Evaluation and Assessment Plan

Final Version
Working Group 3 – Evaluation and Assessment
May 2018
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<td>F</td>
</tr>
</tbody>
</table>
# Table of Contents

Table of Contents .................................................................................................................. 2
List of Figures .......................................................................................................................... 4
List of Tables ............................................................................................................................ 4

1. Introduction ......................................................................................................................... 5
   - Scope of the document ..................................................................................................... 5
   - Milestones to be fulfilled by Working Group 3 .............................................................. 6
   - Future activities of C-Roads Working Group 3 ............................................................. 6
   - Glossary ......................................................................................................................... 7

2. Plan structure ....................................................................................................................... 7


4. Technical Evaluation .......................................................................................................... 11
   - General Approach ......................................................................................................... 11
   - Evaluation criteria .......................................................................................................... 12
     - Service and application ................................................................................................. 12
     - Technical Functionality and Performance ..................................................................... 14
   - Best practices for logging data ......................................................................................... 15

5. User Acceptance ................................................................................................................. 16
   - General Approach ......................................................................................................... 16
   - Preparing the research approach ..................................................................................... 17
     - Considering contextual aspects ..................................................................................... 17
     - Frequency of measuring a priori acceptability, acceptance and appropriation .......... 18
     - Defining topics that are part of the survey .................................................................... 18
     - Combining survey data with logged data ...................................................................... 18
   - Detailed description of acceptance indicators ............................................................... 19
     - General (social) information ......................................................................................... 19
     - General service information (and expectations) ............................................................ 21
     - Specific Questions, related to the use cases ................................................................. 22

6. Impacts Assessment ............................................................................................................. 24
   - Information gathering during C-ITS Pilots ...................................................................... 24
     - Evaluation of C-ITS impact in relation to baseline development .................................. 24
     - Evaluation of differences between C-ITS- and non-C-ITS-related traffic developments .. 25
   - General Approach ......................................................................................................... 25
   - Day 1 Service: Road Works Warning .............................................................................. 28
   - Use Case: Closure of a lane ............................................................................................. 28
     - Safety ............................................................................................................................ 28
     - Traffic Efficiency ......................................................................................................... 30
     - Environment .................................................................................................................. 32
Day 1 Service: In Vehicle Signage ................................................................. 35
Use Case: In-vehicle signage dynamic speed limit information ........................ 35
   Safety ........................................................................................................ 35
   Traffic Efficiency ...................................................................................... 36
   Environment ............................................................................................. 37
Day 1 Service: Other Hazardous Locations Notification ................................. 40
All Use Cases (with punctual events – “weather conditions” and “temporary slippery road – black ice or water” not considered at this stage) ............................................................... 40
   Safety ........................................................................................................ 40
   Traffic Efficiency ...................................................................................... 42
   Environment ............................................................................................. 44
Day 1 Service: Traffic Light Maneuvers  Road and Lane Topology .................... 47
Use Case: GLOSA (Green light optimal speed advisory) .................................. 47
   Safety ........................................................................................................ 47
   Traffic Efficiency ...................................................................................... 48
   Environment ............................................................................................. 50
Annex 1: Examples of inventory tool ............................................................... 53
Annex 2: Examples of research questions as provided by the C-Road members .. 57
Annex 3: User Acceptance Theoretical background ........................................ 60
   Common definitions and differences between public acceptance and user acceptance .............................. 60
   Theories and approaches in User Acceptance ........................................... 60
   Inventory and main indicators in Acceptance/Acceptability research .......... 63
   General indicators ................................................................................... 64
   Device-specific indicators ...................................................................... 65
   References ............................................................................................... 66
Annex 4: User Acceptance evaluation - starting from end-user needs .................. 70
List of Figures
Figure 1 - Scope of impact assessment incl. socio-economic impact assessment (FOT-Net 2017) ............. 9

List of Tables
Table 1 - Involvement of the Pilots in the Impact Areas ................................................................. 6
Table 2 - Mapping of studied impacts to impact areas ........................................................................ 10
Table 3 - RWW - Relation between Sub Research Question for Safety and collected Data .................. 29
Table 4 - RWW - Relation between Field test indicator KPI for Safety and collected Data ....................... 30
Table 5 - RWW - Relation between Sub Research Question for Traffic Efficiency and collected Data .... 31
Table 6 - RWW - Relation between Field test indicator KPI for Traffic Efficiency and collected Data ....... 32
Table 7 - RWW - Relation between Sub Research Question for Environment and collected Data ........... 33
Table 8 - RWW - Relation between Field test indicator KPI for Environment and collected Data ............ 34
Table 9 - IVS - Relation between Sub Research Question for Safety and collected Data ....................... 35
Table 10 - IVS - Relation between Field test indicator KPI for Safety and collected Data ....................... 36
Table 11 - IVS - Relation between Sub Research Question for Traffic Efficiency and collected Data ......... 37
Table 12 - IVS - Relation between Field test indicator KPI for Traffic Efficiency and collected Data ......... 37
Table 13 - IVS - Relation between Sub Research Question for Environment and collected Data .............. 38
Table 14 - IVS - Relation between Field test indicator KPI for Environment and collected Data .............. 39
Table 15 - OHLN - Relation between Sub Research Question for Safety and collected Data ................... 41
Table 16 - OHLN - Relation between Field test indicator KPI for Safety and collected Data .................... 42
Table 17 - OHLN - Relation between Sub Research Question for Traffic Efficiency and collected Data ...... 43
Table 18 - OHLN - Relation between Field test indicator KPI for Traffic Efficiency and collected Data ...... 44
Table 19 - OHLN - Relation between Sub Research Question for Environment and collected Data .......... 45
Table 20 - OHLN - Relation between Field test indicator KPI for Environment and collected Data .......... 45
Table 21 - TLM-RLT - Relation between Sub Research Question for Safety and collected Data ............... 48
Table 22 - TLM-RLT - Relation between Field test indicator KPI for Safety and collected Data ............... 48
Table 23 - TLM-RLT - Relation between Sub Research Question for Traffic Efficiency and collected Data .. 49
Table 24 - TLM-RLT - Relation between Field test indicator KPI for Traffic Efficiency and collected Data ... 50
Table 25 - TLM-RLT - Relation between Sub Research Question for Environment and collected Data ....... 51
Table 26 - TLM-RLT - Relation between Field test indicator KPI for Environment and collected Data ....... 51
1. Introduction

Scope of the document

This “Evaluation and Assessment Plan” fulfills the first milestone (M15) for C-Roads Working Group 3 (WG3) – Evaluation and Assessment – and describes the currently available documentation and assessment dimensions in C-Roads in regard to evaluation, Pilots and policy objectives that need to be targeted in the pilot phase of C-Roads.

Within C-Roads, Pilots will evaluate the impacts of Day 1 C-ITS Services and Use Cases implemented during the different Pilot Tests with respect of the following impact areas:

- User Acceptance
- Safety
- Traffic efficiency
- Environment
- Organizational

The purpose of the Plan is to create the common basis for evaluation and assessment of the C-Roads Pilots. However, the single aspects of assessment, reflected in the chapters of the report, will be defined and decided by the individual pilot implementation in order to be able to fulfill contract obligations and contribute to the assessment of C-ITS introduction on European roads.

The impact areas mentioned above should be considered as mandatory for each Pilot. This means that Pilot Tests must face, when evaluating, each impact area if possible; otherwise they should explain why this is not investigated (e.g. not applicable, not contract obligation). This allows a common framework for C-Roads analysis.

It should be noted that Service Harmonization, as described in WG2 - Task Force 2, with the agreed specifications (containing a functional description of the single C-ITS Services and Use Cases and the communication between C-ITS stations based on standard messages, e.g. CAM or DENM) is a required basis for the service evaluation.

Some documents of the service specifications are currently not completely finished and the inclusion of their additional output should be taken into consideration at a later point.

This plan is the result of a wide series of inputs from all different WG3 Members based on their contributions to projects, evaluation and impact assessment tasks in relation to ITS services.

The Working Group responsible for the fulfillment of this task consists of Partners from all core Member States, plus a significant number of supporting persons¹.

Table 1 below gives an overview of the impact areas that will be faced by the different Pilot Studies, as planned in March 2018.

¹ https://www.c-roads.eu/nextcloud/index.php/s/LNKHnhQ8BuShJqa
### Table 1 - Involvement of the Pilots in the Impact Areas

<table>
<thead>
<tr>
<th>Pilot</th>
<th>Impact Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Functional Validation</td>
</tr>
<tr>
<td>I</td>
<td>+</td>
</tr>
<tr>
<td>A</td>
<td>++</td>
</tr>
<tr>
<td>UK</td>
<td>++</td>
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<td>++</td>
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<tr>
<td>E</td>
<td>++</td>
</tr>
<tr>
<td>B/FL</td>
<td>++</td>
</tr>
<tr>
<td>B/W</td>
<td>+</td>
</tr>
<tr>
<td>D</td>
<td>++</td>
</tr>
<tr>
<td>F</td>
<td>++</td>
</tr>
<tr>
<td>NordicWay</td>
<td>++</td>
</tr>
<tr>
<td>NordicWay2</td>
<td>+</td>
</tr>
<tr>
<td>P</td>
<td>+</td>
</tr>
<tr>
<td>SLO</td>
<td>+</td>
</tr>
</tbody>
</table>

Table legend:
- “++”: Primary evaluation area for the Pilot.
  It implies a major effort and involvement in the evaluation of the impact area.
- “+”: Secondary evaluation area for the Pilot.
  It implies a minor effort and involvement in the evaluation of the impact area.
- “(+)”: Further internal investigation needed to confirm the symbol reported.
- Empty cell: impact area not investigated by the Pilot.

### Milestones to be fulfilled by Working Group 3

<table>
<thead>
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<th>Number</th>
<th>Date</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>M15</td>
<td>Q1/2018</td>
<td>Evaluation and assessment plan</td>
</tr>
<tr>
<td>M32</td>
<td>Q4/2020</td>
<td>Detailed evaluation report</td>
</tr>
</tbody>
</table>

### Future activities of C-Roads Working Group 3

Next steps of WG3 activities will focus on the definition of a common report template in order to facilitate an overview of the evaluation results across different pilots. This document remains open to new inputs and specification arising from WG2 activities. The evaluation approach for other Day 1 – Services and Use Cases will be further developed and presented in new releases of this document. A further deepening for the assessment of Key Performance Indicators on mobility and economic impacts, as described in the next chapters, will be provided.

\(^2\) Organizational impacts are related to management of road infrastructures by road operators. Further details regarding this topic will be analyzed by WG3 in its next activities.
Glossary

Following terminology is used in this deliverable. Any further discussions and considerations are provided in the referenced sections.

<table>
<thead>
<tr>
<th>Term</th>
<th>Interpretation for application in WG3</th>
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<tbody>
<tr>
<td>Evaluation</td>
<td>Systematic and objective process of testing a system under different events and situations and measuring the (key) performance indicators. The objective is to compare the indicator values against standards, metrics or benchmarks or selected baseline.</td>
</tr>
<tr>
<td>Assessment</td>
<td>Process of understanding and qualifying the functionality and behavior of the tested and evaluated systems and behavior of their users in relation to the impact areas. The objective is to improve the organizational, deployment and operational aspects and the specifications and to understand the implications of the service use.</td>
</tr>
<tr>
<td>Benchmark</td>
<td>Test protocol for measuring the functionality and performance of a service or system, and the minimum requirements as a reference point for accepting the service or system as successful and sufficiently conform and interoperable.</td>
</tr>
<tr>
<td>Interoperability</td>
<td>Ability of a communication unit, application or system to operate C-ITS services with those from different make or type, service or Pilot or administrative regions, without any (re)configuration or action.</td>
</tr>
<tr>
<td>User Acceptance</td>
<td>User acceptance is defined as a phenomenon that reflects the extent to which potential users are willing to use a certain system. User acceptance will be influenced by different parameters like usability, usefulness, satisfaction, etc.</td>
</tr>
<tr>
<td>C-ITS “Day 1 - Services”</td>
<td>Set of C-ITS services based on the implementation of standard messages (CAM, DENM, IVI and TLM &amp; RLT) and mentioned in the phase one report of the EU C-ITS platform and further developed in detail in the C-Roads document releases of the Infrastructure communication profile. (release 1.0 from 14.09.2017 – available at <a href="https://www.c-roads.eu/fileadmin/user_upload/media/Dokumente/C-Roads-publishes_C-ITS_interface_specifications.pdf">https://www.c-roads.eu/fileadmin/user_upload/media/Dokumente/C-Roads-publishes_C-ITS_interface_specifications.pdf</a>)</td>
</tr>
</tbody>
</table>

2. Plan structure

After the introductive part (Chapter 1) and a brief state of the art (Chapter 3), Chapter 4 describes Technical Evaluation of C-ITS related services. This covers first the evaluation of the technical functionality and performance of services and the exchanges between Pilots to describe the special validation approach within C-Roads, which needs to take into account the requirement of a European-wide harmonization approach. This means that evaluation needs to cover cross-border interoperability, processes between different Pilots, public and private C-ITS entities and service providers and those between different Stakeholders and C-ITS network operators.

After this first technical step as a basis for Pilots, this Plan covers the various aspects of User Acceptance in Chapter 5, where general information about user acceptance evaluation in ITS services, but especially in C-ITS is covered. The service delivery to end users may consist of contributions from many stakeholders with the consequence that the overall procedure for the
evaluation of user acceptance can be complex and depends from many factors. Additionally, social contexts in many transport environments, and - especially - service information concerning usability, usefulness of C-ITS services, user satisfaction are part of the assessment of user acceptance in C-ITS.

In Chapter 6 of the Plan the main areas of evaluation for C-ITS services are considered and covers the following policy objectives as impact areas in the Pilots:

- Road Safety
- Traffic efficiency
- Environment

These three areas of investigation are the main topic of C-ITS Impact Assessment, which needs to be addressed in this Plan and covers a defined approach how to achieve this for the “Day 1 C-ITS service list”, based on service examples from the release 1.0 in C-Roads, released in September 2017 and publicly available, for every of the four subgroups of the Day 1 - Services with one Use Case explicitly defined per group. These Groups are RWW – Road Works Warning, IVS – In Vehicle Signage, OHLN – Other Hazardous Location Notification and TLM & RLT – Traffic Lane Manoeuvre & Road and Lane Topology (the standard message used at urban intersections and in previous C-ITS standards called SPAT/MAP).

The Plan suggests the data to be collected during the pilot phase of C-Roads for the service evaluation of the four mentioned service groups and formulates links between these data and research questions. With these steps defined in the single chapters of the Plan the Pilots get a sound guideline to assess and evaluate the main impacts of C-ITS service introduction and link the various aspects of this exercise to each other and use the insight of the pilot phase for the following next steps of C-ITS market introduction in the EU.

The single process steps and the comparison within and between Pilots in C-Roads have the possibility to support this development and check some critical aspects in the domain of cooperative, connected and automated mobility.
3. Status of evaluation methods for ITS/C-ITS

Impact assessment serves regularly as an integrated element of technology development projects. The role of impact assessment in Field Operational Tests (FOTs) and Pilots is pretty much obvious and crucial. To that end, existing practice has been arranged a decade ago in the FESTA Handbook which provides a framework how to execute FOTs in general. The most recent version of the FESTA handbook is Version 7 (FOT-Net 2017). Impact assessment is an integrated step in this methodology.

The methodological framework for impact assessment is provided in Figure 1. Impact assessment usually refers to the macro dimension, i.e. it refers to aggregated impacts on (road) safety, mobility and environmental performance. It should be noted that these impacts are triggered by (behavioral) responses and changes to the ITS service provision that take place on a micro level, i.e. on the level of individual drivers. How to deal with these changes, how to upscale from individual data to aggregated impacts, is also taken care for within the FESTA Handbook. These are however preceding steps in the V-model where impact assessment and socio-economics typically represent the last steps, i.e. the upper right of the V-model. It should be also noted that - in a subsequent step (impact appraisal) - impacts can be transformed to monetary values by making use of cost-unit rates per fatality, injury, vehicle hour lost etc. When the benefits have been calculated in such a way, information on costs can help to derive results in an economic dimension (e.g. benefit-cost ratio, net present value, internal rate of return).

![Figure 1 - Scope of impact assessment incl. socio-economic impact assessment (FOT-Net 2017)](image-url)
The impact assessment framework has been practiced by a number of Field Operational Tests and also the first Pilots for deployment of C-ITS services (see Berndt et al. 2016 for an overview of initiatives). The impact assessment which has been prepared in the context of the C-ITS Platform (Ricardo 2016) is also included because of its general importance for the deployment of Day 1 C-ITS Services. Table 2 below maps a selection of these impact assessments against the included impact dimensions.

Table 2 - Mapping of studied impacts to impact areas

<table>
<thead>
<tr>
<th>FOT / Pilot</th>
<th>Publication year of results</th>
<th>Safety Impact</th>
<th>Mobility Impact</th>
<th>Environmental Impact</th>
<th>Socio-economic Impact</th>
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<tr>
<td>DRIVE C2X</td>
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<td>X</td>
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<td>Ricardo</td>
<td>2016</td>
<td>X</td>
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<td>X</td>
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<tr>
<td>NordicWay</td>
<td>2017</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
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</table>
4. Technical Evaluation

General Approach

The main objective of C-Roads is to ensure interoperability across the borders of member states and the (inter) national C-ITS Pilot projects. The borders of pilot sites and projects are not limited to the borders between member states and also include borders between of road operators, services providers, communication networks and in-vehicle services and devices from different suppliers. Interoperability can be evaluated from a technical perspective, as well as from user acceptance and impact perspectives as addressed in the next sections.

From a technical perspective, interoperability and compliance to functional and technical specifications are verified and validated before piloting. During piloting, technical evaluation addresses following objectives:

- Reliability of C-ITS systems and applications in on-board devices, road side and central units, and cloud services.
- Interoperability and compliance to functional and technical specifications under all real-life situations and conditions experienced during piloting and provide feedback to refine the technical and functional specifications.
- Detect any technical flaws or failures and provide feedback to improve the technical maturity of products.
- Filter out events with technical issues to avoid technical bias in the evaluation and assessment of user acceptance and impact.

As a prelude to the following sections on user acceptance and impact assessment, following examples of assumptions on validated technology motivate the necessity of a general approach to technical evaluation throughout piloting:

- Correctness of advice to drivers
  - Check that warnings and information are still valid and are not outdated or expired
  - Warnings and information are real; i.e. warnings or information exist on the road and false detections are filtered out.
- Accuracy of advice to drivers
  - Accuracy of the timing and location of advice relative to the events such as traffic jams, speed limits and lane closures.
- Availability of service to drivers
  - Availability is measured both in time and geographical areas.
- Measure effects of user behavior
  - Location and magnitude of speed adaptation, as accelerations and decelerations or as braking and throttle
  - Location and aggressiveness of lane changes and steering
  - Surrogate safety measures such as gap time and time-to-collision.
- Measure reference points to compare effects in user behavior
  - Location and distance to events such as a traffic sign, Variable Message Signs, lane closures, service vehicles, obstacles or traffic jams
  - Location of presentation on HMI and distance to these events

The general approach to technical evaluation is to collect log data from ITS-Stations and cloud services and evaluate the technical functionality and performance. Evaluation criteria for C-ITS
technology and services are presented in the following section. Best practices for logging communication, positioning, application and HMI events are presented in the next section.

**Evaluation criteria**

The objective of this section is to give examples of relevant technical evaluation criteria for pilot sites. Criteria are provided as hypotheses on the functionality and performance of services and equipment, and indicators to test the hypotheses. Metrics for evaluation, benchmarking and validation cannot be set in this stage of development and maturity.

The criteria are organized by research questions at two levels. First validation criteria are defined for pilot readiness of services and applications. These can be regarded as the top-level criteria for validation of readiness for user acceptance and impact assessments. If any technical issues are expected, the validation can be refined to the technical functionality and performance criteria as a second level. Detailed examples and implementations of metrics, data analysis can be found in the documentation of Pilots, such as the InterCor M12 Evaluation Framework (http://intercor-project.eu/).

**Service and application**

How accurate and reliable are the warnings and information presented to drivers?

The following hypotheses can be tested:

- All relevant information provided by a road operator is sent to and received in the in-vehicle application or device.
- All relevant information of new triggers, updates and cancelations is detected by applications, and presented (or revoked) on the HMI on the intended location and on time, e.g. relative to the awareness, detection or relevance areas, or stop line.

These hypotheses can be measured on the following indicators for application performance to present warnings and information on the HMI or at intermediate steps in the architecture:

- Timeliness
- Location accuracy
- Activation ratio or percentage of events

The following types of situations and events should be distinguished in the evaluation of indicators and hypotheses:

- Communication media used, e.g. ITS-G5 or cellular communication
- Communication frequencies used (e.g. repetition rate or polling frequency on end-user device)
- Geographic coverage of a communication network (e.g. communication range of ITS-G5 road side units)
- Different data flow paths from detection to end-user device to distinguish the effects of services from road operators, data and service providers
- Different data flow paths from detection to end-user-device to distinguish the effects of the number of interfaces and borders crossed, and the number of message format conversions.
What is the end-to-end delay of warnings and information presented to drivers?

The end-to-end (E2E) delay is an indicator for the time delay from detection to presentation on the HMI, or any subset of intermediate steps in the architecture.

The situations and events identified for the previous research question should also be distinguished here and can also be raised as hypotheses to affect the E2E delay:
- Communication media (e.g. ITS-G5 or cellular communication) and communication frequencies affect the E2E delay.
- The sequence and performance of services from road operators, data and service providers, as well as the number of interfaces and borders crossed, and the number of message format conversions, affect the E2E delay.

What is the geographical coverage of services?

The following hypotheses can be tested:
- The effective communication range, environmental conditions and deployment strategy of ITS-G5 road side units determine the local geographical coverage of services.
- The geographical coverage and overlap of the networks of cellular communication services, road operators and service operators determine the local geographical coverage of services.
- The geographical coverage of a service affects the effective dissemination, awareness, detection and relevance zones.
- Hybrid communication solutions increase the geographical coverage of services.

The geographical area of communication or HMI events is the indicator to measure the coverage of services.

What are the differences in the interpretation and implementation of specifications?

The following hypotheses can be tested:
- Differences in traffic management and regulations result in differences in the presentation of information and warnings on the HMI.
- Differences in service provisioning and application logic result in differences in the presentation of information and warnings on the HMI.
- Message format conversions result in loss of relevant information in the presentation of information and warnings on the HMI.

Indicators to measure these hypotheses are:
- Differences in HMI events and the information being presented
- Differences in message contents in messages from similar and different format about the same events.
- Differences in the usage of optional and conditional data elements in messages.
- Differences in application triggers and logic

This evaluation, provides the input to determine which differences lead to significant differences in driver behavior and impact. It is therefore recommended to also monitor and evaluate these differences during piloting.
Are services and applications developed for hybrid communication?

The following hypotheses can be tested:

- Road operators provide data via multiple communication channels (e.g. via ITS-G5 Road Side Units and data provisioning services to service providers).
- Road operators provide the same data in similar formats via hybrid communication channels.
- Road operators provide the same data in one or more standard and open data formats.
- End user devices can receive similar data via hybrid communication media (e.g. ITS-G5 and cellular network communication).
- Services and applications on end user devices can provide probe vehicle data in the same format and quality via multiple communication channels.

Indicators to measure these hypotheses are:

- Communication channels and media
- Message formats

Situations to distinguish are the geographical coverage of services and the different data paths from detection to end-used devices.

Are services continued when crossing borders?

Situations for crossing borders can be defined in several ways, including when end-user devices are switching between pilot sites or geographical areas covered by road operators, service providers or communication networks, services.

The general hypothesis is that the services and information provided on the HMI to the end-user are:

- continued seamlessly for any border crossing event
- presented similarly for any similar events on either side of the border.

The indicators and events are the same as above for measuring the accuracy and reliability of the warnings and information presented to drivers, and also to measure the differences in the interpretation and implementation of specifications.

**Technical Functionality and Performance**

Evaluation criteria can be organized by the technology rather than services.

Communication:

The same set of indicators are used for measuring to compare the performance and availability for ITS-G5 and cellular network communication:

- Packet Delivery Ratio (PDR)
- Effective communication range, which is the communication range with a minimum PDR
- Transmission delay between sending and receiving messages
- Repetition frequency
- Update frequency of message contents
Best practices for logging data

Validation and evaluation requires the collection and analysis of log data. Validation and evaluation of cross border services also requires the exchange and sharing of the data and results. This becomes more and more difficult with the variety of log data formats and differences in data quality. The FOT-Net Data network is developing a framework for data sharing (see http://fot-net.eu/Documents/data-sharing-framework/).

Sharing of open formats for logging is needed to harmonize the validations and evaluations and reduce the efforts for the development of tools for logging and data analysis. The following table is intended to collect an overview of open formats for the definition of log data and data quality (metadata) and file formats for collecting the log data. Pilots are encouraged to use and further develop these open formats.

<table>
<thead>
<tr>
<th>Log Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCAP</td>
<td>Open standard format for Packet CAPture, i.e. to capture messages on a communication network. This format is typically used to log and analyze communication performance. See <a href="https://www.tcpdump.org/">https://www.tcpdump.org/</a></td>
</tr>
<tr>
<td>InterCor_CommonLogFormat</td>
<td>Definition of parameters to log on C-ITS communication, applications and HMI. Several file formats are supported (e.g. csv, XML, JSON, SQL). See <a href="http://intercor-project.eu/">http://intercor-project.eu/</a></td>
</tr>
<tr>
<td>Tlog and Ulog from SCOOP@F project</td>
<td>Definition of the parameters to log on C-ITS System for communication, applications and HMI. They are defined in ASN1 format.</td>
</tr>
</tbody>
</table>
5. User Acceptance

General Approach

In the field of ITS, acceptance is defined as a phenomenon that reflects the extent to which potential users are willing to use a certain system. The FESTA Handbook describes acceptance as the degree of approval of a technology by the users. It depends on whether the technology can satisfy the needs and expectations of its users and potential stakeholders. Within the framework of introducing new technologies, acceptance relates to social and individual aspects as well.

It is possible to distinguish a priori acceptability, acceptance and appropriation. A priori acceptability is studied before use, acceptance is studied in first use and appropriation is studied after several weeks or months of use.

Within C-Roads, the different partners were asked to propose their top 5 research questions on user acceptance. In “Annex 2: Examples of research questions as provided by the C-Road members”, a list can be found with the major questions of some countries as an example. Based on the partners’ input the following high-level research questions/topics were derived:

- What information was provided, how often, over what time period, etc.?
- In which way will C-ITS be relevant in the user’s driving (behavior)?
- Does the user understand how and when the system works?
- Does the C-ITS service support the user in driving when using it? Or does it distract the user when driving?
- How easy is the C-ITS service to use?
- How good (reliable, understandable, timely,…) is the information that the user receives?
- How does the service respect users’ integrity (privacy, etc.)?
- Did C-ITS change the driving behavior (in general)?

In FESTA the following indicators on user acceptance are described:

- The observed rate of use of the system or of specific system parts represents an additional indicator for system acceptance and perceived usefulness.
- Perceived system consequences (perception of positive or negative consequences of the system’s use) is another key indicator for system performance: the user expresses his/her impressions and attitudes regarding the potential consequences when using the system, which can be positive as well as negative. These impressions can best be collected via an interview and be exploited in focus groups, which have the advantage of group dynamics that can provide additional information on the subjective norm.
- Motivation (level of motivation/impetus to use the system) should be connected with the indicator Behavioral intention (level of intention to use the system). Both indicators can best be investigated via self-designed questionnaires based on established methodological findings (see Annex 3: User Acceptance Theoretical background).
- The Response to perceived social control/response to perceived societal expectations indicates the impact of perceived social control of the user’s behavior. Indicator is a more sociological one, which should give an indication whether the user feels a social benefit (for example, social recognition) when using the system, or on the contrary, that he/she hesitates to use the system due to fear of social disapproval when using the system. This is referring to social norm and value granted to use of ITS.
- **Usability/level of perceived usability** concerns the aspects of the user's general capacity to interact with the system. For these indicators, a combination of in-depth interviews, focus groups and self-designed questionnaires based on established methodology is recommended.

In the next sections, this high-level approach is made more operational. Based on a variety of researches and methods, discussions with C-Roads partners and their approaches a framework was developed which can be used to construct the surveys or interviews. The main focus of the user acceptance evaluation in C-Roads is obtaining a better understanding on the users’ perceived experiences with the system. Mainly, user acceptance is defined by holding questionnaires or equivalent tools i.e. specific online or mobile applications to provide users’ feedback related to the usage of the evaluated services. The results on the different items will then be compared with the measured change in driver behavior or perceived changes in behavior. The change in behavior will be discussed as part of the KPI on Impact.

When conducting surveys, it is necessary to take into account the General Data Protection Regulation (GDPR). More information can be found on [https://www.eugdpr.org/](https://www.eugdpr.org/).

The described parameters and questions should be considered as guidelines and not as mandatory aspects: within C-Roads, every country has his own research focus (some of them are more interested in technical evaluation, others have more interests in social aspects). Therefore, it was decided to cover as many aspects as possible within user acceptance. Every Pilot can decide for their own which aspects they should take into account. In Annex 3: User Acceptance Theoretical background, the theoretical background has been described, mainly focused on the different models and approaches on user acceptance that are found in literature. This Annex can help Pilots to define the behavioral intentions of the test users.

**Preparing the research approach**

**Considering contextual aspects**

As mentioned before, Acceptance is the user’s evaluation of the system after their first experiences with the system.

Within C-Roads, the user acceptance should mainly focus on the service provided by the C-Roads network, however user acceptance will be influenced by the provided application, HMI and services that will be given to the driver. The application can be different from demonstration project to demonstration project, or differences can occur among C-ITS service/application providers, such as:

- How the information will be displayed: Text, symbols, combination of text and symbols, the overall screen layout and allowed user interactions from the HMI.
- How the information will be built up for the driver: E.g., one C-ITS solution may provide the information 5 km before an incident, while another C-ITS solution may provide the information 2 km before.
- How the basic information will be reported to the driver: Speed limits, traffic signs, warnings, etc.
- How the C-ITS solution is combined with extra warning features.
- The environmental and situational conditions when receiving the messages

All these aspects will influence on the perceived user acceptance. How intervening (informative, advisory warning, or assisting certain services) the messages are and what is the social
acceptance for these messages and their appearing rate may favor acceptance or by the contrary favor the system rejection.

Therefore, it would be good to make an inventory about these different aspects for every relevant use case or group of services in every country. In the “Annex 1: Examples of inventory tool”, an inventory tool is proposed.

**Frequency of measuring a priori acceptability, acceptance and appropriation**

In many ITS projects, a questionnaire on user a priori acceptability, acceptance and appropriation is held before, during and after the trial depending on the research scope of the trial. The questionnaire before can give more insights in the expectations, knowledge, etc. on the service and to know if/or if not, they are already in favor of using C-ITS solutions.

The questionnaire during trial will be focused more on the usage and findings when using C-ITS in different scenario’s. The questionnaire after several weeks of use will be focused on the misuse or abandonment of use.

a) Questions on general C-ITS service
b) Questions related to the specific use-cases:

- Road work warnings
- In Vehicle Signage
- Other Hazardous Locations Notification
- Traffic Light Manoeuvres & Road and Lane Topology

**Defining topics that are part of the survey**

These main topics should be covered in the questionnaire:

- **General (social) information**
  - Social/ID information
  - Information in relation to their driving behavior
  - Information on their knowledge/experience about technology, traffic information and C-ITS

- **General service information (and expectations)**
  - Opinions, attitudes in general on C-ITS and how they influence their acceptance
  - Specific attitudes on C-ITS services in relation to application usage

- **Use case service information**

In the following chapter, it is described what is meant with every aspect or indicator and suggestions are made about what can be asked. Depending on the research setup, scope, etc. these topics/questions can differ or are not relevant.

**Combining survey data with logged data**

After gathering the survey data, it is possible to combine the outcome of the user survey with the logged data, related to the impact assessment. In this way, certain user behavior can be
explained or predicted. Several acceptance models allow the combination or interaction of survey data on user acceptance with measured behavioral data. Most popular models are:

- Theory of planned behavior (TPB)
- Technology acceptance model (TAM)
- Unified Theory of Acceptance and Use of Technology (UTAUT).

Recently, UTAUT has been used more often. A brief description of these models can be found in Annex 3: User Acceptance Theoretical background. Many of the described acceptance indicators in the next section can be used to construct such a model. It should be considered which theory is the most preferable for the research setup, before constructing the survey. This is important for not forgetting certain topics in your survey, or to avoid unnecessary questions, which are not usable in the model. Other relevant aspects that can be considered deal with the organizational dimensions.

**Detailed description of acceptance indicators**

**General (social) information**

These questions are more related to the background factors of the user. These background factors can have an influence on the acceptance and driving behavior with C-ITS. E.g., older drivers could have more difficulties to cope with the new technology. Frequent speeders would not take into account in-vehicle signs messages, etc. Based on different ITS researches, the following topics can be taken into account.

It is suggested to take at least age, annual mileage, professional vs non-professional drivers, and vehicle type into account.

- Additional individual factors
  - Gender
  - Level of education
  - Having children (or not)
  - Income
  - Employment

- Driving behavior
  - Vehicle choice (brand, power, options like cruise control, ACC, etc.)
  - Driving style (as based on driving behavior questionnaire)
    - Maintain speed – exceeding speed limits (in relation to highway, urban area, etc.)
    - Flustered when faced with danger
    - Influence from other drivers
    - Distraction when driving
    - Planning journeys
    - Braking
    - Lane changing
  - Travel behavior
    - Travel mode (pedestrian – bike – public transport – car) in relation to purpose (work – leisure – shopping - ...). These aspects are good to know, if the test-user is a frequent driver or not.
• **Information and knowledge about C-ITS**
  - Knowledge & information on driving options (traditional; already implemented)
    (e.g. Do you know cruise control?)
  - Knowledge & information on navigation and additional information (e.g. Do you know traffic information) Even brands can be named (TomTom, Here, Waze, etc.)
  - Knowledge & information on C-ITS: Describe the service as good as possible; do not use terms like C-ITS, In Vehicle Signage: e.g. a warning/advice on how you should react (slow down, change lane) when reaching road works.

• **Personal and social aims**
  - How users see the use of C-ITS: beneficial for general road safety, environment, etc. or more for their own safety, reducing fine, planning of alternative routes, getting faster at destination, …

• **Social norms**
  - The use of C-ITS will be influenced by:
    - Peers
    - Social pressure
    - Other road users

• **Responsibility awareness**
  - How do the test-drivers think about the level or responsibility for road safety, environment, etc.?
    - Themselves
    - Police
    - Other road users
    - Policy makers

• **Problem perception**
  - Recognition of the drivers that not having in-vehicle information can cause accidents, bad for environment, etc.
  - Noticed driving errors due to use of the system (can only be asked after the test)

It is suggested to use closed questions with Liker-scale (e.g. never 1 – 2 - 3 - 4 – 5 always), except of individual factors and some attitudes to driving behavior).

These questions can be asked only at the beginning of the test. However, it can be relevant to ask some of these topics again at the end of the test-period; some changes could be identified.
General service information (and expectations)

This approach is based on the described theories in acceptance in Annex 3: User Acceptance. Theoretical background. The main impacts for a device as seen from a user point of view were also taken into account.

Perceived efficiency
Setup: questions on C-ITS compared to other services and the effect users think C-ITS will/can have.

General questions:
In the users' opinion, will the use of C-ITS:
- Reduce fuel consumption
- Increase traffic efficiency
- Increase safety
- Avoiding tickets
- Reduce speeding

Is the C-ITS service better than other information services like:
- Radio information
- VMS signs
- Additional navigation information
- Google, Waze, or similar.

Perceived usability
Setup: questions on the usability of the service

General questions:
• How did the user experience the usability of the service?
• What was the workload for the driver?
• How user-friendly was the service?

Perceived usefulness
Setup: questions on how the service support the driving of the user

General questions (based on Vanderlaan-scale):
• How useful was the C-ITS service to support the driver?
• How good was the service?
• How effective was the C-ITS service to support the driver?
• How assisting was the C-ITS service?
• Did it increase alertness of the driver or not?

Perceived Satisfaction
Setup: questions on how satisfied the user is of the service

General questions (based on Vanderlaan-scale):
• How pleasant was it to use the service?
• How nice was the service?
• How likeable was the service?
• How desirable was the service?
NOTE: Usefulness and satisfaction can be measured combined by using the Vanderlaan method.

**Equity**

*Setup:* To define under which circumstances the user would like to have the service

**General questions:**
- How does the user think that privacy, security, etc. of the user will be affected when using C-ITS?

**Affordability/willingness to pay**

*Setup:* Identify what and when the user will pay for the service

**General questions:**
- How much do you want to pay for purchase/use of the C-ITS service?
- Under which financial conditions would you be willing to use the service?

**Specific Questions, related to the use cases**

It is assumed that the questions related to the effectiveness will differ from service to service, therefore, the following general questions are proposed:

**Perceived effectiveness**

*NOTE:* These research questions are formulated so that mainly the service will be evaluated and not necessarily the used device or service provider. This could/should make comparison easier. It is proposed to focus these questions directly on the different use cases instead of asking it in general.

*Setup:* Questions on C-ITS on the system performance

**Availability:**
- Was the service available when the service was needed?
- Degree of availability (never to always) for the different use cases
- An additional checklist can be proposed to indicate why service was not available
  - Bad connection/not getting messages/…

**Correctness:**
- Was the information correct when the service was active?
- Degree of correctness for the different use cases
- An additional checklist can be proposed to indicate why service was not correct
  - Message received after incident; false spot; …

**Completeness:**
- Was the information complete when the service was active?
- Degree of completeness for the different use cases
- An additional checklist can be proposed to indicate why service was not complete (did not give speed indication, changing lane, …)

**Consistency:**
- Was the service consistent and easy to understand when the service was active?
- Degree of consistency for the different use cases
• An additional checklist can be proposed to indicate why service was not consistent (some use cases information in text, other in symbols; change in kind of messages, …)

Accuracy
• Was the service accurate (geographical accuracy)?
• Degree of accuracy for the different use cases
• An additional checklist can be proposed to indicate why service was not accurate (not the right place, etc.)

Up-to-datedness
• Was the service up-to-date? Was the service available right on time
• Degree of up-to-datedness for the different use cases
• An additional checklist can be proposed to indicate why service was not up-to-date.

Specific Questions related to road managers

If users are employees of road managers, specific impact of ITS on their job can be evaluated. In this case, questions depend on the use case considered and deal with procedures of work. Further details regarding this topic will be analyzed by WG3 in its next activities.
6. Impacts Assessment

Information gathering during C-ITS Pilots

Evaluation of C-ITS impact in relation to baseline development

A core objective of Pilots is to better understand the effects of providing C-ITS services. This necessitates an impact evaluation approach that can compare the observed pattern of behavior to some ‘counterfactual’ for what would have happened without the intervention. I.e. the impacts of C-ITS Services are the result of a comparison between a framework with C-ITS Services that are working or activated on the equipped vehicles/devices and other vehicles that do not have C-ITS services or have them switched off.

So, parameters and Key Performance Indicators (KPIs) are defined as the comparison between revealed measures with C-ITS and the baseline that is the current framework without C-ITS services.

In principle, the following approaches could be deployed to establish a ‘counterfactual’. They are listed in order of increasing robustness, but it will be important for each Pilot to design an approach that is suitable for their specific implementation:

- **Before and after** - comparing outcomes before and after offering C-ITS services. This necessitates the collection of baseline data should be collected in advance of the implementation of C-ITS services.
- **Simple difference in differences** - compares changes in outcomes measured on the scheme to those for other roads or for drivers not equipped with C-ITS services on the same roads. This necessitates the collection of data from a control group in addition to drivers provided with C-ITS services.
- **Regression difference in differences** - is similar to simple difference in differences, but uses statistical techniques to compare changes in outcomes for drivers receiving C-ITS guidance to those not receiving guidance, controlling for a range of other factors.
- **Randomized control trials** - randomly allocating drivers to either receive C-ITS information, or into a control group for comparison purposes from which data is collected, but no services are provided. Drivers could either be permanently allocated to a treatment or control group, or the randomization could be applied each time they trigger an item of C-ITS guidance. The latter approach may be particularly suitable for Pilots involving a small fleet of vehicles.

Further, it’s important to mention that the basic factors that are checked during evaluation are dynamic in many terms - like change over a time period, through different roads, vehicle types etc.

So, whenever there is an evaluation about C-ITS impact, it should be considered that this evaluation never happens versus static elements. In fact, all factors related to the three areas of evaluation mentioned, that is traffic efficiency (such as traffic flow, density, speed, gaps etc.), traffic safety (such as speed, brakes, driver awareness etc. and the overall indicators such as number of crashes, injuries and fatalities) and also environmental issues (such as noise, pollution, CO\textsubscript{2} emissions etc.), are constantly changing, alone and without any C-ITS-involvement.

So, whenever impact-evaluation takes place, it should not be measured against static, but a dynamic baseline (not C-ITS-influenced) development.
Evaluation of differences between C-ITS- and non-C-ITS-related traffic developments

Involvement of planned user vehicles
From 2019 on, evaluation within C-Roads is done through Pilots, to be established throughout C-Roads Member States. Vehicles, properly equipped with C-ITS, collect data, and the output will then, among others, be used for impact-evaluation.

Monitoring of unplanned user vehicles
Data coming from unplanned user information is potentially by far outnumbering the data from planned user information – millions of cars are driving on European roads, and the number of vehicles which collect data output via the use of C-ITS is likely to grow rapidly in the near future, thus creating a massive amount of data. Monitoring and using these data is a matter of privacy and legal rules at time and place of use are to be considered.

General Approach
During the field tests, it will be possible to measure or calculate different parameters that can reveal a different behavior of the driver because of the receipt of information via C-ITS. Basically, just User Behavior of single driver/vehicle will be measured, as it can be assumed that the impact on the whole traffic flow during a field test would be negligible.

The measurement of changes in User Behavior, thanks to the use of Day 1 C-ITS, provides a first indication of the impacts, at a field test scale, of C-Roads implementation for the following impact areas:
- Safety
- Traffic efficiency
- Environment

Insight analysis on safety could be addressed to the evaluation of distraction. The data sources may include Vehicle ITS-Station, CAN Bus data\(^3\), GPS logger, automatic in-vehicle driver monitoring and/or the traffic monitoring systems on the road. Data collection and parameters measurement and calculation during the field test should be designed with the aim of analyzing possible effects of C-ITS Day 1 Services. To investigate the distraction gaze behavior measures could be used, as well as other indicators related to the psychophysical conditions of the drives. Those measures may be obtained by using eye or head tracking system, but also other useful information could be recorded by other wearable tools. Since this technology is relatively expensive and its use in field test is challenging, controlled studies using an instrumented vehicle in real road or test truck, using a driver simulator or any laboratory device may be conducted.

The main objective of the evaluation is the estimation of the effects of C-ITS Services with respect to a “non-C-ITS” situation (see comparison approaches in the previous chapter). In order to achieve this, it is important to consider contextual conditions/boundary conditions such as: road typology (highway, rural, urban.), speed limit, number of lanes, traffic flow, visibility condition, road structure data (materials and tilt), etc. It should be noticed that the boundary conditions for the comparison should be similar.

Drivers should be familiar with the C-ITS service to avoid measurements during learning phase.

\(^3\) However this source of data is very rich, the opportunity to access CAN Bus is uncertain and therefore methodology is independent from this source.
Besides the assessment of the effects of C-ITS, data collection and analysis could also provide feedback for the specification of Day 1 Services that can be used to maximize the benefits of the services. For instance, results may improve features of the service like location and timing of the information provided to the drivers.

An additional step is to use the data measured or calculated during the field test for an estimation of impacts on the entire traffic flow when the penetration rate of C-ITS vehicle will be higher. This means moving from a behavioral change measured on single vehicle (within the Pilots) to an estimation of the overall consequences on traffic in general when Day 1 Services will be more diffused. Such estimation could be based on algorithms and traffic modeling, but even through qualitative assessment. Starting from these outputs economic analysis can be developed, to provide an economic quantification of the estimated impacts.

The following Guidelines for the Evaluation of impacts of Day 1 Services on the mentioned investigation areas (safety, traffic efficiency and environment) are structured for each Use Case based on the “Research Question” approach which follows FESTA Handbook (FOT-Net 2017) whenever pertinent:

- Research Questions: How do drivers change their behavior because of warnings/information given by the service? The way the driver changes the driving behavior following the indication coming from the C-ITS is described;
- Sub Research Questions. The changes of the parameters that characterize the different driver behavior are investigated.
- Data collection (logging needs). Data/parameters that should be collected to be able to measure/calculate the changes in driver behavior are mentioned: e.g. dynamic parameter of the vehicle (speed, steering angle …), information concerning messages (typology, time and position, …). All Data/parameters should be featured, as far as practicable, with information regarding time and position.
- In addition, it is reported how these data could be collected: e.g. GPS Can Bus, On Board Unit, loops … Video recording could be identified as supporting tool for data collection for the whole set of analysis.
- Performance indicators to be calculated from the field data. Based on the measurement or calculation of the mentioned parameters the Performance Indicators of the field test are defined: e.g. speed adaptation, change in acceleration, average speed change …
- Estimated KPIs on mobility (when C-ITS will be more widely diffused). This additional step, using the data measured or calculated during the field test, defines KPIs for a higher C-ITS penetration rate. This estimation could be based on algorithms, traffic modeling but even through qualitative estimation. The methods for the assessment should be described in detail. These KPIs should be based on DG MOVE (https://ec.europa.eu/transport/sites/transport/files/themes/its/studies/doc/its-kpi-final_report_v7_4.pdf) and EU EIP list (https://www.its-platform.eu/highlights/kpis-defined). A possible KPI could be, as example for road safety, “Change in road accident resulting in death or injuries numbers”. Different scenarios could be developed considering different temporal checkpoints, for example 2025 and 2030.
• Assessment of the economic benefits of the C-ITS services generated by the KPI’s mentioned in the previous point.

Further activities of WG3 will be oriented to provide more details about the possible methods and techniques to investigate the last two points of this approach.
Day 1 Service: Road Works Warning
Use Case: Closure of a lane

Research Question: How do drivers change their behavior because of warnings/information given by the C-ITS service?
The drivers are informed in advance and more precisely (e.g. lane/s involved and possible restrictions to traffic flow) of a lane closure due to road works. They know earlier than without this information about the need for lane change. This lane change is done in advance of the road works site and the traffic flow will be ready and constant for lane closure before the critical stretch. The lane change maneuver is hereby done in more regular and safe conditions (for both drivers and road operating agents).

Safety

Main research question
• Is safety affected by changes in driver behavior due to C-ITS service?

Examples of Sub Research Questions
• In the approach of a road works site, how do the instant speed fluctuations of drivers change? (Do drivers apply the break earlier? Do drivers lift off the accelerator earlier? Do vehicles slow earlier? do drivers apply the break less sharply?)
  Research hypothesis: More homogeneous speeds and reduced acceleration and deceleration phases lead to more fluent traffic conditions.
• Is driver’s speed more compliant with speed limit in the approach of and passing by a Road works site? (What is the difference between the behavior of the driver and the advice given by road side systems? Is the speed of test vehicles with the service different from the average speed in the section(s)?)
  Research hypothesis: Higher compliance with speed limits leads to traffic condition more suitable for a section interested by road works, reducing sudden braking and consequent accelerations and thus limiting the creation and the propagation of shockwaves.
• How does the lane change point vary?
  Research hypothesis: A lane change in an earlier position leads to a more regular maneuver (less accelerations and decelerations for the vehicle and for the overall traffic).
• Is the lane change maneuver smoother? (Do drivers make fewer sudden steering movements? Is the acceleration/deceleration of the vehicle lower? In any direction?)
  Research hypothesis: A lane change with a smoother maneuver leads to less disturbances in the traffic flow of the following vehicles.

Data Collection
In order to evaluate the research questions and hypothesis during the C-Roads Pilots, based on the evidence collected, the following parameters/data can be collected:
• Vehicle Speed - source: Can Bus data or GPS data (m/s – resolution 1Hz)
• Acceleration/Deceleration – source: Can Bus data or GPS data (m/s² – resolution 1Hz)
• Time between the reception of the C-ITS message in the device/vehicle (T0, the presentation on the HMI is in most relevant cases directly linked to it) and the arrival at road works starting position (T1) – source: C-ITS device, Can Bus data or GPS data (s)
• Vehicle Position – source: GPS data
• Steering angle – source: Can Bus steering angle
• C-ITS message data log (content, timing and position of the reception, etc.) and HMI (visualization and/or announcement) data log – source: vehicle ITS station or mobile device

Table 3 - RWW - Relation between Sub Research Question for Safety and collected Data

<table>
<thead>
<tr>
<th>Sub Research Question</th>
<th>Speed</th>
<th>Acceleration</th>
<th>Time</th>
<th>Position</th>
<th>Steering angle</th>
<th>Message data log</th>
</tr>
</thead>
<tbody>
<tr>
<td>How do the instant speed fluctuations change?</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Is driver’s speed more compliant with speed limit?</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>How does the lane change point vary?</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Is the lane change maneuver smoother?</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

Field Test Indicator/KPI
The following Key Performance Indicators of the field test can be calculated (difference between C-ITS- and non-C-ITS-vehicles):
- Speed standard deviation
- Speed adaptation (difference between the average speed of the vehicle and the speed limit) - from the reception of the C-ITS message until the starting/ending position of road works
- Travel Time / Average Speed - from the reception of the C-ITS message until the starting/ending position of road works
- Instantaneous accelerations and decelerations
- Lane change point (point where the vehicle performs the lane change maneuver)
- Maximum steering angle

\[\text{\footnotesize\textsuperscript{4}}\] The lane change point could be determined using GPS and time stamp tagged Video or analyzing steering angle with road angulation (requires a map for geo matching and algorithm).
Table 4 - RWW - Relation between Field test indicator KPI for Safety and collected Data

<table>
<thead>
<tr>
<th>Field test indicator KPI</th>
<th>Speed</th>
<th>Acceleration</th>
<th>Time</th>
<th>Position</th>
<th>Steering angle</th>
<th>Message data log</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed adaptation</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Travel Time</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Speed standard deviation</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Instantaneous acceleration</td>
<td></td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Lane change point</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Maximum steering angle</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Estimated KPIs on mobility (when C-ITS will be more widely diffused).
The following Key Performance Indicators (based on EU EIP list) when C-ITS services (both on vehicles and on infrastructures side) will have a greater spread can be estimated starting from the outputs of the field test data:
- Change in road accident resulting in death or injuries numbers

Traffic Efficiency
Main research Question
- Is traffic efficiency affected by changes in driver behavior due to C-ITS service?

Examples of Sub Research Questions
- In the approach of a road works site, how do the instant speed fluctuations of drivers change? (Do drivers apply the break earlier? Do drivers lift off the accelerator earlier? Do vehicles slow earlier? do drivers apply the break less sharply?)
  Research hypothesis: More homogeneous speeds and reduced acceleration and deceleration phases lead to more fluent traffic conditions.
- Is driver’s speed more compliant with speed limit in the approach of and passing by a road works site? (What is the difference between the behavior of the driver and the advice given by road side systems? Is the speed of test vehicles with the service different from the average speed in the section(s)?)
  Research hypothesis: Higher compliance with speed limits leads to traffic condition more suitable for a section interested by road works, reducing sudden braking and consequent accelerations and thus limiting the creation and the propagation of shockwaves.
- How does the lane change point vary?
  Research hypothesis: A lane change in an earlier position leads to a more regular maneuver (less accelerations and decelerations for the vehicle and for the overall traffic)
- Is the lane change maneuver smoother? (Do drivers make fewer sudden steering movements? Is the acceleration/deceleration of the vehicle lower? In any direction?)
  Research hypothesis: A lane change with a smoother maneuver leads to less disturbances in the traffic flow of the following vehicles
Data Collection

In order to evaluate the research questions and hypothesis during the C-Roads Pilots, based on the evidence collected, the following parameters/data can be collected:

- Vehicle speed - source: Can Bus data or GPS data (m/s – resolution 1Hz)
- Acceleration/Deceleration – source: Can Bus data or GPS data (m/s² – resolution 1Hz)
- Time between the reception of the C-ITS message in the device/vehicle (T0, the presentation on the HMI is in most relevant cases directly linked to it) and the arrival at road works starting position (T1) – source: C-ITS device, Can Bus data or GPS data (s)
- Vehicle Position – source: GPS data
- Steering angle – source: Can Bus steering angle
- C-ITS message data log (content, timing and position of the reception, etc.) and HMI (visualization and/or announcement) data log – source: vehicle ITS station or mobile device

Table 5 - RWW - Relation between Sub Research Question for Traffic Efficiency and collected Data

<table>
<thead>
<tr>
<th>Sub Research Question</th>
<th>Speed</th>
<th>Acceleration</th>
<th>Deceleration</th>
<th>Time</th>
<th>Position</th>
<th>Steering angle</th>
<th>Message data log</th>
</tr>
</thead>
<tbody>
<tr>
<td>How do the instant speed fluctuations change?</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Is driver’s speed more compliant with speed limit?</td>
<td>x</td>
<td></td>
<td>x</td>
<td></td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>How does the lane change point vary?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Is the lane change maneuver smoother?</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

Field Test Indicator/KPI

The following Key Performance Indicators of the field test can be calculated (difference between C-ITS- and non-C-ITS-vehicles):

- Speed standard deviation
- Speed adaptation (difference between the average speed of the vehicle and the speed limit) - from the reception of the C-ITS message until the starting/ending position of road works
- Travel Time / Average Speed - from the reception of the C-ITS message until the starting/ending position of road works
- Instantaneous accelerations and decelerations
- Lane change point (point where the vehicle performs the lane change maneuver)
- Maximum steering angle
Table 6 - RWW - Relation between Field test indicator KPI for Traffic Efficiency and collected Data

<table>
<thead>
<tr>
<th>Field test indicator KPI</th>
<th>Speed</th>
<th>Acceleration</th>
<th>Time</th>
<th>Position</th>
<th>Steering angle</th>
<th>Message data log</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed adaptation</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Travel Time</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Speed standard deviation</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Instantaneous acceleration</td>
<td>x</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Lane change point</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Maximum steering angle</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

*Estimated KPIs on mobility (when C-ITS will be more widely diffused).*

The following Key Performance Indicators (based on EU EIP list) when C-ITS services (both on vehicles and on infrastructures side) will have a greater spread can be estimated starting from the outputs of the field test data:

- Change in Bottleneck Congestion (Bottleneck residual capacity)
- Change in travel time
- Change in Total time spent by all vehicles in queue

*Environment*

*Main research Question*

- Is environment affected by changes in driver behavior due to C-ITS service?

*Examples of Sub Research Questions*

- In the approach of a road works site, how do the instant speed fluctuations of drivers change? (*Do drivers apply the break earlier? Do drivers lift off the accelerator earlier? Do vehicles slow earlier? Do drivers apply the break less sharply?*)
  
  Research hypothesis: More homogeneous speeds and reduced acceleration and deceleration phases lead to lower fuel consumption and therefore lower CO$_2$, pollutants and noise emissions.

- Is driver’s speed more compliant with speed limit in the approach of and passing by a road works site? (*What is the difference between the behavior of the driver and the advice given by road side systems? Is the speed of test vehicles with the service different from the average speed in the section(s)?*)
  
  Research hypothesis: Higher compliance with speed limits leads to traffic condition more suitable for a section interested by road works, reducing sudden braking and consequent accelerations and thus limiting CO$_2$, pollutants and noise emissions.

- How does the lane change point vary?
  
  Research hypothesis: A lane change in an earlier position leads to a more regular maneuver (less accelerations and decelerations for the vehicle and for the overall traffic).

- Is the lane change maneuver smoother? (*Do drivers make fewer sudden steering movements? Is the acceleration/deceleration of the vehicle lower? In any direction?*)
Research hypothesis: A lane change with a smoother maneuver leads to less disturbances in the traffic flow of the following vehicles

**Data Collection**

In order to evaluate the research questions and hypothesis during the C-Roads Pilots, based on the evidence collected, the following parameters/data can be collected:

- Vehicle Speed - source: Can Bus data or GPS data (m/s – resolution 1Hz)
- Acceleration/Deceleration – source: Can Bus data or GPS data (m/s² – resolution 1Hz)
- Fuel consumption – source: Can Bus data (l/100km)
- Time between the reception of the C-ITS message in the device/vehicle (T0, the presentation on the HMI is in most relevant cases directly linked to it) and the arrival at road works starting position (T1) – source: C-ITS device, Can Bus data or GPS data (s)
- Vehicle Position – source: GPS data
- Steering angle – source: Can Bus steering angle
- C-ITS message data log (content, timing and position of the reception, etc.) and HMI (visualization and/or announcement) data log – source: vehicle ITS station or mobile device

**Table 7 - RWW - Relation between Sub Research Question for Environment and collected Data**

<table>
<thead>
<tr>
<th>Sub Research Question</th>
<th>Fuel consumption</th>
<th>Speed</th>
<th>Acceleration Deceleration</th>
<th>Time</th>
<th>Position</th>
<th>Steering angle</th>
<th>Message data log</th>
</tr>
</thead>
<tbody>
<tr>
<td>How do the instant speed fluctuations change?</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td></td>
<td>✗</td>
</tr>
<tr>
<td>Is driver’s speed more compliant with speed limit?</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td></td>
<td>✗</td>
</tr>
<tr>
<td>How does the lane change point vary?</td>
<td>✗</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✗</td>
</tr>
<tr>
<td>Is the lane change maneuver smoother?</td>
<td>✗</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✗</td>
</tr>
</tbody>
</table>

**Field Test Indicator/KPI**

The following Key Performance Indicators of the field test can be detected or calculated (difference between C-ITS- and non-C-ITS-vehicles):

- Speed standard deviation
- Instantaneous accelerations and decelerations
- Fuel consumption
- Noise level\(^5\)
- Maximum steering angle
- Speed adaptation (difference between the average speed of the vehicle and the speed limit) - from the reception of the C-ITS message until the starting/ending position of road works
- Lane change point (point where the vehicle performs the lane change maneuver)

\(^5\) The evaluation of the noise level might requires road structure data (materials and tilt) to allow an estimation.
Table 8 - RWW - Relation between Field test indicator KPI for Environment and collected Data

<table>
<thead>
<tr>
<th>Field test indicator KPI</th>
<th>Fuel consumption</th>
<th>Speed</th>
<th>Acceleration Deceleration</th>
<th>Time</th>
<th>Position</th>
<th>Steering angle</th>
<th>Message data log</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed standard deviation</td>
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<td></td>
<td>X</td>
</tr>
<tr>
<td>Instantaneous accelerations and</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>decelerations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Fuel consumption</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Noise level</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Maximum steering angle</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Speed adaptation</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lane change point</td>
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<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

*Estimated KPIs on mobility (when C-ITS will be more widely diffused).*

The following Key Performance Indicators (based on EU EIP list) when C-ITS services (both on vehicles and on infrastructures side) will have a greater spread can be estimated starting from the outputs of the field test data:

- Change in climate-change and polluting emissions (CO₂ emissions and other pollutants)
- Change in noise pollution
- Change in fuel consumption
Day 1 Service: In Vehicle Signage

Use Case: In-vehicle signage dynamic speed limit information

Research Question: How do drivers change their behavior because of warnings/information given by the service?

The drivers are informed of the dynamic speed limit in a more precise and timely manner. They are better aware of it, adapt their speed quicker and avoid speeding. This change is done in advance and the suggested speed can be updated with the change in downstream traffic flow. The driving is smoother and with lower acceleration and deceleration values and therefore lower emissions.

Safety

Main research question
- Is safety affected by changes in driver behavior due to C-ITS service?

Examples of Sub Research Questions
- How do the instant speed fluctuations change? (Do drivers apply the break earlier? Do drivers lift off the accelerator earlier? Do vehicles slow earlier? Do drivers apply the break less sharply?)
  Research hypothesis: More homogeneous speeds and reduced acceleration and deceleration phases lead to more fluent traffic conditions.
- Is driver’s speed more compliant with speed limit? (What is the difference between the behavior of the driver and the advice given by road side systems, is the speed of test vehicles with the service different from the average speed in the sections?)
  Research hypothesis: Higher compliance with speed limits leads to more suitable traffic condition, reducing sudden braking and consequent accelerations and thus limiting the creation and the propagation of shockwaves.

Data Collection

In order to evaluate the research questions and hypothesis during the C-Roads Pilots, based on the evidence collected, the following parameters/data can be collected:
- Vehicle Speed - source: Can Bus data or GPS data (m/s – resolution 1Hz)
- Acceleration/Deceleration – source: Can Bus data or GPS data (m/s² – resolution 1Hz)
- Vehicle Position – source: GPS data
- C-ITS message data log (content, timing and position of the reception, etc.) and HMI (visualization and/or announcement) data log – source: vehicle ITS station or mobile device (s)

Table 9 - IVS - Relation between Sub Research Question for Safety and collected Data

<table>
<thead>
<tr>
<th>Sub Research Question</th>
<th>Speed</th>
<th>Acceleration Deceleration</th>
<th>Position</th>
<th>Message data log</th>
</tr>
</thead>
<tbody>
<tr>
<td>How do the instant speed fluctuations change?</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Is driver’s speed (more) compliant with suggested speed limit?</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
Field Test Indicator/KPI
The following Key Performance Indicators of the field test can be calculated (difference between C-ITS- and non-C-ITS-vehicles):

- Speed adaptation (difference between the average speed of the vehicle and the speed limit) - from the reception of the C-ITS message until the suggested speed limit is no longer relevant.
- Speed standard deviation
- Instantaneous accelerations and decelerations

Table 10 - IVS - Relation between Field test indicator KPI for Safety and collected Data

<table>
<thead>
<tr>
<th>Field test indicator KPI</th>
<th>Speed</th>
<th>Acceleration</th>
<th>Deceleration</th>
<th>Position</th>
<th>Message data log</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed adaptation</td>
<td>✗</td>
<td></td>
<td></td>
<td></td>
<td>✗</td>
</tr>
<tr>
<td>Speed standard deviation</td>
<td>✗</td>
<td></td>
<td></td>
<td></td>
<td>✗</td>
</tr>
<tr>
<td>Instantaneous acceleration</td>
<td></td>
<td>✗</td>
<td></td>
<td></td>
<td>✗</td>
</tr>
</tbody>
</table>

Estimated KPIs on mobility (when C-ITS will be more widely diffused).
The following Key Performance Indicators (based on EU EIP list) when C-ITS services (both on vehicles and on infrastructures side) will have a greater spread can be estimated starting from the outputs of the field test data:

- Change in road accident resulting in death or injuries numbers

Traffic Efficiency

Main research question
- Is traffic efficiency affected by changes in driver behavior due to C-ITS service?

Examples of Sub Research Questions
- Is driver’s speed (more) compliant with suggested speed limit?
  Research hypothesis: The speed limit suggested it’s meant to ease the traffic flow going towards a queue or a traffic jam. Higher compliance with this speed limit leads to an early dissipation of the traffic jam, reducing the number of acceleration and deceleration, granting a higher comfort for the driver and a smoother traffic flow on the road. Driver’s speed can be more compliant to suggested speed with respect to a situation with dynamic speed limits provided via Variable Message Signs
- How do the instant speed fluctuations change?
  Research hypothesis: Having the dynamic speed limit displayed on the HMI and continuously updated leads to more homogeneous speeds, reduced acceleration and deceleration phases. This involves improvements on the traffic flow and more fluent traffic conditions.

Data Collection
In order to evaluate the research questions and hypothesis during the C-Roads Pilots, based on the evidence collected, the following parameters/data can be collected:

- Vehicle speed - source: Can Bus data or GPS data (m/s – resolution 1Hz)
- Acceleration/Deceleration – source: Can Bus data or GPS data (m/s² – resolution 1Hz)
- Vehicle position – source: GPS data
- C-ITS message data log (content, timing and position of the reception, etc.) and HMI (visualization and/or announcement) data log – source: vehicle ITS station or mobile device

**Table 11 - IVS - Relation between Sub Research Question for Traffic Efficiency and collected Data**

<table>
<thead>
<tr>
<th>Sub Research Question</th>
<th>Speed</th>
<th>Acceleration</th>
<th>Deceleration</th>
<th>Position</th>
<th>Message data log</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is driver's speed (more) compliant with suggested speed limit?</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>How do the instant speed fluctuations change?</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

**Field Test Indicator/KPI**
The following Key Performance Indicators of the field test can be calculated (difference between C-ITS- and non-C-ITS-vehicles):
- Speed adaptation (difference between the average speed of the vehicle and the speed limit) - from the reception of the C-ITS message until the suggested speed limit is no longer relevant.
- Speed standard deviation
- Instantaneous accelerations and decelerations

**Table 12 - IVS - Relation between Field test indicator KPI for Traffic Efficiency and collected Data**

<table>
<thead>
<tr>
<th>Field test indicator KPI</th>
<th>Speed</th>
<th>Acceleration</th>
<th>Deceleration</th>
<th>Position</th>
<th>Message data log</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed adaptation</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Speed standard deviation</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Instantaneous acceleration</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

**Estimated KPIs on mobility (when C-ITS will be more widely diffused).**
The following Key Performance Indicators (based on EU EIP list) when C-ITS services (both on vehicles and on infrastructures side) will have a greater spread can be estimated starting from the outputs of the field test data:
- Change in Journey Time
- Change in Total time spent by all vehicles in queue
- Change in Traffic Flow

**Environment**

**Main research question**
- Is environment affected by changes in driver behavior due to C-ITS service?

**Examples of Sub Research Questions**
- How do the instant speed fluctuations change?
Research hypothesis: More homogeneous speeds and reduced acceleration and deceleration phases lead to lower fuel consumption and therefore lower CO$_2$, pollutants and noise emissions.

- Is driver’s speed (more) compliant with transmitted speed limit in the validity area?
  Research hypothesis: Higher compliance with speed limits leads to an ease on the downstream congestion and an early dissipation of the queue, reducing the number of acceleration and deceleration and thus limiting CO$_2$, pollutants and noise emissions.

**Data Collection**

In order to evaluate the research questions and hypothesis during the C-Roads Pilots, based on the evidence collected, the following parameters/data can be collected:

- Vehicle speed - source: Can Bus data or GPS data (m/s – resolution 1Hz)
- Acceleration/Deceleration – source: Can Bus data or GPS data (m/s$^2$ – resolution 1Hz)
- Fuel consumption – source: Can Bus data (l/100km)
- Vehicle position – source: GPS data
- C-ITS message data log (content, timing and position of the reception, etc.) and HMI (visualization and/or announcement) data log – source: vehicle ITS station or mobile device

<table>
<thead>
<tr>
<th>Sub Research Question</th>
<th>Fuel consumption</th>
<th>Speed</th>
<th>Acceleration Deceleration</th>
<th>Position</th>
<th>Message data log</th>
</tr>
</thead>
<tbody>
<tr>
<td>How do the instant speed fluctuations change?</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Is driver’s speed (more) compliant with suggested speed limit?</td>
<td>✗</td>
<td>✗</td>
<td></td>
<td>✗</td>
<td>✗</td>
</tr>
</tbody>
</table>

**Field Test Indicator/KPI**

The following Key Performance Indicators of the field test can be detected or calculated (difference between C-ITS- and non-C-ITS-vehicles):

- Speed standard deviation
- Instantaneous accelerations and decelerations
- Fuel consumption
- Speed adaptation (difference between the average speed of the vehicle and the speed limit) - from the reception of the C-ITS message until the suggested speed limit is no longer relevant
- Noise level
### Table 14 - IVS - Relation between Field test indicator KPI for Environment and collected Data

<table>
<thead>
<tr>
<th>Field test indicator KPI</th>
<th>Fuel consumption</th>
<th>Speed</th>
<th>Acceleration Deceleration</th>
<th>Position</th>
<th>Message data log</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed standard deviation</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Instantaneous accelerations and decelerations</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Fuel consumption</td>
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<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Speed adaptation</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Noise level</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

**Estimated KPIs on mobility (when C-ITS will be more widely diffused).**

The following Key Performance Indicators (based on EU EIP list) when C-ITS services (both on vehicles and on infrastructures side) will have a greater spread can be estimated starting from the outputs of the field test data:

- Change in climate-change and polluting emissions (CO₂ emissions and other pollutants)
- Change in noise pollution
- Change in fuel consumption
Day 1 Service: Other Hazardous Locations Notification

All Use Cases (with punctual events – “weather conditions” and “temporary slippery road – black ice or water” not considered at this stage)

Research Question: How do drivers change their behavior because of warnings/information given by the service?

The drivers are informed about potentially hazardous events more precisely and in advance. Hence, they can adapt their driving behavior in a more aware way. The warning contains, if available, information about the location and the duration of the events and can be linked to a speed advice. If an adaptation of speed is needed, this change is done in advance and the driver will be ready for the event, e.g. braking or change lane earlier. The maneuver is done in more regular and safe conditions.

Safety

Main research question

- Is safety affected by changes in driver behavior due to C-ITS service?

Examples of Sub Research Questions

- In the approach of a hazardous location, do the instant speed fluctuations change? (Do drivers apply the break earlier? Do drivers lift off the accelerator earlier? Do vehicles slow earlier? Do drivers apply the break less sharply?)
  Research hypothesis: More homogeneous speeds and reduced acceleration and deceleration phases lead to fewer perturbations and more fluent traffic conditions.
- Is driver’s speed more compliant with speed limit in the approach of a hazardous location? (What is the difference between the behavior of the driver and the advice given by road side systems? Is the speed of test vehicles with the service different from the average speed in the sections?)
  Research hypothesis: Higher compliance with speed limits leads to traffic condition more suitable for a section interested by hazards, reducing sudden braking and consequent accelerations and thus limiting the creation and the propagation of shockwaves.
- How does the lane change point vary?
  Research hypothesis: A lane change in a proper location leads to a more regular maneuver (less accelerations and decelerations for the vehicle and for the overall traffic).
- Is the lane change maneuver smoother? (Do drivers make fewer sudden steering movements? Do drivers apply less pressure to the steering? Is the acceleration of the vehicle less sharp? In any direction? Do drivers exhibit less driving behavior that could be considered risky?)
  Research hypothesis: A lane change with a smoother maneuver leads to less perturbations to the following vehicles.

Data Collection

In order to evaluate the research questions and hypothesis during the C-Roads Pilots, based on the evidence collected, the following parameters/data can be collected:

- Vehicle speed - source: Can Bus data or GPS data (m/s – resolution 1Hz)
- Acceleration/Deceleration – source: Can Bus data or GPS data (m/s² – resolution 1Hz)
- Time between the reception of the C-ITS message in the vehicle (T0, the presentation on the HMI is in most relevant cases directly linked to it) and the arrival at hazardous location position (T1) – source: C-ITS device, Can Bus data or GPS data (s)
- Vehicle position – source: GPS data
- Steering angle – source: Can Bus steering angle
- C-ITS message data log (content, timing and position of the reception, etc.) and HMI (visualization and/or announcement) data log – source: vehicle ITS station or mobile device

Table 15 - OHLN - Relation between Sub Research Question for Safety and collected Data

<table>
<thead>
<tr>
<th>Sub Research Question</th>
<th>Speed</th>
<th>Acceleration</th>
<th>Deceleration</th>
<th>Time</th>
<th>Position</th>
<th>Steering angle</th>
<th>Message data log</th>
</tr>
</thead>
<tbody>
<tr>
<td>How do the instant speed fluctuations change?</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Is driver’s speed more compliant with speed limit (if suggested)?</td>
<td>x</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>How does the lane change point vary (if the lane of the event is specified)?</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Is the lane change maneuver smoother (if the lane of the event is specified)?</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

**Field Test Indicator/KPI**

The following Key Performance Indicators of the field test can be calculated (difference between C-ITS- and non-C-ITS-vehicles):
- Speed adaptation (difference between the average speed of the vehicle and the speed limit suggested) - from the reception of the C-ITS message until the position of the hazard
- Travel Time / Average Speed - from the reception of the C-ITS message until the position of the hazard
- Speed standard deviation
- Instantaneous accelerations and decelerations
- Lane change point (point where the vehicle performs the lane change maneuver)
- Maximum steering angle
Table 16 - OHLN - Relation between Field test indicator KPI for Safety and collected Data

<table>
<thead>
<tr>
<th>Field test indicator KPI</th>
<th>Speed</th>
<th>Acceleration</th>
<th>Deceleration</th>
<th>Time</th>
<th>Position</th>
<th>Steering angle</th>
<th>Message data log</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed adaptation</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Average Speed</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Maximum Speed</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Speed standard deviation</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Instantaneous acceleration</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Lane change point</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Maximum steering angle</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>

Estimated KPIs on mobility (when C-ITS will be more widely diffused).
The following Key Performance Indicators (based on EU EIP list) when C-ITS services (both on vehicles and on infrastructures side) will have a greater spread can be estimated starting from the outputs of the field test data:
- Change in road accident resulting in death or injuries numbers

Traffic Efficiency

Main research question
- Is traffic efficiency affected by the use of C-ITS service?

Examples of Sub Research Questions
- Does the average speed decrease?
  Research hypothesis: The increased awareness about a hazardous event leads to lower speeds on the road and to reduced sudden and relevant braking when the event is reached, thus more fluent traffic conditions.
- Is driver’s speed more compliant with speed limit transmitted?
  Research hypothesis: The speed limit, besides a more regular driving, involves smoother maneuvers and, thus, more fluent traffic conditions. This implies a reduction in sudden braking and consequent accelerations and thus limiting the creation and the propagation of shockwaves.
- How does the lane change point vary (if the lane of the event is specified)?
  Research hypothesis: An advanced lane change before a confined hazardous event leads to a more regular maneuver (less accelerations and decelerations for the vehicle and for the overall traffic).
- Is the lane change maneuver smoother (if the lane of the event is specified)?
  Research hypothesis: A lane change with a smoother maneuver leads to less perturbations to the following vehicles.
Data Collection

In order to evaluate the research questions and hypothesis during the C-Roads Pilots, based on the evidence collected, the following parameters/data can be collected:

- Vehicle speed - source: Can Bus data or GPS data (m/s – resolution 1Hz)
- Acceleration/Deceleration – source: Can Bus data or GPS data (m/s² – resolution 1Hz)
- Time between the reception of the C-ITS message in the device/vehicle (T0, the presentation on the HMI is in most relevant cases directly linked to it) and the arrival at the hazardous event (T1) – source: C-ITS device, Can Bus data or GPS data (s)
- Vehicle position – source: GPS data
- Steering angle - source: Can Bus steering angle
- C-ITS message data log (content, timing and position of the reception, etc.) and HMI (visualization and/or announcement) data log – source: vehicle ITS station or mobile device.

Table 17 - OHLN - Relation between Sub Research Question for Traffic Efficiency and collected Data

<table>
<thead>
<tr>
<th>Sub Research Question</th>
<th>Speed</th>
<th>Acceleration</th>
<th>Deceleration</th>
<th>Time</th>
<th>Position</th>
<th>Steering angle</th>
<th>Message data log</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does the average speed decrease?</td>
<td>☒</td>
<td>☒</td>
<td></td>
<td>☒</td>
<td></td>
<td></td>
<td>☒</td>
</tr>
<tr>
<td>Is driver’s speed more compliant with speed limit (if suggested)?</td>
<td>☒</td>
<td>☒</td>
<td>☒</td>
<td></td>
<td></td>
<td></td>
<td>☒</td>
</tr>
<tr>
<td>How does the lane change point vary (if the lane of the event is specified)?</td>
<td>☒</td>
<td></td>
<td></td>
<td>☒</td>
<td></td>
<td></td>
<td>☒</td>
</tr>
<tr>
<td>Is the lane change maneuver smoother (if the lane of the event is specified)?</td>
<td>☒</td>
<td></td>
<td></td>
<td>☒</td>
<td>☒</td>
<td></td>
<td>☒</td>
</tr>
</tbody>
</table>

Field Test Indicator/KPI

The following Key Performance Indicators of the field test can be calculated (difference between C-ITS- and non-C-ITS-vehicles):

- Speed standard deviation
- Speed adaptation (difference between the average speed of the vehicle and the speed limit - if suggested)
- Average and Maximum Speed
- Instantaneous accelerations and decelerations
- Lane change point (if the lane of the event is specified)
- Maximum steering angle (if the lane of the event is specified)
**Table 18 - OHLN - Relation between Field test indicator KPI for Traffic Efficiency and collected Data**

<table>
<thead>
<tr>
<th>Field test indicator KPI</th>
<th>Speed</th>
<th>Acceleration Deceleration</th>
<th>Time</th>
<th>Position</th>
<th>Steering angle</th>
<th>Message data log</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed adaptation</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Average Speed</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Maximum Speed</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Speed standard deviation</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Instantaneous acceleration</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Lane change point</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Maximum steering angle</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

**Estimated KPIs on mobility (when C-ITS will be more widely diffused).**
The following Key Performance Indicators (based on EU EIP list) when C-ITS services (both on vehicles and on infrastructures side) will have a greater spread can be estimated starting from the outputs of the field test data:
- Change in Journey Time
- Change in Total time spent by all vehicles in queue

**Environment**

**Main research question**
- Is environment affected by changes in driver behavior due to C-ITS service?

**Examples of Sub Research Questions**
- How do the instant speed fluctuations change?
  *Research hypothesis*: More homogeneous speeds and reduced acceleration and deceleration phases lead to lower fuel consumption and therefore lower CO₂, pollutants and noise emissions.
- How does the lane change point vary (if the lane of the event is specified)?
  *Research hypothesis*: A lane change in a proper location leads to a more regular maneuver (less accelerations and decelerations for the vehicle and for the overall traffic).
- Is the lane change maneuver smoother (if the lane of the event is specified)?
  *Research hypothesis*: A lane change with a smoother maneuver leads to less disturbances in the traffic flow of to the following vehicles.

**Data Collection**
In order to evaluate the research questions and hypothesis during the C-Roads Pilots, based on the evidence collected, the following parameters/data can be collected:
- Vehicle speed - source: Can Bus data or GPS data (m/s – resolution 1Hz)
- Acceleration/Deceleration – source: Can Bus data or GPS data (m/s² – resolution 1Hz)
- Fuel consumption – source: Can Bus data (/100km)
• Position – source: GPS data
• Steering angle - source: Can Bus steering angle
• C-ITS message data log (content, timing and position of the reception, etc.) and HMI (visualization and/or announcement) data log – source: vehicle ITS station or mobile device

Table 19 - OHLN - Relation between Sub Research Question for Environment and collected Data

<table>
<thead>
<tr>
<th>Sub Research Question</th>
<th>Fuel consumption</th>
<th>Speed</th>
<th>Acceleration Deceleration</th>
<th>Position</th>
<th>Steering angle</th>
<th>Message data log</th>
</tr>
</thead>
<tbody>
<tr>
<td>How do the instant speed fluctuations change?</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>How does the lane change point vary (if the lane of the event is specified)?</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Is the lane change maneuver smoother (if the lane of the event is specified)?</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

Field Test Indicator/KPI
The following Key Performance Indicators of the field test can be calculated (difference between C-ITS- and non-C-ITS-vehicles):
• Speed standard deviation
• Instantaneous accelerations and decelerations
• Fuel consumption
• Noise level
• Lane change point (if the lane of the event is specified)
• Maximum steering angle (if the lane of the event is specified)

Table 20 - OHLN - Relation between Field test indicator KPI for Environment and collected Data

<table>
<thead>
<tr>
<th>Field test indicator KPI</th>
<th>Fuel consumption</th>
<th>Speed</th>
<th>Acceleration Deceleration</th>
<th>Position</th>
<th>Steering angle</th>
<th>Message data log</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed standard deviation</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Instantaneous accelerations and decelerations</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel consumption</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Noise level</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lane change point</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum steering angle</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Estimated KPIs on mobility (when C-ITS will be more widely diffused).
The following Key Performance Indicators (based on EU EIP list) when C-ITS services (both on vehicles and on infrastructures side) will have a greater spread can be estimated starting from the outputs of the field test data:

- Change in climate-change and polluting emissions (CO₂ emissions and other pollutants)
- Change in noise pollution
- Change in fuel consumption
Day 1 Service: Traffic Light Maneuvers  Road and Lane Topology

Use Case: GLOSA (Green light optimal speed advisory)

Research Question: How do drivers change their behavior because of warnings/information given by the service?

The drivers approaching the traffic lights are provided with a speed advice and information about the traffic light phases, based on which they can adapt their travelling speed to cross the intersection or decelerate to wait less for the upcoming green. This use case leads to a reduced number of stops at the red light and a faster restart when the light turns green.

Safety

Main research question

• Is safety affected by changes in driver behavior due to C-ITS service?

Examples of Sub Research Questions

• How does the instant speed change immediately after message reception?
  Research hypothesis: According to the received information, the driver can accelerate to reach the crossing before the red light or decelerate to wait shorter for the green phase. The abruptness of the maneuver potentially decreases the fluency of the traffic flow.

• Is driver’s speed compliant with the speed limit in the approach of the traffic light?
  Research hypothesis: Higher compliance with speed suggestions leads to less vehicles waiting to cross the intersection, reducing the number of acceleration and deceleration, queue’s length and improving the crossing efficiency.

• Does the driver start quicker after the traffic light turns green?
  Research hypothesis: Knowing when the light is becoming green leads to faster restart of the vehicles and quicker acceleration, positively impacting the traffic flow across the intersection.

Data Collection

In order to evaluate the research questions and hypothesis during the C-Roads Pilots, based on the evidence collected, the following parameters/data can be collected:

• Vehicle speed - source: Can Bus data or GPS data (m/s – resolution 1Hz)
• Acceleration/Deceleration – source: Can Bus data or GPS data (m/s² – resolution 1Hz)
• Time between the reception of the C-ITS message in the device/vehicle (T0, the presentation on the HMI is in most relevant cases directly linked to it) and the arrival at the traffic lights position (T1) – source: C-ITS device, Can Bus data or GPS data (s)
• Vehicle position – source: GPS data
• C-ITS message data log (content, timing and position of the reception, etc.) and HMI (visualization and/or announcement) data log – source: vehicle ITS station or mobile device
### Table 21 - TLM-RLT - Relation between Sub Research Question for Safety and collected Data

<table>
<thead>
<tr>
<th>Sub Research Question</th>
<th>Speed</th>
<th>Acceleration</th>
<th>Deceleration</th>
<th>Position</th>
<th>Message data log</th>
</tr>
</thead>
<tbody>
<tr>
<td>How does the instant speed change immediately after message reception?</td>
<td>x</td>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Is driver’s speed compliant with the speed limit?</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Does the driver start quicker after the traffic light turns green?</td>
<td>x</td>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

### Field Test Indicator/KPI

The following Key Performance Indicators of the field test can be calculated (difference between C-ITS- and non-C-ITS-vehicles):

- Speed adaptation (difference between the average speed of the vehicle and the speed limit) - from the reception of the C-ITS message until the position of the traffic lights
- Travel Time / Average Speed - from the reception of the C-ITS message until the position of the traffic lights
- Speed standard deviation
- Instantaneous accelerations and decelerations

### Table 22 - TLM-RLT - Relation between Field test indicator KPI for Safety and collected Data

<table>
<thead>
<tr>
<th>Field test indicator KPI</th>
<th>Speed</th>
<th>Acceleration</th>
<th>Deceleration</th>
<th>Position</th>
<th>Message data log</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed adaptation</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Travel Time/Average Speed</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Speed standard deviation</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Instantaneous accelerations and decelerations</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

### Estimated KPIs on mobility (when C-ITS will be more widely diffused)

The following Key Performance Indicators (based on EU EIP list) when C-ITS services (both on vehicles and on infrastructures side) will have a greater spread can be estimated starting from the outputs of the field test data:

- Change in road accident resulting in death or injuries numbers

### Traffic Efficiency

**Main research question**

- Is traffic efficiency affected by changes in driver behavior due to C-ITS service?

**Examples of Sub Research Questions**

- How does the instant speed change immediately after message reception?
Research hypothesis: According to the received information, the driver can accelerate to reach the crossing before the red light or decelerate to wait shorter for the green phase. The abruptness of the maneuver potentially decreases the fluency of the traffic flow.

- Is driver's speed compliant with suggested speed in the approach of the traffic light? 
  Research hypothesis: Higher compliance with speed suggestions leads to less vehicles waiting to cross the intersection, reducing the number of acceleration and deceleration, queue's length and improving the crossing efficiency.

- Does the driver start quicker after the traffic light turns green?
  Research hypothesis: Knowing when the light is becoming green leads to faster restart of the vehicles and quicker acceleration, positively impacting the traffic flow across the intersection.

Data Collection
In order to evaluate the research questions and hypothesis during the C-Roads Pilots, based on the evidence collected, the following parameters/data can be collected:

- Vehicle speed - source: Can Bus data or GPS data (m/s – resolution 1Hz)
- Acceleration/Deceleration – source: Can Bus data or GPS data (m/s² – resolution 1Hz)
- Vehicle Position – source: GPS data
- C-ITS message data log (content, timing and position of the reception, etc.) and HMI (visualization and/or announcement) data log – source: vehicle ITS station or mobile device

Table 23 - TLM-RLT - Relation between Sub Research Question for Traffic Efficiency and collected Data

<table>
<thead>
<tr>
<th>Sub Research Question</th>
<th>Speed</th>
<th>Acceleration</th>
<th>Deceleration</th>
<th>Position</th>
<th>Message data log</th>
</tr>
</thead>
<tbody>
<tr>
<td>How does the instant speed change immediately after message reception?</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Is driver’s speed compliant with suggested speed?</td>
<td>✗</td>
<td></td>
<td></td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Does the driver start quicker after the traffic light turns green?</td>
<td>✗</td>
<td>✗</td>
<td></td>
<td>✗</td>
<td>✗</td>
</tr>
</tbody>
</table>

Field Test Indicator/KPI
The following Key Performance Indicators of the field test can be calculated (difference between C-ITS- and non-C-ITS-vehicles):

- Speed adaptation (difference between the average speed of the vehicle and the speed limit) - from the reception of the C-ITS message until the stop line
- Instantaneous accelerations and decelerations
- Percentage of test vehicles able to cross the intersection without stopping⁶ (with and without GLOSA)
- Time between the point in time when the light turns green and the departure of the test vehicle⁷ (if it's the leading vehicle, that is the first vehicle stopped at the traffic light)
- Time to cross the intersection

---

⁶ This evaluation can take advantages if combined with data describing congestion at traffic lights (magnetic loops or other sensors).
⁷ This evaluation can take advantages if combined with traffic lights stop line position to know the first vehicle in lane.
Table 24 - TLM-RLT - Relation between Field test indicator KPI for Traffic Efficiency and collected Data

<table>
<thead>
<tr>
<th>Field test indicator KPI</th>
<th>Speed</th>
<th>Acceleration</th>
<th>Deceleration</th>
<th>Position</th>
<th>Message data log</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed adaptation</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Instantaneous accelerations and decelerations</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>% of test vehicles able to cross the intersection without stopping</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Time between the instant the light turns green and the departure</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Travel Time/Delay</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Estimated KPIs on mobility (when C-ITS will be more widely diffused).
The following Key Performance Indicators (based on EU EIP list) when C-ITS services (both on vehicles and on infrastructures side) will have a greater spread can be estimated starting from the outputs of the field test data:

- Change in Bottleneck Congestion
- Change in Journey Time
- Change in Traffic Flow
- Change in Total time spent by all vehicles in queue

Environment

Main research question
- Is environment affected by changes in driver behavior due to C-ITS service?

Examples of Sub Research Questions
- How do the instant speed fluctuations change? How does the instant speed change immediately after message reception?
  - Research hypothesis: According to the received information, the driver can accelerate to reach the crossing before the red light or decelerate to wait less for the green. The abruptness of the maneuver potentially affects fuel consumption and therefore CO₂, pollutants- and noise-emissions How does the instant speed change immediately after message reception?
  - Research hypothesis: Abrupt accelerations or decelerations resulting from the advice, lead to less fluent traffic flow upstream.
- Is driver speed compliant with suggested speed in the approach of the traffic lights?
  - Research hypothesis: Higher compliance with speed suggestions leads to less vehicles waiting to cross the intersection, reducing the number of acceleration and deceleration, as well as queue’s length, fuel consumption, CO₂, pollutants and noise emissions.

Data Collection
In order to evaluate the research questions and hypothesis during the C-Roads Pilots, based on the evidence collected, the following parameters/data can be collected:
- Vehicle speed - source: Can Bus data or GPS data (m/s – resolution 1Hz)
- Acceleration/Deceleration – source: Can Bus data or GPS data (m/s² – resolution 1Hz)
- Vehicle position – source: GPS data
- C-ITS message data log (content, timing and position of the reception, etc.) and HMI (visualization and/or announcement) data log – source: vehicle ITS station or mobile device

Table 25 - TLM-RLT - Relation between Sub Research Question for Environment and collected Data

<table>
<thead>
<tr>
<th>Sub Research Question</th>
<th>Fuel consumption</th>
<th>Speed</th>
<th>Acceleration</th>
<th>Deceleration</th>
<th>Position</th>
<th>Message data log</th>
</tr>
</thead>
<tbody>
<tr>
<td>How do the instant speed fluctuations change?</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>How does the instant speed change immediately after message reception?</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Is driver’s speed compliant with suggested speed?</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Field Test Indicator/KPI
The following Key Performance Indicators of the field test can be calculated (difference between C-ITS- and non-C-ITS-vehicles):
- Speed adaptation (difference between the average speed of the vehicle and the speed limit) - from the reception of the C-ITS message until the stop line
- Instantaneous accelerations and decelerations
- Percentage of test vehicles able to cross the intersection without stopping (with and without GLOSA)
- Time between the point in time when the light turns green and the departure of the test vehicle (if it’s the leading vehicle, that is the first vehicle stopped at the traffic light)
- Fuel consumption
- Noise level

Table 26 - TLM-RLT - Relation between Field test indicator KPI for Environment and collected Data

<table>
<thead>
<tr>
<th>Field test indicator KPI</th>
<th>Fuel consumption</th>
<th>Speed</th>
<th>Acceleration</th>
<th>Deceleration</th>
<th>Position</th>
<th>Message data log</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed adaptation</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Instantaneous accelerations and decelerations</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% of test vehicles able to cross the intersection without stopping</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time between the instant the light turns green and the departure</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel consumption</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Noise level</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
Estimated KPIs on mobility (when C-ITS will be more widely diffused).
The following Key Performance Indicators (based on EU EIP list) when C-ITS services (both on vehicles and on infrastructures side) will have a greater spread can be estimated starting from the outputs of the field test data:

- Change in climate-change and polluting emissions (CO2 emissions and other pollutants)
- Change in noise pollution
- Change in fuel consumption
Annex 1: Examples of inventory tool

1. General information

   Country: 
   Author: 
   Version: 
   Date: 

   DESCRIPTION (as described on C-Roads site)

   LOCATION DESCRIPTION (as described on C-Roads site)

2. Field trial information

   1. How many test-drivers:

   1.1 Which type of drivers:

      professional
      non-professional

   2. In which area will the trial take place:

      urban
      highways
      rural roads

   3. How long will the drivers use C-ITS?

      weeks

   4. Which type of C-ITS

      G5
      cellular

3. Available services
Which Day 1 services will be tested in your country?

<table>
<thead>
<tr>
<th>Hazardous location notification</th>
<th>Weather conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Road works warning</td>
</tr>
<tr>
<td></td>
<td>Slow or stationary vehicles</td>
</tr>
<tr>
<td></td>
<td>Emergency vehicle approaching</td>
</tr>
<tr>
<td></td>
<td>Emergency brake light</td>
</tr>
<tr>
<td></td>
<td>Other hazardous location notifications</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Signage application</th>
<th>Traffic jam ahead warning</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In-vehicle signage</td>
</tr>
<tr>
<td></td>
<td>In-vehicle speed limits</td>
</tr>
<tr>
<td></td>
<td>Probe vehicle data</td>
</tr>
<tr>
<td></td>
<td>Shockwave damping</td>
</tr>
<tr>
<td></td>
<td>Green Light Optimal Speed Advisory</td>
</tr>
<tr>
<td></td>
<td>Signal violation/intersection safety</td>
</tr>
</tbody>
</table>

How will the information be given to the user: (i) pictures/symbols; (ii) text; (iii) combination; (iv) other?

- Weather conditions
- Road works warning
- Slow or stationary vehicles
- Emergency vehicle approaching
- Emergency brake light
- Other hazardous location notifications
- Traffic jam ahead warning
- In-vehicle signage
- In-vehicle speed limits
- Probe vehicle data
- Shockwave damping
- Green Light Optimal Speed Advisory
- Signal violation/intersection safety
Which basic information will be given: speed limits, traffic sign, …?

**Weather conditions**
**Road works warning**
**Slow or stationary vehicles**
**Emergency vehicle approaching**
**Emergency brake light**
**Other hazardous location notifications**
**Traffic jam ahead warning**
**In-vehicle signage**
**In-vehicle speed limits**
**Probe vehicle data**
**Shockwave damping**
**Green Light Optimal Speed Advisory**
**Signal violation/intersection safety**

Are there advanced features in the information? Sound & light, signals, …?

**Weather conditions**
**Road works warning**
**Slow or stationary vehicles**
**Emergency vehicle approaching**
**Emergency brake light**
**Other hazardous location notifications**
**Traffic jam ahead warning**
**In-vehicle signage**
**In-vehicle speed limits**
**Probe vehicle data**
**Shockwave damping**
**Green Light Optimal Speed Advisory**
**Signal violation/intersection safety**
How would you categorize the service: INFORMATIVE: Only providing information of the situation to the driver; ADVISORY: Besides basic info, extra information on e.g. speed, lane, … ASSISTING: Besides basic info, providing extra support (sound & light) if e.g. driver is speeding, audio signal?

<table>
<thead>
<tr>
<th>Weather conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road works warning</td>
</tr>
<tr>
<td>Slow or stationary vehicles</td>
</tr>
<tr>
<td>Emergency vehicle approaching</td>
</tr>
<tr>
<td>Emergency brake light</td>
</tr>
<tr>
<td>Other hazardous location notifications</td>
</tr>
<tr>
<td>Traffic jam ahead warning</td>
</tr>
<tr>
<td>In-vehicle signage</td>
</tr>
<tr>
<td>In-vehicle speed limits</td>
</tr>
<tr>
<td>Probe vehicle data</td>
</tr>
<tr>
<td>Shockwave damping</td>
</tr>
<tr>
<td>Green Light Optimal Speed Advisory</td>
</tr>
<tr>
<td>Signal violation/intersection safety</td>
</tr>
</tbody>
</table>
Annex 2: Examples of research questions as provided by the C-Road members

Project INTERCOR suggested the following general remark:

*Please keep in mind that the questions that were selected are main research questions. It has not the intention to give the impression that by addressing only these questions, the whole area of user acceptance is covered. In order to answer these top questions, various sub questions need to be listed. It depends on many factors such as Pilot length, budget, etcetera what type of study (questionnaire, interview …) should be conducted to obtain the answers. It is important to first determine what you want to know and why you want to know it, before being able to determine how you are going to tackle the questions.*

<table>
<thead>
<tr>
<th>Source</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercor</td>
<td>Do drivers report perceiving the information presented?</td>
</tr>
<tr>
<td></td>
<td>Do drivers feel like they use the services and that the service influences their behavior? If so, how?</td>
</tr>
<tr>
<td></td>
<td>How do drivers value the services?</td>
</tr>
<tr>
<td></td>
<td>Do drivers believe the services improve their overall trip quality? If so, how?</td>
</tr>
<tr>
<td></td>
<td>How do drivers value the HMI and could it be improved? (distracting/easy to use)</td>
</tr>
<tr>
<td>Finland</td>
<td>How satisfied were you with the C-ITS service on a scale of 1 = very satisfied, 2 = somewhat satisfied, 3 = somewhat dissatisfied, 4 = very dissatisfied</td>
</tr>
<tr>
<td></td>
<td>In your opinion, what is the order of importance of the warnings given by the C-ITS service? Please rate the following from 1 to 6, where 1 = the most important and 6 = least important (each score may be selected only once)</td>
</tr>
<tr>
<td></td>
<td>a) Object on the road: 1 2 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td>b) Poor visibility: 1 2 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td>c) Slippery road: 1 2 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td>d) Exceptional weather: 1 2 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td>e) Accident: 1 2 3 4 5 6</td>
</tr>
<tr>
<td></td>
<td>f) Roadworks: 1 2 3 4 5 6</td>
</tr>
</tbody>
</table>
What kind of impacts did the C-ITS service warning of an obstacle on the road generally have on your driving behavior? You may select several impacts. Note that further details will be asked of the impacts you select below.

- [ ] It had an impact on my driving speed.
- [ ] It had an impact on the distance I kept to the vehicle in front.
- [ ] It had an impact on my overtaking behavior.
- [ ] It had an impact on my secondary tasks while driving, e.g. use of radio, mobile phone or other device.
- [ ] It had an impact on where I focused my attention in traffic.
- [ ] It had an impact on my route choice, if there was an alternative route available.
- [ ] It had an impact on my driving comfort.
- [ ] It had no impact on my driving behavior.

When using the C-ITS service, did any of the following happen? (You may select several alternatives.)

- [ ] It was hard to stay in lane
- [ ] My speed decreased for a while (unintentionally)
- [ ] The gap to the vehicle in front of me got too short
- [ ] I noticed another road user, object on the road or another vehicle too late
- [ ] None of the above
- [ ] Another driving error, what:
  ________________________________
  ________________________________
On what kinds of trip do you think you would activate the C-ITS service if a production-phase service were available to you after this Pilot? You may select several options if needed.

- I’d try to activate it always
- I’d activate it when I have a tight schedule
- I’d activate it for longer trips
- I’d activate it when driving on congested routes
- I’d activate it for trips on which I either expect to receive a warning or experience situations worth warning others about

Spain

Below questions are aimed to be addressed for the Spanish Pilots. Final questionnaires are to be elaborated yet:

- What are the factors influencing users’ acceptability towards Cooperative Intelligent Transportation Systems (C-ITS)?
- Are perceptions determined by the need or ability of the user?
- What is the potential impact of ITS services on the mobility and independence of vulnerable social groups?
- How the access to ITS services is related to people with varying needs and abilities?
- Is there any evidence to conclude that Cooperative Intelligent Transportation Systems are equitable?
- Is this transport policy making transport more affordable to the less wealthy people/regions and to vulnerable groups?
- Is there any evidence of discrimination against the most economically and socially disadvantaged regions/people?
- How is the distribution (and the perception of the distribution) of gains and losses of the proposed services for the disadvantaged users?

According to the Spanish stakeholders’ preliminary survey, the main interests from the C-ITS product owner relies on the perceived utility and usability of the C-ITS services. Therefore these aspects will have priority in the questionnaires.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceived efficiency</td>
<td>39</td>
</tr>
<tr>
<td>Perceived effectiveness</td>
<td>39</td>
</tr>
<tr>
<td>Perceived usability</td>
<td>40</td>
</tr>
<tr>
<td>Perceived usefulness</td>
<td>49</td>
</tr>
<tr>
<td>Satisfaction</td>
<td>37</td>
</tr>
<tr>
<td>Equity</td>
<td>21</td>
</tr>
<tr>
<td>Affordability/willingness to pay</td>
<td>37</td>
</tr>
</tbody>
</table>
Annex 3: User Acceptance Theoretical background

Common definitions and differences between public acceptance and user acceptance

Acceptance, acceptability, social acceptance, public support, social support, etc. are all terms frequently used to describe a similar phenomenon, how potential users will react and act if a certain measure or device is implemented. The interest in defining acceptance or acceptability lies in the precondition that the effectiveness and success of a measure will increase if there is public/social support for it. Under favorable conditions a positive assessment leads to an increased willingness to accept a measure and even to support it actively (Nelissen & Bartels, 1998; Goldenbeld, 2002). Although it is recognized that acceptance, acceptability, and support are important, a clear definition of what acceptance and acceptability are and precisely how they should be measured is still absent (Adell, 2008a; Regan et al., 2006; Vlassenroot, 2006).

To a certain extent the terms acceptance and support are strongly related. Goldenbeld (2002), however, introduces an important nuance between both concepts. The basic idea is that even if acceptance exists, it would not necessarily lead to the support of a measure.

In the field of ITS, Ausserer and Risser (2005) define acceptance as a phenomenon that reflects to what extent potential users are willing to use a certain system. Hence, acceptance is linked closely to usage, and acceptance will depend on how user needs are integrated into the development of the system. Nielsen (cited in Young et al., 2003) described acceptability as related to the question of whether the system is good enough to satisfy all the needs and requirements of the users and other potential stakeholders. More generally, in Rogers’ (2003) diffusion of innovations, acceptability research is defined as the investigation of perceived attributes of an ideal innovation in order to guide research and development to create such an innovation. Van der Laan et al. (1997) distinguished between user acceptance and social acceptance. User acceptance is directed more towards evaluation of the ergonomics of the system while social acceptance is a more indirect evaluation of consequences of the system.

In another distinction between acceptance and acceptability, Schade and Schlag (2003) described acceptance as the respondents’ attitudes, including their behavioral responses, after the introduction of a measure, and acceptability as the prospective judgment before such future introduction. In this case, the respondents will not have experienced any of the measures or devices in practice, which makes acceptability a construction of attitude.

Theories and approaches in User Acceptance

One of the most frequently used frameworks to define acceptance is the Theory of Planned Behavior (TPB). Based on the Theory of Reasoned Action (Fischbein & Ajzen, 1975), the TPB assumes that behavioral intentions, and therefore behavior, may be predicted by three components (Van Acker et al., 2007, 2010): attitudes towards the behavior, which are individuals’ evaluation of performing a particular behavior; subjective norms, which describe the perception of other people’s beliefs; and perceived behavioral control, which refers to people’s perception of their own capability.

TPB has been used successfully to predict behavior in a wide variety of applied research settings within different domains, including several studies dealing with driving behavior and traffic safety, such as the effects of drinking and driving (Aberg, 1993; Parker et al., 1992a), driving violations (Parker et al., 1992b), and speeding and speed behavior (Elliot et al., 2005; Haglund et al., 2000). Warner and Aberg (2006) specifically used the TPB related to the use of ISA.
Comparing self-reported speeding of test drivers within an ISA trial with logged data explained 28% of the variance in logged speeding. In their study, Warner and Aberg (2006) noted that perceived behavioral control did not add significantly to the prediction of drivers’ logged speed.

Another successful model is the Technology Acceptance Model (TAM) (Davis et al., 1989). TAM was designed to predict information technology acceptance and usage on the job. TAM assumes that perceived usefulness and perceived ease of use determine an individual’s intention to use a system with the intention to use serving as a mediator of actual system use. TAM has been used – in the field of ITS – in the prediction of electronic toll collection (Chen et al., 2007).

Van der Laan et al. (1996) published a simple method to define acceptance. Acceptance is measured by direct attitudes towards a system and provides a system evaluation in two dimensions. The technique consists of nine rating-scale items. These items are mapped on two scales, the one denoting the usefulness of the system, and the other satisfaction.
Venkatesh et al. (2003) noted that there are several theories and models of user acceptance of information technology, which presents researchers with difficulties in choosing the proper model. Venkatesh et al. (2003) found different underlying basic concepts in acceptance models by means of a detailed description and analysis of different models such as TPB, the motivational model, TAM, innovation diffusion theory, and combined models. Based on these theories, they constructed a unified model they named the Unified Theory of Acceptance and Use of Technology (UTAUT). In the UTAUT, four constructs play a significant role as direct determinants of user acceptance: (i) performance expectancy – the degree to which an individual believes that using the system would help him or her to attain gains in job performance; (ii) effort expectancy – the degree of convenience with the use of the system; (iii) social influence – the importance of other people’s beliefs when an individual uses the system; and (iv) facilitating conditions – how an individual believes that an organizational and technical infrastructure exists to support use of the system. The supposed key moderators within this framework are gender, age, voluntariness of use, and experience. Although in several models, ‘attitude towards use’, ‘intrinsic motivations’, or ‘attitude towards behavior’ are the most significant determinants of intention, these are not mentioned in the UTAUT. Venkatesh et al. (2003) presumed that attitudes towards using the technology would not have a significant influence.
Stern (2000) developed the value–belief–norm (VBN) theory to examine which factors are related to acceptability of energy policies. Stern and colleagues proposed the VBN theory of environmentalism to explain environmental behavior, including the acceptability of public policies. They proposed that environmental behavior results from personal norms, that is, a feeling of moral obligation to act pro-environmentally. These personal norms are activated by beliefs that environmental conditions threaten the individual values (awareness of consequences) and beliefs that the individual can adopt to reduce this threat (ascription of responsibility). VBN theory (Steg et al., 2005) proposes that these beliefs are dependent on general beliefs on human–environment relations and on relatively stable value orientations. VBN theory was successful in explaining various environmental behaviors, among which consumer behavior, environmental citizenship, willingness to sacrifice, and willingness to reduce car use (Stern et al., 1999; Nordlund & Garvill, 2003).

Schlag and Teubel (1997) defined the following essential issues determining acceptability about traffic measures: problem perception, important aims, mobility-related social norms, knowledge about options, perceived effectiveness and efficiency of the proposed measures, equity (personal outcome expectation), attribution of responsibility, and socio-economic factor.

**Inventory and main indicators in Acceptance/Acceptability research**

This inventory an approach is based on the above-described theories in acceptance.

In the figure above a distinction is made between general indicators (related to the context awareness of the system) and system-specific indicators (directly related to the characteristics of the device). The 14 indicators are considered to be the most relevant that can or will influence...
acceptance. These general and specific indications will influence each other and the level of acceptance. A brief description of every indicator is given.

**General indicators**

**Individual factors**

Gender, age, level of education, and (income) employment are considered to influence how people think ITS and the use of C-ITS. Gender and age are considered as relevant determinants within the performance of driving behavior.

**Attitudes to driving behavior**

Travel behavior, driving style and the choice of vehicle are also related to driving behavior.

**Personal and social aims**

Social aims have been described as the dilemma between social or personal aims and benefits. They assume that a higher valuation of common social aims will be positively related to acceptance.

**Social norms**

Perceived social norms and perceived social pressure refer to the (assumed) opinions of their peers multiplied by the importance of the others’ opinions for the individual. In other words, social norms refer to an individual's assumptions about whether peers would think that he or she should accept the device. It is assumed that peers, e.g. co-workers or specific other road users, will influence the attitudes and behavior of individuals.

**Problem perception**

The extent to which not having certain information or guidance is perceived as a problem is a necessary indication in defining acceptance.

**Responsibility awareness**

Responsibility awareness explains how individual stands in respect to the issue of whether it is the government (others/extrinsic) or the individual (own/intrinsic) that is deemed to be responsible. It is assumed that environment-preserving behavior becomes more likely if individuals perceive the damaging consequences of their own actions on the environment and others, and at the same time ascribe the responsibility for the consequences to themselves.

**Information and knowledge about the device/service**

The level of acceptance can depend on how well informed the respondents are about the problem and about any new device that is to be introduced to solve the problem. The hypothesis may be that the more that people are informed, the higher the acceptance will be. However, better knowledge about a problem can also lead to less acceptance for a specific solution caused by, for instance, awareness of alternatives to solve the problem.
Device-specific indicators

Device-specific beliefs are directly related to the characteristics of the system. Seven indicators could have the potential to define acceptance and how user needs are integrated into the system.

**Perceived efficiency**

Perceived efficiency indicates the possible benefits users expect of a concrete measure (or device) as compared with other measures.

<table>
<thead>
<tr>
<th>Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-ITS better than VMS</td>
</tr>
<tr>
<td>C-ITS better than other info</td>
</tr>
<tr>
<td>Fuel consumption</td>
</tr>
<tr>
<td>Traffic efficiency</td>
</tr>
<tr>
<td>Safety</td>
</tr>
<tr>
<td>Avoiding fines</td>
</tr>
</tbody>
</table>

**Perceived effectiveness**

Effectiveness refers to the system’s functioning according to its design specifications, or in the manner it was intended to function. In most ITS trials, this was found through an evaluation of the technical/ergonomic issues. The main question in these trials remained whether the system assisted the driver in their driving. The level of effectiveness can depend on how interventionist a system is or was.

<table>
<thead>
<tr>
<th>Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Availability</td>
</tr>
<tr>
<td>Completeness</td>
</tr>
<tr>
<td>Correctness</td>
</tr>
<tr>
<td>Accuracy</td>
</tr>
<tr>
<td>Consistency</td>
</tr>
<tr>
<td>Up-to-dateness</td>
</tr>
</tbody>
</table>

**Perceived usability**

Perceived usability is the ability to use the system successfully and with minimal effort. Usability is also an indication for how users understand how the system works. User friendliness can be associated with usability: the users will expect a service that does not distract or overload them with information and (difficult) tasks.

<table>
<thead>
<tr>
<th>Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workload</td>
</tr>
<tr>
<td>HMI (?)</td>
</tr>
</tbody>
</table>

**Perceived usefulness**

Perceived usefulness is related to how the system supports the drivers’ tasks and driving behavior. Usefulness is, in a certain way, different from effectiveness. A potential user can find C-ITS effective in general but not for his own driving behavior. Usefulness is also defined as the degree to which a person believes that using a particular system will enhance his or her performance.
Satisfaction

Satisfaction is one of two factors derived from the items within the ITS acceptance scale that Van der Laan et al. (1997) developed to study user acceptance.

| Useful | Good | Effective | Assisting | Alertness |

Equity

In general, equity refers to the distribution of costs and benefits among affected parties. However, from a psychological viewpoint, perceived justice, integrity, privacy, etc., are basic requirements for acceptability. This may differ from the objective costs and benefits, but equity is an important indicator influencing personal perceptions. The integrity of driver information, privacy, and loss of certain freedom in driving can be an issue for willingness to use C-ITS.

| Privacy |

Affordability/willingness to pay

It may be assumed that socio-economic status will affect acceptance and acceptability, as users will consider ITS as a symbol of status, or they will want to be among the early adopters. On the other hand, affordability will depend on the individual’s budget and/or public/private funding.

References


Annex 4: User Acceptance evaluation - starting from end-user needs

User Acceptance will be mainly defined on how the end-user needs are integrated in the service. Throughout a market point view, these aspects are important to define.

- **Status/relevance of the service:** The user needs to have a clear understanding of the role of the in-car service: The road traffic regulations are legally binding, the C-ITS service has a supportive and purely informative role. The service can be subject to errors.
- **User friendliness/distraction:** The user expects a service which does not distract or overload him with information, e.g.:
  - The driver should receive concise but comprehensive information.
  - No over-burdening, otherwise there will be non-observance
  - No other graphical designs than those agreed by international agreements should be used, in order to prevent misunderstandings
- **Service availability:** The user expects a sufficiently high proportion of driving situations where the service is technically operational including coverage. In particular, service interoperability between regions and country is important.
- **Good informational content of service:**
  - Where the service is operational the end user expects a high rate of completeness of content.
  - Correctness of content including availability of additional information.
- **Accurate timing of the information:** The user expects timely information, i.e. sufficient time for reading and understanding, reaction time, decision time, response time of brakes, time for covering the distance until new information will be provided.
- **Integrity of driver information and respect for drivers’ privacy**
- **Integration in different services and platforms:** The user can expect it to be available on different platforms and devices.

The above described theories and approaches, allows to define evaluation approach on user acceptance.