
Toll Station Approaching (TI-TSA)	Motorway	0
Point of Interest (POI)		
Parking Availablity (POI-PA)	All	2
Collective Perception (CP)		
Collective Perception on Motorways (CP-MW)	Motorway	4
Collective Perception on Urban/Interurban Intersections (CP-UI)	Urban area/intersection	25
Probe Vehicle Data (PVD)		
Vehicle Data Collection (PVD-VDC)	All	1
Event Data Collection (PVD-EDC)	All	2

It should be emphasised that the purpose of Table 24 is to describe the relationship between investments rather than to give an impression of the actual magnitude. Investments of up to EUR 1 million may include automated validation processes of source data, software development to combine the information behind the messages and to generate C-ITS messages. Meanwhile, an investment of several million may include sensors and monitoring stations on the road network. An investment of the magnitude of EUR 10 million may involve significant development or renewal of back-end systems and of EUR 100 million may include significant implementation of roadside equipment.

The costs of the services are also strongly linked to the coverage of service deployment. For example, Alert Wrong Way Driving would be deployed via DfRS to the NAP and generated from there into C-ITS messages. This generates only minor costs. The coverage of a service can be improved by sensors, e.g. sensor-facilitated detection at the ends of a motorway or intersections that detect if someone starts driving in the wrong direction. This may considerably increase costs.

The costs do not include the implementation costs of the national C-ITS central station, as the central station will be implemented in any case, regardless of the service range available. However, service-specific investments include the integration of the service into the central station and its functions when service integration requires special measures.

In many cases, the annual operating and maintenance costs of services are likely to be 7–15% of the investment costs. For services whose initial data

is based on initial data regulated by the EU SRTI and RTTI Regulations, the percentage is likely to be significantly lower.

The above costs correspond to the implementations that would produce the socio-economic impacts examined above. In reality, the implementations are likely to only concern a part of the transport network, which means that the costs are naturally lower than the figures presented in the table, but so are also the impacts presented earlier in the report.

5.6 Validation of prioritisation criteria – workshop results

The aim of the workshop was to validate the criteria used in the study, their weights, and the scored and prioritised C-ITS services. The implementation of the workshop was presented in more detail in section 3.1.

The first structured question asked the participants about their opinion about the selected weight given to the criterion areas. Figure 3 shows the distribution of the answers to the question based on the weight given.

The most commonly assigned weights were those originally proposed and used in the study, 0.3/0.3/0.3/0.1. There was the most deviation in the responses in the criterion area of impacts promoting the needs of users.

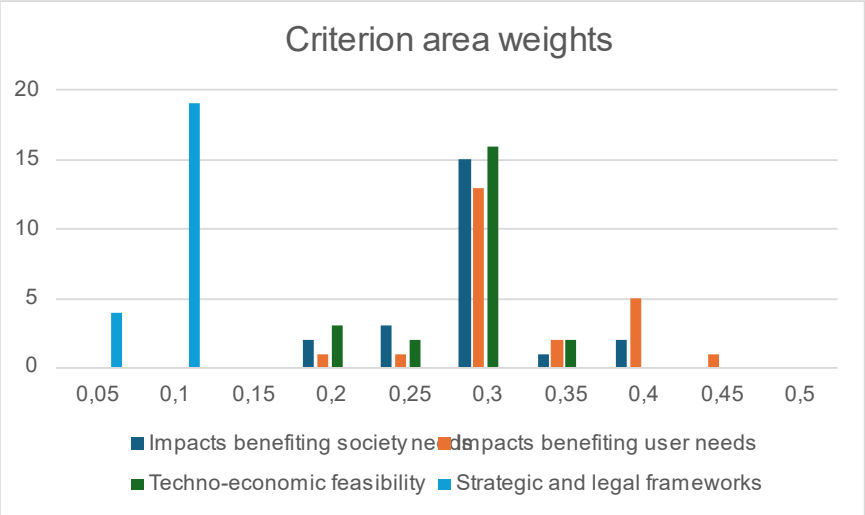

Figure 3. Responses on the weights assigned to the criterion areas in the workshop.

The second structured question asked the participants for their opinion on "On what basis should services be selected for first-phase implementation?". Figure 4 shows the answers to the question.

The most popular options were B) "only services with real C-ITS added value..." and C) "Start with services that are easy to deploy now...", both of which were selected by six respondents (38%). Other criteria mentioned included affordable, easy-to-implement service clusters that can be

expected to have positive impacts and services for which there is a commercial need due to their effectiveness.

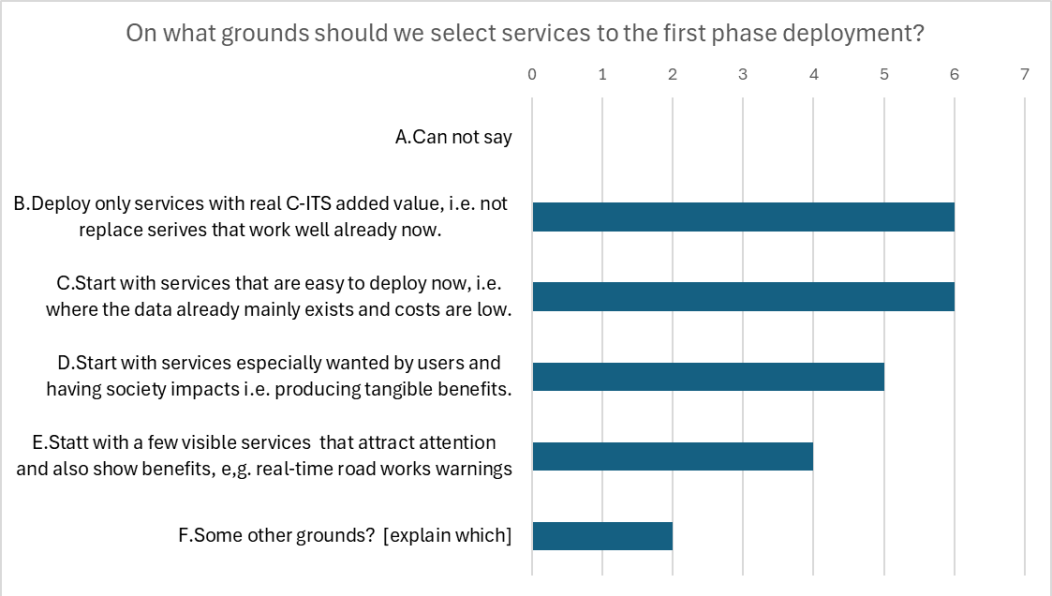

Figure 4. Distribution of responses to question 2 in the workshop.

In addition, changes were made to the assessments of service criteria, i.e. their scores and prioritizations, based on the comments made using the interaction tool at the workshop. The biggest impacts occurred in the user needs assessments, which included value increases for the following criteria and services:

- Public transport: traffic light services
- Logistics, transport companies and companies providing transport services: Loading zone service
- Active modes of transport: traffic light services
- Companies providing transport services: Park & ride service
- Motorists and public transport operators: event data collection service

Changes were also made to the investment cost estimate for slippery road warnings, and an error was detected in the impact assessment of vulnerable road user protection on roads.

6 Prioritisation of C-ITS services in Finland

The services were prioritised in the following order:

- by criterion area (societal needs, user needs, techno-economic feasibility)
- based on the needs of society and users
- only services with easy techno-economic implementation
- only services that effectively meet the needs of society
- only services that bring significant C-ITS added value
- on roads, all criteria simultaneously
- on streets, all criteria simultaneously.

6.1 Forming service clusters

Some of the services were combined because they were similar in terms of data types and information on their impacts was only available in combination. This was the reason for combining:

- Warnings concerned with road conditions and weather (Weather Condition Warning and Temporarily Slippery Road)
- warnings about an obstacle on the road (Obstacle on the Road and Unsecured Blockage of a Road)
- warnings concerning emergency vehicles (Emergency or Rescue/Recovery Vehicle in Intervention and Emergency or Prioritized Vehicle Approaching)
- warnings concerning roadworks resulting in lane or road closure (Lane Closure and Other Restrictions and Road Closure).

In addition, forming clusters of services that operate on the same hardware and software platform was considered to make sense. This was the reason for combining:

- warnings concerning public transport vehicle crossing and being at stop (Public Transport Vehicle Crossing and Public Transport Vehicle at a Stop)
- traffic light C-ITS services (Signal Phase and Timing Information, Green Light Optimal Speed Advisory, Imminent Signal Violation Warning, Traffic Light Prioritisation and Emergency Vehicle Priority.

Traffic light services were prioritised both as separate services and as clusters, but other services were prioritised only as clusters.

6.2 Prioritisation by criterion area

Background information about the methods used to prioritise C-ITS services presented in this section is provided in Chapter 3 Methods used. In

addition, Chapter 5 Prioritisation criteria presents justifications for the assessments by the criteria group.

The prioritisation tables usually only show the services ranking the highest in each analysis. An effort has been made to select the breaking points in the tables where there is a large difference to the succeeding figure. The 'Result' in the prioritisation tables means the weighted average of the criteria values of the prioritisation area(s) calculated using the method presented in section 3.5 using the weighting coefficients given in Table 5.

Tables 25 and 26 show the C-ITS services given the highest prioritizations based on the needs of society, i.e. traffic safety, flow, carbon emissions and accessibility impacts on roads and streets.

*Table 25. C-ITS services assessed to best meet **societal needs** on **roads.***

C-ITS service	Result
In-Vehicle Speed Limit (VSPD)	52.5
Event Data Collection (PVD-EDC)	49.3
Cooperative collision risk warning	44.4
Traffic information & Smart routing (SmartR)	41.5
Vehicle Data Collection (PVD-VDC)	32.5
Emergency Electronic Brakelight (EBL)	33.3
Animal or person on the road (HLN-APR)	22.2
Traffic Jam Ahead (HLN-TJA)	13.0
Stationary vehicle (HLN - SV)	12.0
Obstacle or Unsecured Blockage of Road (HLN-OR & UBR)	12.0
Motorcycle approaching indication	12.0
Parking Availability (POI-PA)	11.1
Information on alternative fuelled vehicle charging and fuelling stations (iFuel)	11.0
In-Vehicle Speed Limit (VSPD)	52.5

Smart routing for traffic, producing speed limit information, event data collection, vehicle data and cooperative collision risk warnings are among the most effective services on both roads and streets.

Emergency braking warnings are among the most effective services on roads. On streets, traffic light control services and, in particular, the green light optimal speed recommendation are listed as the most effective services.

*Table 26. C-ITS services assessed to best meet **societal needs** on **streets.***

C-ITS service	Result
Traffic information & Smart routing (SmartR)	60.0
All SI use cases (SPTI + GLOSA + ISVW + TLP + EVP)	49.7
In-Vehicle Speed Limit (VSPD)	43.8
Event Data Collection (PVD-EDC)	42.2
Cooperative collision risk warning	41.8
Green Light Optimal Speed Advisory (SI-GLOSA)	36.4
Vehicle Data Collection (PVD-VDC)	27.9
Park & Ride information (P&Ride)	25.2
Loading zone management (LZM)	22.5
Vulnerable road user protection (pedestrians and cyclists)	19.8
Traffic Light Prioritisation (SI-TLP)	12.8
Motorcycle approaching indication	11.3
Parking Availability (POI-PA)	9.8
Information on alternative fuelled vehicle charging and fuelling stations (iFuel)	9.8
Collective Perception on Urban/Interurban Intersections (CP-UI)	9.2

Tables 27 and 28 present the services that received the highest criteria values for meeting user needs on roads and streets.

Different warning services were assessed to best meet the needs of users. The services alert users of accident zones, obstacles on the road, road works, poor and/or slippery road conditions, people and animals on the road, and winter maintenance and vehicles. In addition, collective perception on intersections and protection of vulnerable road users proved to be services that meet users' needs.

*Table 27. C-ITS services assessed to best meet **user needs** on **roads**.*

C-ITS service	Result
Accident Zone (HLN-AZ)	98.0
Obstacle or Unsecured Blockage of Road (HLN-OR & UBR)	91.7
Lane and road closure (and other restr.) (RWW-LC & RC)	88.5
Weather Condition & Slippery road (HLN-WCW + TSR)	85.4
Animal or person on the road (HLN-APR)	83.6
Collective Perception on Urban/Interurban Intersections (CP-UI)	80.3
Winter Maintenance (RWW-WM)	80.1
Road Works Mobile (RWW-RM)	80.0
Vulnerable road user protection (pedestrians and cyclists)	77.3
Traffic Signs (IVS-TS)	72.8
Imminent Signal Violation Warning (SI-ISVW)	69.7
Traffic information & Smart routing (SmartR)	69.6
Smart Routing (IVS-SM)	69.1
Emergency Electronic Brakelight (EBL)	69.0
Collective Perception on Motorways (CP-MW)	68.3
Event Data Collection (PVD-EDC)	68.2
In-Vehicle Speed Limit (VSPD)	67.3

*Table 28. C-ITS services assessed to best meet **user needs** on **streets**.*

C-ITS service	Result
Accident Zone (HLN-AZ)	97.6
Obstacle or Unsecured Blockage of Road (HLN-OR & UBR)	89.8
Lane and road closure (and other restr.) (RWW-LC & RC)	86.6
Collective Perception on Urban/Interurban Intersections (CP-UI)	83.8
Weather Condition & Slippery road (HLN-WCW + TSR)	83.4
Vulnerable road user protection (pedestrians and cyclists)	80.7
Animal or person on the road (HLN-APR)	79.7
Road Works Mobile (RWW-RM)	79.1
Winter Maintenance (RWW-WM)	78.5
Imminent Signal Violation Warning (SI-ISVW)	73.6
Traffic Signs (IVS-TS)	72.2
Emergency Electronic Brakelight (EBL)	71.0
Traffic information & Smart routing (SmartR)	69.7
Smart Routing (IVS-SM)	69.3
In-Vehicle Speed Limit (VSPD)	68.1
Emergency vehicle warnings (HLN-ERVI & EPVA)	67.7

Tables 29 and 30 show the services considered best in terms of technical economic feasibility on roads and streets.

Animal or Person on the Road, Railway Level Crossings, mobile and stationary road work warning, Obstacles or Unsecured Blockage of Road, Alert Wrong Way Driving, Weather Condition and Accident Zones services and Traffic Signs and In-Vehicle Speed Limit were the best services on the roads based on techno-economic criteria.

The same services also ranked at the top on streets. In addition, the services scoring the highest for streets included loading the zone location and reservation service.

*Table 29. C-ITS services assessed best in terms of **techno-economic** feasibility on **roads**.*

C-ITS service	Result
Animal or person on the road (HLN-APR)	83.3
Railway Level Crossing (HLN-RLX)	82.5
Road Works Mobile (RWW-RM)	82.5
Traffic Signs (IVS-TS)	81.3
Obstacle or Unsecured Blockage of Road (HLN-OR & UBR)	80.8
Lane and road closure (and other restr.) (RWW-LC & RC)	80.0
In-Vehicle Speed Limit (VSPD)	78.8
Alert Wrong Way Driving (HLN-AWWD)	78.8
Weather Condition & Slippery road (HLN-WCW + TSR)	77.3
Accident Zone (HLN-AZ)	76.3
Emergency vehicle warnings (HLN-ERVI & EPVA)	66.3
Collective Perception on Motorways (CP-MW)	63.3
Park & Ride information (P&Ride)	61.5
Winter Maintenance (RWW-WM)	58.8
Signal Phase and Timing Information (SI-SPTI)	57.0
Free Text (IVS-FT)	56.8

*Table 30. C-ITS services assessed best in terms of **techno-economic** feasibility on **streets**.*

C-ITS service	Result
Animal or person on the road (HLN-APR)	83.3
Railway Level Crossing (HLN-RLX)	82.5
Road Works Mobile (RWW-RM)	82.5
Traffic Signs (IVS-TS)	81.3
Obstacle or Unsecured Blockage of Road (HLN-OR & UBR)	80.8
Lane and road closure (and other restr.) (RWW-LC & RC)	80.0
In-Vehicle Speed Limit (VSPD)	78.8
Alert Wrong Way Driving (HLN-AWWD)	78.8
Accident Zone (HLN-AZ)	76.3
Loading zone management (LZM)	71.3
Weather Condition & Slippery road (HLN-WCW + TSR)	70.1
Emergency vehicle warnings (HLN-ERVI & EPVA)	66.3
Park & Ride information (P&Ride)	61.5
Collective Perception on Urban/Interurban Intersections (CP-UI)	61.3
Parking Availability (POI-PA)	60.8
Vulnerable road user protection (pedestrians and cyclists)	58.8
Winter Maintenance (RWW-WM)	58.8
Signal Phase and Timing Information (SI-SPTI)	57.0
Free Text (IVS-FT)	56.8

6.3 Prioritisation according to the needs of society and users

Table 31 shows the C-ITS services that best meet the needs of both users and society on roads. In-Vehicle Speed Limit, Event Data Collection, Smart Routing and Cooperative Collision Risk warning rank at the top of the list. These were succeeded by warnings about animals or people on the road, obstacles on the road, emergency braking and accident zones in terms of necessity. Various road works warnings were also among the necessary services.

Table 32 shows a corresponding examination for streets. On streets, Smart Routing, speed limit information, C-ITS services for traffic light control and cooperative collision risk warning rank at the top of the list. They are followed by accident zone warnings, vulnerable road user protection, collective perception on intersections and a speed recommendation for green lights optimised based on individual services for signalised intersections. Road works services also ranked relatively high for streets.

*Table 31. C-ITS services assessed to best meet both **societal and user needs** on **roads**.*

C-ITS service	Result
In-Vehicle Speed Limit (VSPD)	59.9
Event Data Collection (PVD-EDC)	58.7
Traffic information & Smart routing (SmartR)	55.6
Cooperative collision risk warning	55.0
Animal or person on the road (HLN-APR)	52.9
Obstacle or Unsecured Blockage of Road (HLN-OR & UBR)	51.8
Emergency Electronic Brakelight (EBL)	51.2
Accident Zone (HLN-AZ)	50.7
Lane and road closure (and other restr.) (RWW-LC & RC)	47.9
Vehicle Data Collection (PVD-VDC)	44.9
Weather Condition & Slippery road (HLN-WCW + TSR)	43.9
Winter Maintenance (RWW-WM)	42.5
Road Works Mobile (RWW-RM)	41.4
Traffic Signs (IVS-TS)	40.8
Collective Perception on Urban/Interurban Intersections (CP-UI)	40.1

*Table 32. C-ITS services assessed to best meet both **societal and user needs** on **streets**.*

C-ITS service	Result
Traffic information & Smart routing (SmartR)	64.8
All SI use cases (SPTI + GLOSA + ISVW + TLP + EVP)	56.3
In-Vehicle Speed Limit (VSPD)	55.9
Event Data Collection (PVD-EDC)	54.5
Cooperative collision risk warning	53.3
Accident Zone (HLN-AZ)	50.4
Vulnerable road user protection (pedestrians and cyclists)	50.2
Collective Perception on Urban/Interurban Intersections (CP-UI)	46.5
Green Light Optimal Speed Advisory (SI-GLOSA)	46.2
Obstacle or Unsecured Blockage of Road (HLN-OR & UBR)	44.9
Lane and road closure (and other restr.) (RWW-LC & RC)	43.3
Weather Condition & Slippery road (HLN-WCW + TSR)	42.9
Vehicle Data Collection (PVD-VDC)	42.7
Winter Maintenance (RWW-WM)	41.5
Road Works Mobile (RWW-RM)	40.8
Traffic Signs (IVS-TS)	40.2

6.4 Conditional prioritisation

From the perspective of economic efficiency, it could be most effective to first invest in services whose techno-economic implementation is sufficiently easy. From the perspective of public sector organisations working to achieve transport policy objectives, it only makes sense to implement services that promote the achievement of the transport policy objectives. For this reason, both perspectives are first examined separately before all criteria are used simultaneously.

Only services with easy techno-economic implementation

Table 33 shows the services that best meet the needs of both society and users of those services, whose techno-economic feasibility was found to be adequate. In this respect, the table is a reduced version of Table 31.

The services that were found to be the best in terms of techno-economic feasibility as well as meeting the needs of both society and users were In-Vehicle Speed Limit, warnings alerting road users of an animal or person on the road, obstacles on the road, Accident Zone, Lane and road closure due to road works, Weather Condition and Slippery road, Winter Maintenance, Road Works Mobile and Traffic Signs.

*Table 33. C-ITS services assessed to best meet **the needs of society and users** offered on **roads** with a **techno-economic** feasibility score of at least 55.*

C-ITS service	Result
In-Vehicle Speed Limit (VSPD)	59.9
Animal or person on the road (HLN-APR)	52.9
Obstacle or Unsecured Blockage of Road (HLN-OR & UBR)	51.8
Accident Zone (HLN-AZ)	50.7
Lane and road closure (and other restr.) (RWW-LC & RC)	47.9
Weather Condition & Slippery road (HLN-WCW + TSR)	43.9
Winter Maintenance (RWW-WM)	42.5
Road Works Mobile (RWW-RM)	41.4
Traffic Signs (IVS-TS)	40.8
Free Text (IVS-FT)	35.5
Collective Perception on Motorways (CP-MW)	34.4
Emergency vehicle warnings (HLN-ERVI & EPVA)	32.9
Railway Level Crossing (HLN-RLX)	31.9
Alert Wrong Way Driving (HLN-AWWD)	30.1

An equivalent analysis for streets is presented in Table 34. The list of best services for streets resembles the list presented for roads quite a lot. For streets, vulnerable road user protection and collective perception on intersections rank high on the list.

*Table 34. C-ITS services assessed to best meet **the needs of society and users** offered on **streets** with a **techno-economic** feasibility score of at least 55.*

C-ITS service	Result
In-Vehicle Speed Limit (VSPD)	55.9
Accident Zone (HLN-AZ)	50.4
Vulnerable road user protection (pedestrians and cyclists)	50.2
Collective Perception on Urban/Interurban Intersections (CP-UI)	46.5
Obstacle or Unsecured Blockage of Road (HLN-OR & UBR)	44.9
Lane and road closure (and other restr.) (RWW-LC & RC)	43.3
Weather Condition & Slippery road (HLN-WCW + TSR)	42.9
Winter Maintenance (RWW-WM)	41.5
Road Works Mobile (RWW-RM)	40.8
Traffic Signs (IVS-TS)	40.2
Animal or person on the road (HLN-APR)	39.9
Park & Ride information (P&Ride)	38.3
Free Text (IVS-FT)	35.4
Emergency vehicle warnings (HLN-ERVI & EPVA)	34.0
Railway Level Crossing (HLN-RLX)	31.8
Alert Wrong Way Driving (HLN-AWWD)	30.1
Signal Phase and Timing Information (SI-SPTI)	29.0
Parking Availability (POI-PA)	28.8
Loading zone management (LZM)	28.4

Only services that effectively meet the needs of society

Table 35 only examines services that adequately meet the needs of society in terms of traffic safety, traffic flow, reduction of carbon emissions and accessibility of services. The table presents the best of these services for roads in terms of user needs and techno-economic feasibility. A similar breakdown for streets is shown in Table 36.

In this review, warnings on obstacles, animals and people on the road, as well as information on speed limits and smart routing for traffic, proved to be the best services for roads. These services were followed by warnings about stationary vehicles, traffic jams ahead and emergency braking as well as the production of event data on the list. Cooperative collision warning and information on fuelling and recharging stations for alternative fuelled vehicles also ranked among the top ten services in the breakdown concerning road conditions.

Meanwhile, the list of best services for streets was rather different: the highest-ranking services were In-Vehicle Speed Limit, Vulnerable Road User Protection, Smart routing, Park & Ride information, All SI use cases as well as the services they contain, Traffic Light Prioritisation and Green Light Optimal Speed Advisory (SI-GLOSA). The Loading Zone Management service, Even Data Collection and Cooperative Collision Risk Warning also placed among the top ten services.

*Table 35. C-ITS services assessed as best in terms of both **user needs and techno-economic feasibility** offered on **roads** scoring at least 10 in meeting **societal** needs.*

C-ITS service	Result
Obstacle or Unsecured Blockage of Road (HLN-OR & UBR)	86.2
Animal or person on the road (HLN-APR)	83.4
In-Vehicle Speed Limit (VSPD)	73.0
Traffic information & Smart routing (SmartR)	56.8
Stationary vehicle (HLN - SV)	50.6
Event Data Collection (PVD-EDC)	49.1
Traffic Jam Ahead (HLN-TJA)	45.4
Emergency Electronic Brakelight (EBL)	43.3
Cooperative collision risk warning	41.6
Information on alternative fuelled vehicle charging and fuelling stations (iFuel)	39.1
Motorcycle approaching indication	38.8
Vulnerable road user protection (pedestrians and cyclists)	38.6
Vehicle Data Collection (PVD-VDC)	34.8
Parking Availability (POI-PA)	24.8

*Table 36. C-ITS services assessed as best in terms of both **user needs and techno-economic feasibility** offered on **streets** scoring at least 10 in meeting **societal** needs.*

C-ITS service	Result
In-Vehicle Speed Limit (VSPD)	73.4
Vulnerable road user protection (pedestrians and cyclists)	69.7
Traffic information & Smart routing (SmartR)	58.1
Park & Ride information (P&Ride)	56.5
All SI use cases (SPTI + GLOSA + ISVW + TLP + EVP)	54.1
Loading zone management (LZM)	52.8
Traffic Light Prioritisation (SI-TLP)	52.2
Event Data Collection (PVD-EDC)	43.8
Green Light Optimal Speed Advisory (SI-GLOSA)	43.3
Cooperative collision risk warning	41.1
Motorcycle approaching indication	38.8
Vehicle Data Collection (PVD-VDC)	34.9

6.5 Overall prioritisation on roads and streets

The overall prioritisation used all the prioritisation criteria multiplied by the weighting coefficients presented earlier in this report. For roads, the prioritisation of services is presented in Table 37. In addition to the weighted result of the prioritisation criteria, the table shows the C-ITS added value of the service and the magnitude of the public sector investment cost required by the service. The table excludes road toll services and a shockwave damping service, whose implementation is considered unrealistic in the near future.

At the top of the list of services are in-vehicle speed limit information, animal or person on the road, obstacles on the road and accident zone. The investments required by all these services are rather moderate.

These services are followed by warnings of road works resulting in lane and road closures, mobile road works, weather conditions and slippery roads, and traffic sign information. The implementation of C-ITS road work warnings and information about slippery conditions require moderate investments, as do the winter maintenance vehicle warning and wrong-way driving alert, which follow them on the list.

The services that generate clear added value, ranking the highest on the list, include warnings of an animal or person or an obstacle on the road, warnings of road works that cause lane and road closure and mobile road works, traffic sign information, winter maintenance vehicle warning and wrong way driving alert. Railway level crossing warning, smart routing and emergency vehicle warning are also among the best services that produce a clear C-ITS added value.

Table 38 shows a corresponding examination for streets. For streets, the priority results were the highest for in-vehicle speed limit information and warnings concerning an accident zone, obstacle on the road, lane and road closure due to road works or mobile road works. The investment costs were at least moderate for road works warnings, but more reasonable for the other services.

The services succeeding the above on the list were warnings of animals or people on the road, traffic sign information, warnings about weather and slippery conditions, smart routing and winter maintenance vehicle warnings. The latter two have significant cost impacts.

When only examining the services with clear C-ITS added value, the situation changes somewhat. At the top of the list are warnings of obstacles on the road, road works closing a lane or road, mobile road works and animals or people on the road. They are followed in the order of priority by traffic sign information, smart routing, winter maintenance vehicle warnings and a warning about a vehicle driving in the wrong direction. Collective perception on intersections, railway level crossing warnings and protection of vulnerable road users ranked right below them on the list. Of these, the implementation of collective perception and the protection of vulnerable road users is estimated to cause significant costs.

*Table 37. C-ITS services in the order of priority based on **all the criteria** for **roads** and a classification of their C-ITS added value criterion values and investment cost values. The 12 best services in each criterion area are shown in a darker shade of green.*

Criteria	***Societal needs***	***User needs***	***Techno-economic feasibility***	***Legislation & strategies***	***Total***	***C-ITS added value ****	***Public investment *****
C-ITS Service Weight:	***0.3***	***0.3***	***0.3***	***0.1***	***1***		
In-vehicle speed limit	53	67	79	100	**70**	++	€
Animal or person on the road	22	84	83	100	**67**	+++	€
Obstacle or unsecured blockage of r.	12	92	81	100	**65**	++++	€
Accident zone	3	98	76	100	**63**	++	€
Lane and road closure (& other restr.)	7	89	80	100	**63**	+++	€€
Road works mobile	3	80	83	100	**60**	++++	€€€
Weather condition & slippery road	3	85	77	100	**60**	+	€€
Traffic signs	9	73	81	100	**59**	+++	€
Winter maintenance	5	80	59	100	**53**	++++	€€€
Alert wrong way driving	0	60	79	100	**52**	+++	€€
Event data collection	49	69	30	50	**49**	++	€€
Railway level crossing	5	59	83	50	**49**	++++	€
(Traffic signs) free text	7	64	57	100	**48**	+	€
Traffic information & smart routing	42	70	44	0	**47**	++++	€€€
Emergency vehicle warnings	2	64	66	50	**45**	+++	€
Collective perception on motorways	1	68	63	50	**45**	++++	€€€
Traffic jam ahead	13	56	35	100	**41**	++	€
Emergency electronic brakelight	33	69	18	50	**41**	++++	€
Vehicle data collection	33	59	12	100	**41**	++	€
Imminent signal violation warning	0	70	45	50	**39**	+	€€
Stationary vehicle	12	61	40	50	**39**	++++	€
Cooperative collision risk warning	44	66	18	0	**38**	++++	€€€€
Signal phase and timing information	0	53	57	50	**38**	++++	€€
Emergency vehicle priority	1	63	47	50	**38**	0	€€
All signalised intersection use cases	4	59	45	50	**38**	++	€€€
Smart routing	2	69	38	50	**38**	++	€€
Traffic light prioritisation	3	53	47	50	**36**	0	€€
Park & Ride information	10	47	62	0	**35**	++++	€€
Information on alternative fuelled vehicle charging and fuelling stations	11	24	54	50	**32**	+	€
Collective perception on urban/inter-urban intersections	0	80	0	50	**29**	++++	€€€€
PT vehicle crossing & at stop	0	54	26	50	**29**	++++	€€€
SAE level guidance	2	24	49	50	**27**	++++	€
Motorcycle approaching indication	12	60	18	0	**27**	++++	€
Parking availablity	11	42	8	50	**23**	+++	€€
Vulnerable road user protection	0	77	0	0	**23**	++++	€€€€
Platoon support information	1	21	32	50	**21**	++++	€
Loading zone management	7	33	0	50	**17**	++	€€

** C-ITS added value rating 0, 1–25, 25–50, 51–75, 76–100*
*** investment cost classification 0–1, 1–3, 3–20, over EUR 20 million*

*Table 38. C-ITS services in the order of priority based on **all the criteria** for **streets** and a classification of their C-ITS added value criterion values and investment cost values. The 12 best services in each criterion area are shown in a darker shade of blue*

Criteria	***Societal needs***	***User needs***	***Techno-economic feasibil.***	***Legislation & strat..***	***Total***	***C-ITS added value***	***Public investment***
C-ITS Service Weight:	***0.3***	***0.3***	***0.3***	***0.1***	***1***	*	**
In-vehicle speed limit	44	68	79	100	67	++	€
Accident zone	3	98	76	100	63	++	€
Obstacle or unsecured blockage of r.	0	90	81	100	61	++++	€
Lane and road closure (& other restr.)	0	87	80	100	60	+++	€€
Road works mobile	3	79	83	100	59	++++	€€€
Animal or person on the road	0	80	83	100	59	+++	€
Traffic signs	8	72	81	100	58	+++	€
Weather condition & slippery road	2	83	70	100	57	+	€€
Traffic information & smart routing	60	70	47	0	53	++++	€€€
Winter maintenance	4	79	59	100	53	++++	€€€
All signalised intersection use cases	50	63	45	50	52	++	€€€
Alert wrong way driving	0	60	79	100	52	+++	€€
Collective perception on urban/inter-urban intersections	9	84	61	50	51	++++	€€€€
Railway level crossing	4	59	83	50	49	++++	€
Free text	6	65	57	100	48	+	€
Vulnerable road user protection	20	81	59	0	48	++++	€€€€
Emergency vehicle warnings	0	68	66	50	45	+++	€
Event data collection	42	67	21	50	44	++	€€
Loading zone management	22	35	71	50	43	++	€€
Green light optimal speed advisory	36	56	31	50	42	+	€€
Imminent signal violation warning	4	74	45	50	42	+	€€
Park & ride information	25	51	62	0	41	++++	€€
Emergency vehicle priority	8	65	47	50	41	0	€€
Parking availability	10	48	61	50	41	+++	€€
Traffic light prioritisation	13	57	47	50	40	0	€€
Vehicle data collection	28	59	12	100	40	++	€
Signal phase and timing information	2	56	57	50	40	++++	€€
PT vehicle crossing & at stop	7	57	48	50	39	++++	€€€
Smart routing	2	69	40	50	38	++	€€
Traffic jam ahead	1	57	35	100	38	++	€
Cooperative collision risk warning	42	65	18	0	37	++++	€€€€
Stationary vehicle	0	61	40	50	35	++++	€
Information on alternative fuelled vehicle charging and fuelling stations	10	27	54	50	32	+	€
Emergency electronic brakelight	0	71	18	50	32	++++	€
Motorcycle approaching indication	11	60	18	0	27	++++	€
Collective perception on motorways	0	67	0	50	25	0	€€€
SAE Level guidance	1	22	44	50	25	++++	€
Platoon support information	1	17	14	50	14	++++	€

** C-ITS added value rating 0, 1–25, 25–50, 51–75, 76–100*
*** investment cost classification 0–1, 1–3, 3–20, over EUR 20 million*

It should be emphasised that all C-ITS services hold added value brought by information security, even if the service does not provide any information-based added value.

The tables also show that the criteria values for societal needs are relatively low for the C-ITS services with high overall priority. This is partly due to the long-term efforts made in Finland to solve key transport challenges. As a result, there are already many existing services, for example, to address the key challenges related to user needs. Examples include information and maintenance services produced to respond to road conditions-related problems, which means that warnings related to weather and road conditions do not bring any significant additional benefits in the current situation.

In addition, the criteria values for societal needs are generally lower than in other criteria areas. The reason for this is that few services benefit all four criteria for societal needs (safety, travel time, carbon emissions, accessibility of services), but usually only one or two of them, whereas the remaining criteria receive values close to zero. This is reflected in Table 6 in section 5.1. Therefore, the weighted average of the criteria area has a fairly low value for most services.

It should also be noted that the needs of users also include some needs of society. Examples of this include logistics efficiency and the needs of public transport and people using active modes of travel.

6.6 Proposal for national prioritisation

According to the method used in this study, three types of services should be prioritised in the implementation of C-ITS services in Finland:

- hazardous location warnings
- road works warnings
- traffic sign information.

For example, the high priority hazardous location warnings included accident zone warnings, warnings related to road and weather conditions, warnings of persons or animals on the road, warnings of obstacles on the road and warnings of vehicles driving in the wrong direction.

What all these services have in common is that the knowledge base they require already exists or will exist in the next few years as a result of the implementation of the EU's ITS Directive and its Delegated Regulations. The Data for Road Safety ecosystem established to implement the requirements laid down in the SRTI Delegated Regulation (European Commission 2013) produces warnings about people, animals and obstacles on the road, short-term road works, unprotected accident areas, slippery road sections and other poor weather conditions, and vehicles driving in the wrong way.

The RTTI Regulation (European Commission 2022a) requires the production of signage data indicating speed limits and other traffic rules as well as road works and road weather data, among other things.

Although the data content of the above services is available, especially for roads, and Fintraffic is a member of the Data for Road Safety ecosystem, the quality of the available data, with the exception of traffic sign data, is apparently not sufficient for C-ITS services even on roads in Finland. Preliminary requirements for the quality of C-ITS data have been set by Lubrich et al. (2022). With regard to at least the coverage, timeliness, location accuracy and correctness of the information, it is likely that clear improvements will be needed before the services can be implemented.

A key tool for improving hazardous location data is the increase in the number of users of the C-ITS service as data providers for the service. For road works information and warnings, the C-Roads specifications are largely based on a hybrid C-ITS station at the start and end points of road works and in road works vehicles. The C-ITS station continuously transmits accurate location data to approaching road users. The implementation of such a solution increases costs to road contractors and, consequently, road work clients, which has also been taken into account above (Tables 24, 37 and 28).

On streets, the availability of data content is at a lower level compared to roads. As required by the RTTI Regulation, at least traffic sign information will probably be produced in the next few years, at least in large cities.

In addition to the three main service types, high-priority services on both roads and streets included:

- event data production
- level crossing warnings
- smart routing.

Of these, the implementation of smart routing was considered rather difficult and also resource-intensive. The implementation of level crossing warnings, on the other hand, is fairly easy as the information is available, although the number of users of the warnings is low and is distributed around the country. Event data is useful for both traffic management and road users, but its implementation is difficult and resource-intensive, mainly because of the diversity of events and their organisers.

Signalised intersection services received a relatively high priority on streets. As a rule, signalisation services are implemented either in connection with the investments for replacing traffic lights or when implementing completely new traffic lights in cities that have not yet introduced a prioritised public transport or emergency vehicle feature, for instance. During the study, a need was identified for a C-ITS service which combines traffic

light prioritisation and a green light optimal speed advisory for heavy goods vehicles. This is expected to improve the flow of freight traffic and, above all, reduce harmful emissions. Such services should be tested to ensure their functionality and impact.

The following views, identified during different stages of the study, provide a basis for selecting C-ITS services for first-phase implementation:

a) The service should produce **information that is new** in terms of its type or quality and has not been previously available to road users.

b) The services should be **visible and interesting** to attract interest from the public and the media as well as commercial stakeholders.

c) The services should produce **significant impacts** and particularly benefits to ensure that decision-makers are ready for new C-ITS implementations.

d) The work should begin with services that are **easy and affordable to implement** and enable collecting data rapidly on the operation of the basic C-ITS infrastructure (national C-ITS station, interchange service, authentication feature).

Table 39 examines how well the C-ITS services that are currently prioritised respond to the above criteria for selecting services for implementation.

None of the services fully correspond to all the selection criteria as such. Hazardous location warnings succeed best in meeting all the criteria, especially if the quality of the information can be raised to an adequate level.

Table 39. Link between prioritised services and the selection criteria for the implementations. Green indicates that the service meets the selection criteria. Yellow means that the grounds require improving the quality of information.

Implementation grounds: / Service	a) new or better information	b) visible or interesting	c) significant benefits	d) easy/inexpensive to implement
Hazardous location warnings				
Road works warnings				
Traffic sign information	Variable signs			
Event data production				
Smart routing				
Level crossing warning				

7 Conclusions

7.1 Implementation of C-ITS services

The analysis of priorities identified several good services and service clusters. However, no single service or service cluster was found whose characteristics would meet all the selection criteria for implementation in the current situation. As a result, the choice of the first services must also be based on factors other than those used in the multicriteria analysis.

The national implementation of the RTTI Regulation supports starting with **traffic sign information** and **road works warnings**, both on roads and streets.

On **roads**, **hazardous location warnings** and **level crossing warnings** would emerge as the following promising implementation targets, as they are a traditional part of road traffic management, but their impacts are likely to increase as a result of C-ITS communications.

On streets, road works warnings and event data production play a key role in the functioning of the transport system. The implementation of new traffic lights and other services considered important to urban regions in a C-ITS-compatible form is highly recommended. The C-ITS architecture will bring reliability, information security and interoperability to all services at both national and international levels.

7.2 Consistency with EU development

The results of the study are consistent with development at the EU level in that the study focused on the services specified by C-Roads. In practice, C-Roads has so far defined services that individual Member States have already tested or introduced.

Hazard location warnings and road works warnings are part of the mainstream of European implementations, which means that the priority services recommended in this study are consistent with the EU development.

Topics highlighted in the meetings of the expert group from the reference countries included the traffic light C-ITS services and emergency vehicle services (traffic light prioritisation and prioritized vehicle approaching), which ranked high in these countries' implementation plans. However, Finland's advanced public transport and emergency vehicle priority services and traffic light optimisation reduce the added value and impacts of traffic light C-ITS services in Finland.

C-ITS communications, planned to be largely based on Finland's existing mobile phone networks, do not differ significantly from the plans of the

reference countries and therefore do not result in a need to change the prioritisation of the services. However, the low traffic volumes on Finnish roads, the high prevalence of winter conditions and the large number of single vehicle accidents as well as accidents involving cervids in comparison with the southern EU area result in differences in the service priorities. For example, speed limit information is necessary and effective in Finland due to the large share of motorists driving outside traffic queues, single vehicle accidents and annual wintertime speed limits.

7.3 Assessment of the research method

This section provides an assessment of the reliability and reproducibility of the study, i.e. its validity and reliability, and how transparently the study was reported. The section is mainly focused on assessing the multicriteria analysis used to prioritise C-ITS services as the main method used.

Multicriteria analysis has been previously considered a good option in the assessment of intelligent transport systems (Brucker et al. 2004) and it has been applied to intelligent transport services such as public transport and smart city services (Choosakun & Yeom 2021; Zapolskytė et al. 2020).

In this study, a linear function was used to calculate the results of the multicriteria analysis, in which the weights of the criteria with a sum of 1 were formed; subsequently, the alternatives were scored (0–100) and these scores were lastly used to calculate the total result scores. In other words, a multicriteria analysis (system) consists of the sum of its parts. The assessment and scoring of the criteria for the multicriteria analysis were carried out qualitatively and quantitatively using a literature review, interviews, a workshop and expert assessments.

The suitability of multicriteria analysis for assessing the prioritisation of C-ITS services can be examined by comparing the results obtained using the method with the priorities that have emerged in the implementation of real-life road transport C-ITS systems and services, as well as related experiments.

In order to operate, Cooperative Intelligent Transport Systems for Road Transport (C-ITS) require several actors in an extensive value chain. The actors develop technology and services, which are then utilised by vehicles, infrastructure and road users in the traffic environment. These complex interdependencies are well reflected by the various criteria groups and their individual criteria used in the multicriteria analysis performed in this study (Chapter 5).

In other words, highly complex chains as well as major variation and differences in various situations may occur in the interaction between the implementation of C-ITS services and traffic. C-ITS systems and services are a

prime example of a complex system that consists of several components that interact with each other. The behaviour or operation of such a complex system cannot be restored to system components, i.e. the system as a whole is more than the sum of system components (Ladyman et al. 2011). Modelling such systems is considered considerably difficult due to issues such as their non-linear and dynamic nature, the dependencies between their parts and the environment and the interaction (e.g. Hastings et al. 2017). Non-linear effects are highlighted and increased in the system as the number of networked nodes it contains increases, which may further increase interactivity between the nodes. Table 40 presents a summary of such a situation and shows examples between the multicriteria analysis and the real-life implementation of C-ITS services in road traffic.

Table 40. Example comparison of the assessment of C-ITS services using multicriteria analysis and C-ITS services in road traffic.

Type	Assessment of C-ITS services based on the multicriteria analysis	C-ITS services in road traffic
Objective	To assess and prioritise the implementation of C-ITS services	C-ITS services implemented in the a real-life road traffic environment
Function	Linear	Non-linear
Model / system composition	Sum of its parts	More than the sum of its parts
Dynamism of the system	Static, describes a point in time, weightings and criteria	Dynamic, constantly changing
Complexity	Medium	Very high
Interactions between networked nodes	Low	Very high

A road works area can be used as an example of the interaction between C-ITS services on the road or street network. C-ITS services and their interactions between actors (components) in a (random) traffic situation in a road works area may include road works warnings, smart routing (strategic decision-making on route before a journey), traffic jam information, traffic sign information, emergency braking information, hazardous location notifications, cooperative collision risk warnings and probe vehicle data. The use of individual or several services in different traffic situations is affected by factors such as vehicle system algorithms. Other intelligent transport services can also be used in parallel with C-ITS services. The use of services also affects the driver's decision-making at different stages of the journey: for example, a strategic decision to select a particular route may result in later avoiding some situation and the use of a service in a tactical or operative driving environment. Similarly, in a tactical and operational

environment, the interaction between vehicles and infrastructure and the use of certain services depend on the individual traffic situation.

The criteria used in the multicriteria analysis and the results of the prioritisation of services obtained based on the assessment may include dependencies and risks that, if realised, may significantly affect the implementation of the services. In other words, they are events that cannot be taken into account in the multicriteria analysis. Below is an assessment of events, from the viewpoint of the criteria areas used in this study, that could have a significant impact on the implementation of C-ITS services in Europe and Finland. These events and their impacts were highlighted in the interviews conducted in this study as well as in the steering and expert groups. It should be noted that this list describes some of the events identified in this study and their impacts, but previously unidentified events and consequences may also occur. The assessment also does not take a stance on the likelihood of the events, but rather only on the impacts estimated to be significant.

- The *societal* impacts include risks related to national and political decision-making. The currently prepared European legislation on C-ITS services will affect the way different services are implemented, their future prevalence and coverage, and, consequently, their societal impacts.
- Factors impacting *user needs* include the acceptability of services, i.e. only services approved and used by users will create an impact on the road network. The impacts must also be concerned with solving the right problems.
- The development and deployment of *technology* have a significant impact on the development of C-ITS services. Major technological advancements reflected in areas such as the accelerated deployment of vehicle C-ITS stations would further accelerate the deployment of C-ITS services.
- *Legislative* changes at the international level may limit the implementation of services and related strategies. This could involve a European Commission Delegated Regulation laying down provisions on the implementation of certain C-ITS services or internationally favouring certain technology in legislation. With regard to legislation, service providers perceived data protection risks as a challenge for the implementation of C-ITS services in this study.
- With regard to *costs*, the investments and decisions of vehicle manufacturers, service providers and the public sector on the deployed C-ITS technologies, architectures and services will significantly affect the implementation solutions in the future. The distribution of the

deployment and maintenance costs between different actors and agreeing on business models may pose challenges and risks.

In conclusion, it can be noted that the results of the prioritisation scores in the multicriteria analysis on C-ITS services in this study have moderate reliability and reproducibility. The reliability and, further, validity are undermined by the use of a linear multicriteria analysis model, which is also partly based on subjective estimates, to assess a non-linear C-ITS environment. These assessments were validated by the steering group, the group of reference countries and a separate validation workshop. The prioritisation results primarily reflect the assessment of C-ITS services for the road and street network, conducted at a specific time and under Finnish conditions. The reliability of the study results is improved by qualitative and strategic analysis of the scoring results, which took into account the needs and problems of users and the strategic background, current status and cooperation of European service packages. In other words, the scoring results of the multicriteria analysis of C-ITS services do not, as such and on their own, serve as the recommended outcomes. The report comprehensively presents the criteria, emphases and priorities of the multicriteria analysis as a part of the results, which increases the transparency of the results of the study.

7.4 Additional knowledge and risk management required by implementation

The implementation of C-ITS services still requires a lot of additional knowledge, as there is no experience of large-scale implementations built on the mobile phone network.

The key is to identify the reliability of existing information that is also shared with C-ITS services, the adequacy of its quality and any related shortcomings. In addition, the best cost-effective means of improving the quality of the data transmitted by C-ITS services to an adequate level must be investigated. For example, is it possible to avoid the equipment of road works and vehicles with hybrid C-ITS stations that share real-time location data, which causes major additional costs? Can similar information be obtained from contractors' own fleet monitoring systems without significant additional costs and contractual changes?

The implementation of C-ITS services involves uncertainties that cannot be fully managed. Insufficient knowledge can be compensated and the risks presented in the previous chapter can be limited by measures such as the following, which were also included in the proposal on national prioritisation:

- Experimenting and implementing services through iterations in a dynamic real-life environment in cooperation with market players,

which allows, for example, testing the impacts of the services and business models in practice.

- Limiting the magnitude of a service experiment or implementation to a small scale and progressing in stages.
- Implementing services that have been jointly introduced in Europe and that have been previously implemented nationally in intelligent transport and found to work well and be preferred by users.
- Avoiding any technological choices that would overly constrain or limit the use of solutions available on the market, i.e. following a technology neutrality principle.
- Identifying and preparing for risks, for example, by mitigating their impact when they materialise.

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Appendix 1 C-Roads Platform (2024) C-ITS services (version 2.2.1)

C-ITS service and service use cases	Interchange	Source
In-Vehicle Signage (IVS)		
Traffic Signs (IVS-TS)	I2V	C-Roads
Free Text (IVS-FT)	I2V	C-Roads
Smart Routing (IVS-SM)	I2V	C-Roads
Hazardous Locations Notification (HLN)		
Accident Zone (HLN-AZ)	I2V	C-Roads
Traffic Jam Ahead (HLN-TJA)	I2V	C-Roads
Stationary vehicle (HLN - SV)	I2V	C-Roads
Weather Condition Warning (HLN-WCW)	I2V	C-Roads
Temporarily slippery road (HLN-TSR)	I2V	C-Roads
Animal or person on the road (HLN-APR)	I2V	C-Roads
Obstacle on the road (HLN-OR)	I2V	C-Roads
Emergency or Rescue/Recovery Vehicle in Intervention (HLN-ERVI)	Verv2V	C-Roads
Emergency or Prioritized Vehicle Approaching (HLN-EPVA)	Verv2V	C-Roads
Railway Level Crossing (HLN-RLX)	I2V	C-Roads
Unsecured Blockage of a Road (HLN-UBR)	I2V	C-Roads
Alert Wrong Way Driving (HLN-AWWD)	I2V	C-Roads
Public Transport Vehicle Crossing (HLN-PTVC)	Vpt2V	C-Roads
Public Transport Vehicle at a Stop (HLN-PTVS)	Vpt2V	C-Roads
Road Works Warning (RWW)		
Lane closure (and other restrictions) (RWW-LC)	I2V	C-Roads
Road Closure (RWW – RC)	I2V	C-Roads
Road Works Mobile (RWW-RM)	I2V	C-Roads
Winter Maintenance (RWW-WM)	Vro2V	C-Roads
Signalized Intersections (SI)		
Signal Phase and Timing Information (SI-SPTI)	I2V	C-Roads
Green Light Optimal Speed Advisory (SI-GLOSA)	I2V	C-Roads
Imminent Signal Violation Warning (SI-ISVW)	I2V	C-Roads
Traffic Light Prioritisation (SI-TLP)	I2V, V2I	C-Roads
Emergency Vehicle Priority (SI-EVP)	I2V, V2I	C-Roads
Toll Station Crossing (SI-TSC)	I2V	C-Roads
Automated Vehicle Guidance (AVG)		
SAE Level Guidance (AVG-SAELG)	I2V	C-Roads
Platoon Support Information (AVG-PSI)	I2V	C-Roads
Topology Information (TI)		
Toll Station Approaching (TI-TSA)	I2V	C-Roads
Collective Perception (CP)		
Collective Perception on Motorways (CP-MW)	I2V	C-Roads
Collective Perception on Urban/Interurban Intersections (CP-UI)	I2V	C-Roads
Points of Interest (POI)		
Parking Availability (POI-PA)	V2I	C-Roads
Probe Vehicle Data (PVD)		
Vehicle Data Collection (PVD-VDC)	V2I	C-Roads
Event Data Collection (PVD-EDC)	V2I	C-Roads

Appendix 2 C-ITS Platform (2016) C-ITS services and their descriptions

Abbreviation	Name of C-ITS service	Bundle
EBL-1	Emergency electronic brake light	1
EVA-1	Emergency vehicle approaching	1
SSV-1	Slow or stationary vehicle(s) warning	1
TJW-1	Traffic jam ahead warning	1
HLN-1	Hazardous location notification	1
RWW-2	Roadworks warning	2
WTC-2	Weather conditions	2
VSGN-2	In-vehicle signage	2
VSPD-2	In-vehicle speed limits	2
PVD-2	Probe vehicle data	2
SWD-2	Shockwave damping	2
GLOSA-3	Green Light Optimal Speed Advisory/Time to Green (GLOSA/TTG)	3
SigV-3	Signal violation / Intersection Safety	3
TSP-3	Traffic signal priority request by designated vehicles	3
iFuel-4	Information on alternative fuelled vehicle charging and fuelling stations	4
Pinfo-4	On-street parking information and management	4
PMang-4	Off-street parking information and management	4
P&Ride-4	Park & Ride information	4
SmartR-5	Traffic information & Smart routing	5
LZM-6	Loading zone management	6
VRU-7	Vulnerable road user protection (pedestrians and cyclists)	7
CCRW-8	Cooperative collision risk warning	8
MCA-8	Motorcycle approaching indication	8
WWD-9	Wrong way driving warning	9

C-ITS Platform (2016) C-ITS service descriptions.

C-ITS service	Service description
Emergency brake light	This use case occurs when any vehicle abruptly slows down, it switches on emergency electronic brake lights. The application warns the local followers, in due time, so they can adopt their speed to avoid collision with the vehicle.
Emergency vehicle approaching	This system uses information provided by the emergency vehicle to help the driver on how to clear the road even when the siren and light bar may not yet be audible or visible.
Road works warning	A service whereby the road operator can communicate with drivers through I2V communication about road works, restrictions and instructions.
Slow or stationary vehicle(s)	A slow/stationary vehicle can signal its presence to other vehicles. This improves traffic fluidity by encouraging other vehicles to take an alternative route

Traffic jam ahead warning	A Self-Organising Traffic Information System (SOTIS) uses Car-2-Car Communication to collect information on the local traffic situation and this information is exchanged between vehicles by wireless ad hoc communication
Weather conditions	The use case refers to increasing traffic safety by informing drivers about critical weather conditions ahead especially where the danger can hardly be visually perceived
Green Light Optimal Speed Advisory (GLOSA)	Traffic lights are connected to a roadside unit. Via this connection, information can be broadcast 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.
In-vehicle signage	Via V2I communication, information on relevant road signs is given 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.
In-vehicle speed limits	Roadside units at key points along roads can broadcast information to drivers about speed limits.
Probe vehicle data: CAM aggregation	Also known as Floating Car Data (FCD), PVD is data generated by vehicles. Contains vehicle positional information, time stamp and motion. Driver actions e.g. steering, braking, flat tyre, windscreen wiper status, air bag status, weather and road surface conditions can also be transmitted. Probe data is used to manage traffic flows, maintain roads and to alert users in hot spots, where the danger of accidents accumulates.
Shockwave Damping (also has other names, falls under the general ETSI category “local hazard warning”)	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.
Signal violation / Intersection Safety	Also known as the Red Light Violation Warning (RLVW), this service's primary objective is to reduce the number and severity of collisions at signalised intersections. Drivers are 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.
Traffic signal priority request by designated vehicles	Different levels of priority can be applied, e.g. extension or termination of current phase to switch to the required phase. What level of green priority is appropriate depends on the vehicle type (e.g. HGV or emergency vehicle) and status (e.g. public transport vehicle on-time or behind schedule).
Information on fuelling & charging stations for alternative fuel vehicles	Broadcasts charge point availability, allowing users to book charging point time windows and to plan routes with available charge points on the way. May also include eBilling information.
Off street parking information	Feeds space availability to interested vehicles.
On street parking management and information	Feeds space availability to interested vehicles.

Park & Ride information	Feeds Park and Ride space availability to the vehicle, allowing them to determine whether to use the facility and allowing maximum utilisation from the perspective of the operator. This improves overall network efficiency and has environmental benefits.
Traffic information & Smart routing	Improve traffic flow management by optimizing traffic lights and speed limits and by offering re-routing suggestions based on real-time traffic jam alerts.
Vulnerable Road user protection	The system improves the safety via protection of road users outside the vehicle such as pedestrians, cyclists and other vehicles. The system takes the driver's place in case the driver does not brake at all or not sufficiently. Pedestrians are detected within a distance of 40 meters.
Loading zone management	To support the driver, fleet manager and road operator in the booking, monitoring and management of the urban parking zones for freight driver activities. The driver/fleet operator can book in advance an urban loading bay specifying the delivery mission, the planned delivery time, the loading/unloading time required, the vehicle type, any flexibility (e.g. ±15 mins) in the delivery time and the estimated time to reach the parking zone (interaction with traffic management). The fleet operator can optimize delivery times, reduce driver stress and anticipate congestion problems. The road operator can optimize the management of loading zones through better knowledge of the delivery time period and duration.
Cooperative Collision Risk Warning	Detection of a turning, crossing or merging collision risk by a roadside ITS station. Informs the user if a collision is likely with a vehicle (which may be obscured) by taking location data from a RSU in direct line of sight with both parties.
Motorcycle Approaching Indication	Informs the driver of a passing, or an about to pass, motorcycle. Assists with blind spots.

Appendix 3 5GAA C-V2X use cases (2023)

5GAA C-V2X use cases per category (2023)	C-V2X data exchange	Source
Safety		
Cross-Traffic Left-Turn Assist	V2V	5GAA (vol. I)
Intersection Movement Assist	V2V	5GAA (vol. I)
Emergency Brake Warning	V2V	5GAA (vol. I)
Traffic Jam Warning and Route Information	V2V, I2V	5GAA (vol. I)
Real-Time Situational Awareness and High-Definition Maps: Hazardous Location Warning	V2V, I2V	5GAA (vol. I)
Cooperative Lane Change (CLC) of Automated Vehicles: Lane Change Warning	V2V	5GAA (vol. I)
Vulnerable Road User	V2V, I2V, V2I and/or V2P/P2V	5GAA (vol. I)
Cooperative Traffic Gap	V2V	5GAA (vol. II)
Interactive VRU Crossing	P2V	5GAA (vol. II)
Cooperative Adaptive Cruise Control (CACC)	V2V	5GAA (vol. III)
Vehicle Operations Management		
Software Update	I2V, N2V, V2V, private C-V2X capability/RSU	5GAA (vol. I)
Vehicle Health Monitoring	V2I and I2V	5GAA (vol. I)
Software Update of Reconfigurable Radio System	I2V	5GAA (vol. II)
Advanced Driving Assistance		
High Definition Sensor Sharing	V2V	5GAA (vol. I)
See-Through for Passing	V2V	5GAA (vol. I)
Convenience		
Automated Valet Parking - Joint Authentication and Proof of Localisation	V2I / I2V	5GAA (vol. II)
Automated Valet Parking (Wake Up)	I2V	5GAA (vol. II)
Awareness Confirmation	V2X	5GAA (vol. II)
Cooperative Curbside Management	V2X	5GAA (vol. II)
Cooperative Lateral Parking	V2X	5GAA (vol. II)
In-Vehicle Entertainment (IVE) - High-Definition Content Delivery, On-line Gaming and Virtual Reality	I2V / V2I	5GAA (vol. II)
Obstructed View Assist	V2X	5GAA (vol. II)
Vehicle Decision Assist	V2V	5GAA (vol. II)
Autonomous/Automated Driving		
Automated Intersection Crossing	I2V	5GAA (vol. II)
Autonomous Vehicle Disengagement Report	V2I, V2V, I2V	5GAA (vol. II)
Cooperative Lane Merge	V2V	5GAA (vol. II)
Cooperative Manoeuvres of Autonomous Vehicles for Emergency Situations	V2V	5GAA (vol. II)
Coordinated, Cooperative Driving Manoeuvre	V2X	5GAA (vol. II)
Data collection and sharing for HD Maps	I2V, V2I	5GAA (vol. II)
Infrastructure Assisted Environment Perception	I2V	5GAA (vol. II)
Infrastructure-Based Tele-Operated Driving	V2I, I2V	5GAA (vol. II)
Remote Automated Driving Cancellation (RADC)	I2V, V2I	5GAA (vol. II)
Tele-Operated Driving	V2I, I2V	5GAA (vol. II)
Tele-Operated Driving Support	V2I, I2V	5GAA (vol. II)
Tele-Operated Driving for Automated Parking	V2I, I2V	5GAA (vol. II)
Hazard information and road event collection for AVs	V2X	5GAA (vol. II)
Data sharing of dynamic objects	V2X	5GAA (vol. III)
Non-analyzed Sensor Signal Sharing	V2X	5GAA (vol. III)
Automated Valet Parking (AVP)	V2I, I2V	5GAA (vol. III)
Platooning		
Vehicles Platooning in Steady State	V2V	
Traffic Efficiency and Environmental Friendliness		
Speed Harmonisation	I2V	5GAA (vol. I)
Bus Lane Sharing Request	V2I, I2V	5GAA (vol. II)
Bus Lane Sharing Revocation	I2V	5GAA (vol. II)
Continuous Traffic Flow via Green Lights Coordination	V2I, I2V	5GAA (vol. II)
Group Start	I2V	5GAA (vol. II)
Society and Community		
Accident Report	V2I	5GAA (vol. II)
Patient Transport Monitoring	V2I	5GAA (vol. II)

Appendix 4 CAR 2 CAR Communication Consortium Basic System Profile use cases (2015)

CAR 2 CAR Communication Consortium Basic System Profile use cases (v1.1.0) (2015)	Data ex-change	Source
Emergency Vehicle Warning	V2V	C2C-CC BSP v1.1.0
Dangerous Situation	V2V	C2C-CC BSP v1.1.0
- Emergency Brake Light	V2V	C2C-CC BSP v1.1.0
- Pre-Crash	V2V	C2C-CC BSP v1.1.0
- Automatic Emergency Breaking	V2V	C2C-CC BSP v1.1.0
Stationary Vehicle Warning, V2X Rescue Signal V3.2.0	V2V	C2C-CC BSP v1.1.0
Traffic Jam Ahead Warning V3.3.0	V2V	C2C-CC BSP v1.1.0
Collision Risk (Exchange of IRCs) V3.2.0	V2V	C2C-CC BSP v1.1.0
Adverse Weather Conditions	V2V	C2C-CC BSP v1.1.0
In-Vehicle Signage V1.0	I2V	C2C-CC BSP v1.1.0
Green Light Optimal Speed Advisory TBD	I2V	C2C-CC BSP v1.1.0
Road Work Warning V2.0	I2V	C2C-CC BSP v1.1.0
Probe Traffic Data TBD	I2V	C2C-CC BSP v1.1.0
Hazardous Location Warning	I2V	C2C-CC BSP v1.1.0

Appendix 5 CAR 2 CAR Communication Consortium "beyond Release 1" use cases (2023)

CAR 2 CAR Communication Consortium "beyond Release 1" use cases (Use Cases v1.0) (2023)	Data exchange	Source
Vehicles Coordination		
Cooperative Lane Merging (CLM)	V2V	C2C-CC UCs v.10
Cooperative Transition of Control	V2V	C2C-CC UCs v.10
Advanced Cooperative ACC (String) (AC-ACC S)	V2V	C2C-CC UCs v.10
Intersection Crossing Assist		
Automated Green Light Optimum Speed Advisory (A-GLOSA)	I2V	C2C-CC UCs v.10
Optimized Traffic Light Information with V2I	V2I	C2C-CC UCs v.10
Automated GLOSA with negotiation	V2I	C2C-CC UCs v.10
Partial and high automation		
Hazardous Location Notification – Vehicle Assistance	V2V, I2V	C2C-CC UCs v.10
Cooperative Adaptive Cruise Control (CACC)	V2V, I2V	C2C-CC UCs v.10
CACC String	V2V, I2V	C2C-CC UCs v.10
Cooperative Automated Emergency Brake System (C-AEBS)	V2V	C2C-CC UCs v.10
Advanced Pre-crash sensing	V2V, I2V	C2C-CC UCs v.10
Advanced warning and information		
Advanced Slow Vehicle Warning (ASVW)	V2V, I2V	C2C-CC UCs v.10
Advanced Intersection Collision Warning (AICW)	V2V, I2V	C2C-CC UCs v.10
Filtering motorcycle	V2V, I2V	C2C-CC UCs v.10
Overtaking motorcycle	V2V	C2C-CC UCs v.10
Overtaking motorcycle and turning vehicle	V2V	C2C-CC UCs v.10
Turning vehicle with PTW in the blind spot	V2V	C2C-CC UCs v.10
VRU Presence Awareness	V2X	C2C-CC UCs v.10
VRU Collision Warning	V2X	C2C-CC UCs v.10
VRU Brake or Steering Intervention	V2X	C2C-CC UCs v.10
Agriculture specific use cases		
Task data exchange	P2P	C2C-CC UCs v.10
Geo referenced data	P2P	C2C-CC UCs v.10
Agricultural Platooning	V2V	C2C-CC UCs v.10
In field safety	V2V	C2C-CC UCs v.10
Agricultural work awareness	V2V	C2C-CC UCs v.10

Appendix 6 ETSI TR 102 638 – ITS Vehicular Communication Basic Set of Applications Release 2 (2024)

The latest updated publicly available list of applications updated for Release 2. A summary of the services, use cases, service category of objectives and comments is provided in section 6.3 of the publication in Table 1.

ETSI TR 102 638 v2.2.1 (2024-04); Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications;
Partial and high automation
Hazardous Location Notification - Vehicle Assistance Use Case
Cooperative Adaptive Cruise Control (C-ACC) use case
C-ACC string use case
Cooperative Adaptive Emergency Brake System (C-AEBS) use case
Advanced Pre-Crash sensing use case
Cooperative Active Lane Keeping (C-ALK) use case
Cooperative Intelligent Speed Adaptation (C-ISA) use case
Cooperative Tyre Pressure Adjustment System use case
Cooperative Vehicle Energy Critical Situation Assistance use case
Infrastructure support for ADS use case
CCAM augmented perception
Perception of a non-connected vehicle at an intersection use case
Perception of a non-connected stationary vehicle at the high of a slop use case
Advanced non-connected slow vehicle warning use case
V2V/I2V non-connected VRU perception use case
Perception into a tunnel use case
Perception of traffic when merging use case
Vehicles' coordination
Cooperative Lane Merging (CLM) use case
Cooperative Lane Change (CLC) use case
Advanced Cooperative ACC (String) (AC-ACC S) use case
Truck platooning management use case
Toll Plaza Guidance use case
Cooperative transition control use case
Multi-Car Collision avoidance
Advanced signal violation warning use case
Advanced wrong way driving warning use case
Intersection crossing assist
Advanced Intersection Collision Warning (AICW) use case
Not controlled intersection use case
Traffic light-controlled intersection - Priority vehicles management use case
Optimized traffic light information from V2I use case
Automated GLOSA (A-GLOSA) use case
Automated GLOSA with negotiation use case
Railway level crossing use case
Other intersection/area crossing use case
Advanced warning and information, VRU protection
Advanced Slow Vehicle Warning (ASVW) use case
Filtering motorcycle use case
Overtaking motorcycle use case
Overtaking motorcycle and turning vehicle use case
Turning vehicle with PTW in the blind spot use case
VRU presence awareness use case
VRU collision warning use case
VRU brake or steering intervention use case
VRU safety beacon use case
VRU complex interaction use case
Interactive VRU crossing use case
Extended cluster management use case
Dynamic navigation
Detour management use case
Contextual dedicated corridor management

Corridor dedicated to an emergency vehicle, rescue/recovery, prioritized/safety vehicle use case
Active highway corridor for electrical vehicles reloading use case
Corridor dedicated to other priority vehicles use case
Hard Shoulder Running use case
Roadwork warning (long-term) use case
POIs management
Parking Availability Service use case
Parking Booking Service use case
Automated Valet Parking use case
Parking payment service use case
Other POIs use cases
Agricultural specific application
Task data exchange use case
Geo referenced data exchange use case
Agricultural platooning use case
In field safety use case
Agricultural work awareness use case
Integration of C-ITS in Public Warning System
Natural disaster alert use case
Vehicle lawful interception
Operational safety management use case
Stolen vehicle use case
Police interception use case

ETSI TS 103 324 V2.1.1 (2023-06) Intelligent Transport System (ITS); Vehicular Communications; Basic Set of Applications; Collective Perception Service; Release 2.
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