C-ITS

Quality package

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Preface

EU EIP Sub-Activity 4.1 has so far provided several frameworks to define and assess the quality of data, information and services in various domains of ITS.

The current task is to take a closer look at data and information quality in the context of C-ITS.

This document presents the results in form of a “Quality Package”, containing quality-related definitions and concepts, proposed and agreed by EU EIP partners for the use in Europe. The results are based on evidence from conditions and operating environments in combination with the expert knowledge of the public and private stakeholders involved in the EU EIP quality work.

The document is prepared as part of the sub-activity 4.1 of the EU EIP project.

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1. Introduction

1.1. Background and objective

A major driver in recent discussions on data quality are new technologies such as C-ITS, where new types and big amounts of highly-accurate data will be generated and exchanged between different entities of the transport system. It is expected, that such technologies and novel services will bring a lot of changes to quality frameworks, as elaborated by EU EIP previously, and quality itself.

As a consequence, quality aspects related to these technologies should be explored, eventually redefining the quality criteria and requirements (e.g. looking at "latency" in the range of milliseconds) and exploring new quality assessment methods (e.g. checking the reliability of C-ITS data sources and using C-ITS as an independent ground truth).

The Grant Agreement of the EU EIP project sees the C-ITS Quality work in the context of the individual EU Delegated Regulations:

"Propose European minimum quality requirements and quality assessment practices for all ITS Directive's priority services involving road authorities/operators in a major role."

In fact, a draft for an EU Delegated Regulation for C-ITS has been proposed, however not yet adopted at the time of the EU EIP work. Nevertheless, the need to explore and define C-ITS quality is still imminent, as many C-ITS harmonization and implementation activities across the EU are progressing. Thus, such activities should be considered in the envisioned C-ITS quality task. The Grant Agreement states:

"The collaboration with the C-ITS stakeholder community (e.g. C-ITS platform and further implementation of the EC master plan on C-ITS, Amsterdam group) is described in the relevant sub-activity, i.e. 4.4, and a phase-in of quality work on C-ITS is to be expected."

The concrete quality work is expected to end up in the following result:

"Proposal for quality criteria, minimum quality requirements and quality assessment practices for selected V2I Cooperative ITS services."

This document presents such a proposal in form of a "Quality Package". It contains quality-related definitions and concepts for the data and service provision of C-ITS. It is intended to add quality-related aspects to other stipulations for C-ITS deployments (being set up by standardisation and legislation). Such quality-related aspects are eventually recommended to be applied across all C-ITS deployments in Europe.

1.2. EU EIP sub-activity 4.1

The scope of EU EIP sub-activity 4.1 ("Determining Quality of European ITS Services") is the development of quality requirements and quality assessment practices for all ITS Directive priority services involving the transport and road authorities and operators in a major role, building up on results from EIP and EIP+ and widening the scope to all EU EIP priority services.

Four tasks have been identified to be developed to achieve the objectives of the sub-activity:

- Task 1: Identify stakeholders, value chains, recommended work processes, quality assurance, and introduction paths for road operator relevant ITS Directive priority services.
- Task 2: Propose European minimum quality requirements and quality assessment practices for all ITS Directive's priority services involving road authorities/operators in a major role.
- Task 3: Validate and improve the quality criteria, requirements and assessment practices proposed.
- Task 4: Work towards specifying optimum quality for selected priority services.

The quality definitions in this document were drafted as part of Task 2, proposing minimum Quality Requirements and Quality Assessment methods for C-ITS.

1.3. Definitions

Throughout this document, three elements of quality assessment are elaborated, as it has been done in former Quality Packages (see section 2.1). These are defined as follows:

- Quality Criteria are basic parameters to describe various quality dimensions of a service and the related data.
- Quality Requirements describe (minimum) quality levels to be reached by a C-ITS services, i.e. they populate the above Quality Criteria with concrete target values.
- Quality Assessment Methods represent potential methods for quality assurance and assessment in the responsibility of one or multiple C-ITS actors.

1.4. Document structure

The following work is organised as follows:

- Chapter 2 describes previous works which form the baseline for defining C-ITS quality in this paper. Previous elaborations on quality for conventional ITS as well as for Automated driving are analysed, and put in the context of C-ITS. Further, on-going C-ITS projects in Europe are explored for any existing quality implications.
- Chapter 3 sets the scope for which the quality definitions in this paper are related. It discusses relevant C-ITS services, data categories and data flows, and the "objects being evaluated".
- Chapter 4 introduces a concept of "Data Use Cases", which are referenced for the subsequent quality definitions.
- Chapter 5 describes the proposed Quality Criteria for C-ITS services.
- Chapter 6 describes the proposed Quality Requirements for C-ITS services.
- Chapter 7 describes the proposed Quality Assessment Methods for C-ITS services, indicating their applicability for different uses and feasibility for studying different quality criteria.
- Chapter 8 contains conclusions on the scope and the proposed use of this Quality Package.

The Quality Package has been elaborated by EU EIP sub-activity 4.1, considering expertise of European stakeholders and practitioners on this field.

2. Previous works

2.1. Previous EU EIP Quality Packages

EU EIP (and its antecessor projects) has previously developed frameworks how to commonly describe and document quality in the context of different ITS data domains. The work has been so far related to the different data domains of ITS Directive 2010/40/EU[1] and its corresponding Delegated Regulations.

These frameworks have been published as so-called Quality Packages, each mapping quality aspects to the various Delegated Regulations:

- Safety-related traffic information (SRTI) and Real-time traffic information (RTTI): Quality Package[2]
- Multimodal Travel Information Services (MMTIS): Quality Package[3]
- Intelligent Truck Parking Services (ITPS): Quality Package[4]

These Quality Packages contain quality-related definitions and concepts, as proposed and agreed by EU EIP partners for the use in Europe. They include sets of quality criteria, quality requirements and corresponding assessment methods. Some of the Quality Packages have been validated since their initial publication, involving stakeholders and testing data qualities in real-world applications. Such validation resulted in improved and updated Quality Packages.

2.2. Quality perspectives in on-going C-ITS projects

Several on-going C-ITS projects have been analysed by EU EIP sub-activity 4.1, in order to explore existing quality concepts and perspectives in these projects, as a potential input for the quality definitions made in this C-ITS Quality Package. These analysed projects include:

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

[2] Kulmala, R. et al. (2019), "Quality Package for safety-related and real-time information services", Deliverable by EU EIP sub-activity 4.1, https://itsforum2020.com/achievement/its-quality-frameworks/

[3] Niculescu, M., Jansen, M., Barr, J., Lubrich, P. (2019): Multimodal Travel Information Services (MMTIS): Quality Package, Deliverable by EU EIP sub-activity 4.1, https://itsforum2020.com/achievement/its-quality-frameworks/

[4] Milea, R.D., Vaduva, F.C., Niculescu, M., Lubrich, P. (2019): Intelligent Truck Parking Services (ITPS): Quality package, Deliverable by EU EIP sub-activity 4.1, https://itsforum2020.com/achievement/its-quality-frameworks/

- C-ROADS[5]
- C-ITS-Corridor[6]
- NordicWay[7]
- Intercor[8]

As a starting point, contents and set-ups of these projects were introduced during an EU EIP kick-off session on C-ITS Quality (March 2019), indicating potential quality issues within these projects. As a preliminary conclusion, quality aspects on data and information seem to be barely covered at this point of time. Instead, these projects seem to focus more on technical aspects such as interoperability.

As a next step, stakeholders from the C-ITS projects were interviewed, in order to go more into details regarding quality perspectives of the involved partners. In particular, it was asked if and to which extend quality aspects have been covered so far, and which quality aspects are relevant.

A template for the questionnaire is shown in Annex I.

The results of the questionnaire are summarised as follows:

- In question no. 2, the C-ITS services being deployed in the project were assessed. In total, 11 “Day 1” services are being implemented by the interviewees, which is giving a quite wide range of possible C-ITS use cases for examining closely. (see the figure below)

[5] https://www.c-roads.eu/platform.html
[6] https://c-its-korridor.de/?menuId=1&sp=en
[7] https://www.nordicway.net
[8] https://intercor-project.eu

	#1	#2	#3	#3	#4
	InterCor	C-ITS Corridor	C-Roads	NordicWay	C-Roads
	(NL)	(DE)	(DE)	(FI)	(ES)
2. What C-ITS services are developed?					
Road works warning (RWW)	x	x	x	x	x
In-vehicle signage (IVS)	x			x	x
Probe vehicle data (PVD)	x	x	x	x	x
Green light optimal speed advisory (GLOSA)	x		x		
Emergency vehicle approaching (EVA)			x	x	x
Shockwave damping (SWD)			x		x
Traffic signal priority request by designated vehicles (TSP)			x	x	
Traffic jam ahead warning (TJW)			x	x	x
Maintenance vehicle warning (MVW)			x		
Slow or stationary vehicle(s)				x	x
Weather conditions				x	x
Other hazardous notifications					x

Table 1. Evaluation of question no. 2 "What Day 1 C-ITS service do you develop?" (C-ITS project liaison questionnaire by EU EIP sub-activity 4.1)

- In question no. 4, generic expectations towards data by a data user within a project were explored. (This is a common approach to capture relevant quality aspects from an individual user perspective, and therefore find out if the data fits well for the user's tasks. This approach has been proven before in the academia for data quality[9].) The highest rates were given to the parameters accessibility, understandability and processability of data. However, all other parameters (except re-usability) were given high ratings, indicating high expectations to data in various aspects, see the figure below.

[9] Beyond Accuracy: What Data Quality Means to Data Consumers, Wang, R., Strong, D. M., Journal of Management Information Systems, Vol. 12, No. 4, 1996

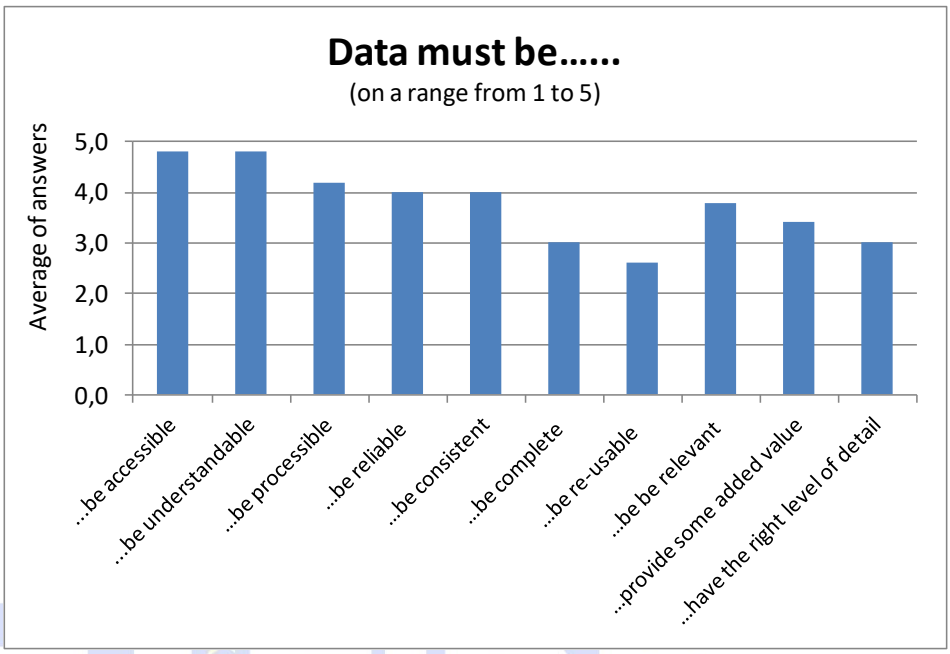

Figure 1. Evaluation of question no. 4 "In general, what are your expectations towards characteristics of the data?" (C-ITS project liaison questionnaire by EU EIP sub-activity 4.1)

- In question no. 10, typical quality criteria (corresponding to the former EU EIP Quality packages) were examined for interpretation and relevance within the project. For Quality Criteria, it was either stated that they all are "applied without level definition" or "not applied at all". This indicates some uncertainty of the responders on Quality Criteria within their projects. As these projects often aim to demonstrate the technical feasibility of C-ITS services, we imply that some Criteria (such as "Completeness") must be considered somehow (otherwise the service would be maybe evaluated as "incomplete"). However, such Quality dimensions are not expressed explicitly in these projects.
- The same conclusion is made for concrete Quality Levels: it was often stated that no Quality Levels have been defined in the projects. Instead, the upcoming evaluations of these projects are likely to give indications on "possible" quality levels. This is a rather pragmatic approach, looking at the feasibility of C-ITS services, while this C-ITS Quality Package intends to set (minimum) quality levels as benchmarks to be met by any C-ITS deployment.
- For Assessment Methods (question no. 11), often the (upcoming) technical evaluation of a C-ITS project was cited. Further, potential "communication errors" are stated which may occur during a project. Consequently, Quality Assessment in this context seem to be rather techniques for error detection (any maybe correction)

within the system set-up, and not really an external Quality Assurance, as e.g. an instrument to evaluate and report data qualities.

- In question no. 13, the responders gave a personal feeling on the consideration of data quality within their projects so far. Accordingly, either no consideration or only partial consideration (i.e. only looking on quality aspects within the project, but not for a roll-out of the tested C-ITS service) is stated. This implies that there is some demand for a C-ITS Quality framework, as being presented here.

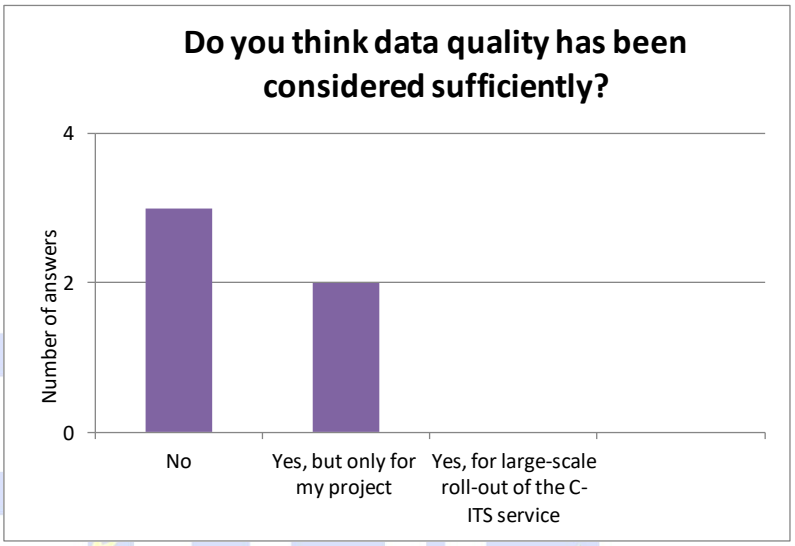

Figure 2. Evaluation of question no. 13 "In your particular project, do you think data quality has been considered sufficiently?" (C-ITS project liaison questionnaire by EU EIP sub-activity 4.1)

Further C-ITS actor perspectives on quality were also examined in another questionnaire by WG 1, which focuses on organisational aspects, of the C-Roads Platform[10]. There was an open question raised: *"How have you or how do you think C-ITS Service quality and service consistency could be ensured in a multi-actor and/or multi-channel delivery environment (e.g. message quality & relevancy, no conflict, minimal duplication…)?".* According to the responses given by more than 40 C-ITS actors, the main issues relate to the need for consistently used data standards (or protocols, formats), the need for commonly defined quality indicators (or levels) and the usage of assessment (or monitoring, validation) of C-ITS deployments. The latter two issues will be addressed by this C-ITS Quality Package. However, the responses gave no concrete hints how to resolve the issues, so this Quality Package needs to give corresponding answers.

[10] C-ITS – REPORT ON "LESSONS LEARNED" C-Roads Platform Working Group 1 - C-ITS Organisation, Draft from May 2020

Further quality insights from these C-ITS projects were sought in the evaluation activities within these projects. Some interim results from such evaluations were presented in the "C-ITS deployment and evaluation workshop" (Brussels, November 05+06[11]). In the current evaluation activities, mostly user acceptance and impacts are evaluated. Sometimes some technical aspects are also evaluated, e.g. time delays which may be translated into the EU EIP Quality Criterion "Timeliness". However, there are no hints for other Quality Criteria in the evaluations so far.

As a conclusion, the analyses of questionnaires and evaluation activities from the C-ITS projects give only little inputs to determine concrete C-ITS quality criteria, quality requirements or assessment methods. However, there are some indications on the importance of working on the present C-ITS Quality Package, and on specific technical requirements, which may be translated into quality criteria. These implications will be considered in the C-ITS Quality Package.

2.3. C-ITS Delegated Regulation

The (planned) Delegated Regulation aimed to foster the Europe-wide implementation of the so-called „Day 1 applications" and focused on security/trust, service harmonisation and communication/technology aspects.

However, data quality aspects, or even concrete obligations, are only a side-issue here.

Specific quality aspects can be found in „Annex 1 - service profiles for the C-ITS priority services". This annex relates to a data element called „informationQuality" from the ETSI standardisation for Decentralized Environmental Notification Message (DENM), at least for V2V use cases. According to this Annex, this data element should describe the fulfilment of the so-called, pre-defined triggering conditions, i.e. describing how an event is detected. They usually can be set to pre-defined values in the range of "0" to "3". E.g. for the use case "STATIONARY VEHICLE WARNING - STOPPED VEHICLE", the value "0" describes a condition which is not compliant at all with the pre-defined triggering conditions, while the value "3" is used when a set conditions is in place, which clearly indicate a stopped vehicle in reality (ignition is off, parking brake is on, etc.).

In the definition part of this Quality Package, a suggestion is made how to embed the data element "informationQuality" as a C-ITS Quality criterion (see section 5).

It is understood that this EU EIP Quality Package needs to elaborate a wider spectrum of data quality definitions for the C-ITS domain, in addition to the data element

[11] https://www.its-platform.eu/highlights/c-roads-and-eu-eip-c-its-deployment-workshop-proceedings-now-online

"informationQuality". Eventually, the EU EIP outcomes may serve as an (informal) addition to data requirements laid out in the C-ITS Delegated Regulation.

2.4. EIP+ White Paper on Cooperative ITS Services

This paper[12] was developed in the former EIP+ project. A major outcome here was a vision how quality requirements for individual RTTI/SRTI services could be enhanced with C-ITS technology. This was even quantified for individual quality criteria and summarised in tables. These tables compare quality requirements which may be achieved via state-of-the-art information services, on the one hand, with (Day 1) C-ITS information services, on the other hand. A presumption here was a 100% penetration rate on the perceiving and sending site, and communication networks that operate properly. Looking at the potentials of C-ITS information services, a statement was made that *"… even a star-level higher than the 4 star-level can be reached in some cases."*

An example for such a table is shown below.

It is noted that the quality criteria listed here correspond to the previous definitions within the Quality work for SRTI. Any amendments or re-redefinitions specifically to C-ITS have not been considered.

[12] EIP+ White Paper on Cooperative ITS Services, Deliverable 1 of EIP+ Sub-Activity 4.1, Version 1.0, 2016, https://www.its-platform.eu/filedepot_download/2192/6241

Table 2: Table with Quality Requirements from the EIP+ White Paper

	Criteria	Road Works Warning (for short term road works), SRTI, event based information			
		ITS (Warning via radio broadcast or RDS-TMC)		C-ITS (RWW via ITS-R on warning trailer (DENM))	
Level of Service	**Geographical coverage**	★	Best effort	★★★★	100%
	Availability	★	Best effort	★★★★	99,9% (~365 days a year)
Level of Quality	**Timeliness (start)**	★	Best effort	>★★★★	Event is detected immediately after starting road works
	Timeliness (update)	★	Best effort	>★★★★	End or change of event is detected immediately
	Latency (content side)	★	Best effort	(>)★★★★	< 2 min
	Location accuracy Road	★★	link between intersections	>★★★★	exact GPS-Position
	Error rate	★	Best effort	n/a	
	Event coverage	★★★	> 80% of all occurring Road works	(>)★★★★	>> 90% of all occuring events

European ITS Platform

2.5. Road operator's view on C-ITS Quality

C-ITS applications will affect the way how all elements of the transportation system interact. One important element is road infrastructure, usually in the hand of road operators. With C-ITS deployment, there are many opportunities for road operators, in particular with the prospect to enhance safety. There are also many challenges that need specific attention.

In a recent position paper by the World Road Association[13], such implications and recommendations for road operators have been formulated in a generic way. Data quality is seen here as a key challenge to enable C-ITS applications with the envisioned effects, e.g. for safety.

[13] World Road Association (PIARC): Connected Vehicles - Challenges and Opportunities for Road Operators, 2019

The paper lists some relevant quality criteria ("accuracy, validity/integrity, completeness, consistency, timeliness, availability"), and states about quality requirements:

"The different C-ITS applications require access to data with varying levels of quality requirements. Real-time safety-critical C-ITS applications, for example, have strict data timeliness requirements compared to predictive traffic services/applications."

Consequently, quality requirements have to be set individually depending on a particular C-ITS application. Also, these requirements *"need to be quantified as much as possible to avoid any ambiguities."*

Further, factors that might affect data quality are listed such as the various data sources, communication channels, and data processing.

This has implications on assessment methods. With *"a clear set of guidance on the generation and collection processes for the different types of data", data quality can be commonly assessed (and potentially improved). It is thus required to have "a common framework for the assessment of data quality that defines clear processes for assessing and reporting data quality".*

Even if this work does not give detailed suggestions for definitions of C-ITS quality, some generic implications are given, which will be considered in this Quality Package.

2.6. Quality of data for Automated Driving

Several references exist which deal with quality aspects of data in the domain of Automated Driving.

The DIRIZON project explored data quality requirements placed by automated vehicles[14]. Three different use cases involving public road authorities were analysed: the provision of HD maps; the distribution of digital traffic regulations; and infrastructure support services for CAD. The data requirements are based on an identification of data types and data flows relevant for each of the use cases.

As a baseline for defining Quality Criteria and Requirements, the recent EU EIP Quality Package for SRTI and RTTI (see section 2.1) was referenced, among others. Eventually, nine data quality criteria were defined. These include some criteria from EU EIP (sometimes with minor redefinitions), added by two new criteria "variance" and "predictability" which are referenced from some Dutch research on Automated Driving.

[14] Malone, K., Schreuder, M., Berkers, F., Helfert, K., Radics, L., Boehm, M., Lüpges, C., Kleine, C., Mann, M., Tucker, M., Kakouris, E. (2019): Digitalisation and Automation: Implications for use cases, Identification of Stakeholders and Data Needs and Requirements. Deliverable 3.1 of the DIRIZON project, commissioned by CEDR, October, 2019

For each criterion, the DIRIZON project defines data quality levels “low”, “medium” and “high”. These levels are expressed quantitatively in most cases, and are distinguished by four different data categories (static data, traffic data, safety-related events or conditions, and dynamic regulations). However, no levels for the new criteria ”variance” and “predictability” are defined. It is further stated that these level definitions serve “as a proposal, to be discussed among Road Operators and with other actors for usefulness and desirability”. Thus, no validation has been made of these definitions so far.

Another reference is a so-called Quality Model developed for “Ko-HAF”, a recent pilot project of Automated Driving in Germany[15]. Looking at data flows and data requirements relevant for this particular project, this Quality Model established a set of Quality Parameters, Quality Requirements and Quality Methods. Again, the EU EIP Quality Package for SRTI and RTTI was referenced.

The quality perspective was focused on data embedded in a HD map, and corresponding data inputs and outputs. The Quality Parameters were introduced in a hierarchical system, consisting of 6 “Quality Criteria” which are broken down into 16 “Quality Indicators” and 22 “Quality Metrics”. While the “Criteria” are rather abstract, the “Metrics” describe measurable values (as quantitatively as possible), regarding an object to be evaluated. An example is given below:

→ Quality criterion: “Availability”

→ Quality indicator: “Scope of recorded objects/events”

→ Quality metric: “What kind of objects/events is recorded?”

This hierarchy approach considers the variability of quality aspects, depending on the use case, data category and quality relevance of sub-elements in projects of Automated Driving. Besides such parameters, examples for (quantitative) quality requirements are given based pragmatically on experiences in the Ko-HAF project. Lastly, example assessment methods are described conceptually, also relating to the specific Ko-HAF environment.

The author states that such quality model represents a first approach to define data quality concepts in the domain of Automated Driving, but it is only backed up by a limited project environment. Consequently, open questions and future actions are formulated regarding the validation and concretisation of such quality concepts, across all actors and stakeholders of Automated Driving.

[15] Lubrich P. (2019): A practical approach for defining and assessing data quality in automated driving. In: Lu, M. (Ed.) (2019). Cooperative Intelligent Transport Systems: Towards High-Level Automated Driving. IET (Institution of Engineering and Technology), London.

3. Scope of C-ITS Quality

3.1. Types of C-ITS services

The C-ITS Platform[16] defines so-called C-ITS "Day 1" services, which are proposed to be deployed first, because of the expected benefits and existing maturity.

To rely on experience from most-mature services, this C-ITS Quality Package will first focus on two selected C-ITS "Day 1" services:

- Road Works Warning (RWW)
- Weather Conditions Warning (WCW)

For comparison, the other "Day 1" services are:

- Emergency Brake Light
- Emergency Vehicle Approaching (EVA)
- Slow or Stationary Vehicle(s)
- Traffic Jam Ahead Warning (TJW)
- In-Vehicle Signage (IVS)
- In-Vehicle Speed Limits
- Probe Vehicle Data (PVD)
- Shockwave Damping (SWD)
- Signal Violation / Intersection Safety
- Traffic Signal Priority request by designated vehicles (TSP)
- Green Light Optimal Speed Advisory (GLOSA)

It is suggested to also consider these remaining C-ITS "Day 1" services, as long as there are sufficient inputs und references, to eventually gain a full picture of possible C-ITS applications.

3.2. "Objects being evaluated"

In the standardisation of Quality Management Systems (QMS), quality is understood as a *„degree to which a set of inherent characteristics of an object fulfils requirements"*[17]. The question now is what an "object" represents in the field of C-ITS quality.

[16] C-ITS Platform, Final Report, January 2016

[17] ISO 9000:2015(en), Quality management systems — Fundamentals and vocabulary. Geneva: International Organization for Standardization; 2015.

On a higher level, relevant quality objects in the ITS domain can be found in the standardisation work for ITS[18], defining quality dimensions as follows:

- System Quality (e.g. availability of an entire technical system)
- Device Quality (e.g. reliability of devices within a system)
- Functional Quality (e.g. efficiency of an expected function of the system)
- Data Quality (e.g. accuracy of data used for a function)

Following the nature of previous EU EIP Quality Packages, the criteria of this C-ITS Quality Package relate mainly to the category "Data Quality". As the technical provision of data is also relevant, "System Quality" and "Device Quality" are touched on. On the other hand, "Functional Quality" is covered elsewhere, e.g. in the evaluation activities of current C-ITS projects.

On a more specific level, "objects" can be found in the context of the provision and transmission of data and information. The SRTI/RTTI Quality Package (see section 2.1) defines two such "objects":

- The quality of the provision and transmission of data is expressed via "Level of Service" criteria. In this context, the "object" is typically a data-delivery service, e.g. installed at a traffic management centre and connected to a National Access Point (NAP).
- The quality of the data as such is expressed via "Level of Quality" criteria. In this context, the "object" is typically a data set containing messages on road status or events. Such data sets are often formatted in a standardised way (e.g. DATEX II) and published in NAPs.

Both definitions are also transferable for C-ITS. However, they imply an aggregated view, either looking at quality levels of an entire data service, or at quality levels resulting from multiple messages. For example, the SRTI/RTTI Quality Package contains the quality criterion "Classification correctness", which is calculated based on the sum of reported events. If there were one single non-correct message, this would not necessarily impede the quality level of the entire data set.

For C-ITS services, also the quality of a single message may be important, as there are specific safety and efficiency implications related to each single message. For example, one single incorrect signal timing message (in the GLOSA use case) may cause critical vehicle reactions, so the quality level here has to be looked on separately.

Eventually, the question is whether to relate C-ITS quality definitions to individual message quality (on a micro level) or to aggregated information quality (on a macro level)

[18] CEN/TC 278: „Intelligent transport systems—Traffic management systems—Status, fault and quality requirements"

It is suggested to define a suitable aggregation level depending on the applicability of specific "Data Use Cases" (see later in section 3.4) and the corresponding definitions of Quality Criteria (see later in section 4).

3.3. Data actors, data categories and data flows

Regarding data categories, the scope of the SRTI/RTTI Quality Package was referenced to the data categories of the relevant Delegated Regulations of ITS Directive 2010/40/EU. Thus, there is a clearly defined list of data categories, both for SRTI and RTTI.

For C-ITS applications, however, the relevant data categories depend on the deployed service type. In the questionnaire exercise with C-ITS projects (see section 2.2), some data categories were listed in the context of each C-ITS service. These include:

- Road Works Warning (RWW): status of warning trailer, road work info
- Weather Condition Warning (WCW): bad weather warnings
- Emergency Brake Light: vehicle status information
- Emergency Vehicle Approaching (EVA): location of an emergency vehicle
- Slow or Stationary Vehicle(s): location of broken-down vehicles, obstacles, accidents
- Traffic Jam Ahead Warning (TJW): location and speed of the road users
- In-Vehicle Signage (IVS): data from TCC (or sub-centers)
- In-Vehicle Speed Limits: data from TCC (or sub-centers)
- Probe Vehicle Data (PVD): location and speed of road users
- Shockwave Damping (SWD): location and speed of road users, data from TCC (or sub-centers)
- Traffic Signal Priority request by designated vehicles (TSP): location of the emergency vehicle
- Green Light Optimal Speed Advisory (GLOSA): signal phase

It is noted that the list above is not an "official" or complete list of all C-ITS data categories, but just examples from our investigation. Besides this, some specifications of C-ITS projects reveal which data is communicated among the various C-ITS elements. However, a complete list of all relevant data categories across all C-ITS deployments and "Day 1" services has not been identified so far.

Regarding data flows, the scope the RTTI/SRTI Quality Package was referenced to the Value Chain of Traffic Information. The elaborated definitions were limited to the content side of the Value Chain, see the next figure. Corresponding definitions for the service side were left to Service Providers, i.e. outside the responsibility of road authorities.

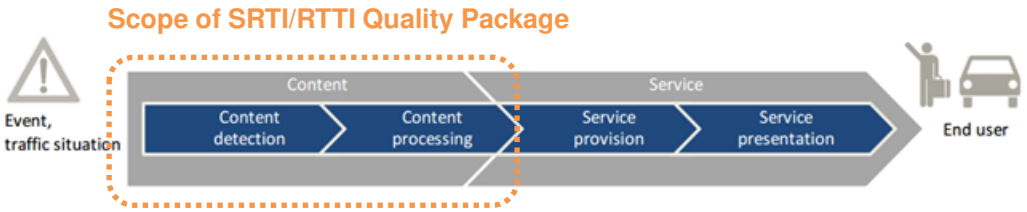

Figure 3. Value Chain of Traffic Information, as applied for the RTTI/SRTI Quality Package (based on TISA[19])

The concept of the Value Chain implies a rather linear information flow and a clear assignment of actors to individual elements of such flow. In C-ITS data-ecosystems, however, the information chains may become far more complex, as seen from the French C-ITS implementation below.

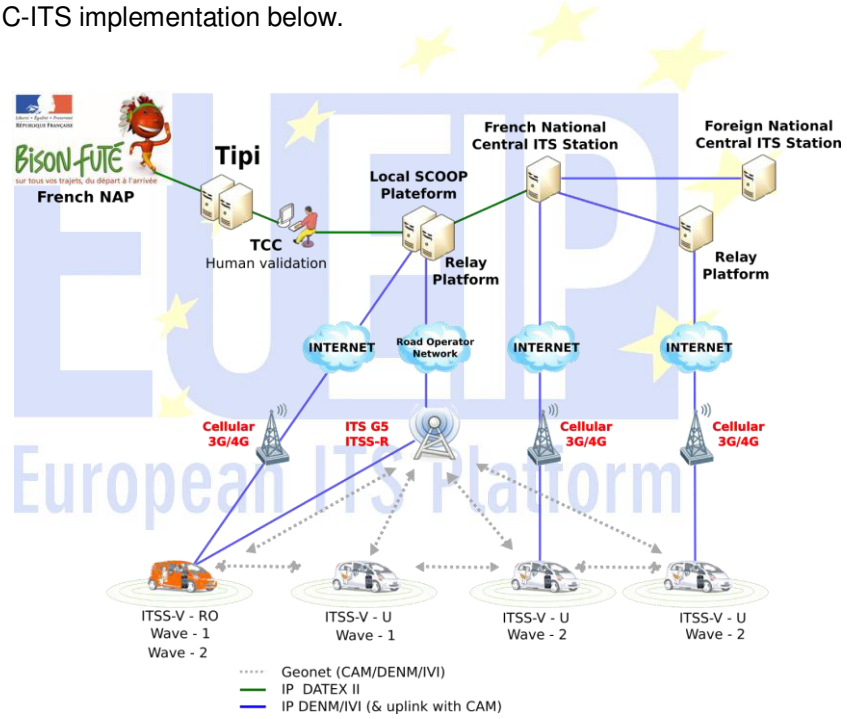

Figure 4. Implementation of C-ITS data ecosystem in France (based on SCOOP and C-ROADS)

[19] TISA (2012). Terms and Definitions for the Traffic and Travel Information Value Chain, Terms and Definitions EO12013, Traveller Information Services Association (TISA), Brussels

Important actors of such data ecosystems are:

- R-ITS-S = ITS Roadside station
- V-ITS-S = ITS Vehicle Station
- C-ITS-S = ITS Central Station
- TCC = Traffic Control Centre
- NAP = National Access Point

The EIP+ White Paper lays out concepts of the Value Chain for different C-ITS services, assigning the above actors to parts of the Value Chain. Similarly, Value Chain concepts have been defined in frame of the C-ITS Corridor and C-ROADS. The following figure shows an example of such concept for Road Work Warning (RWW) services from the EIP+ White Paper.

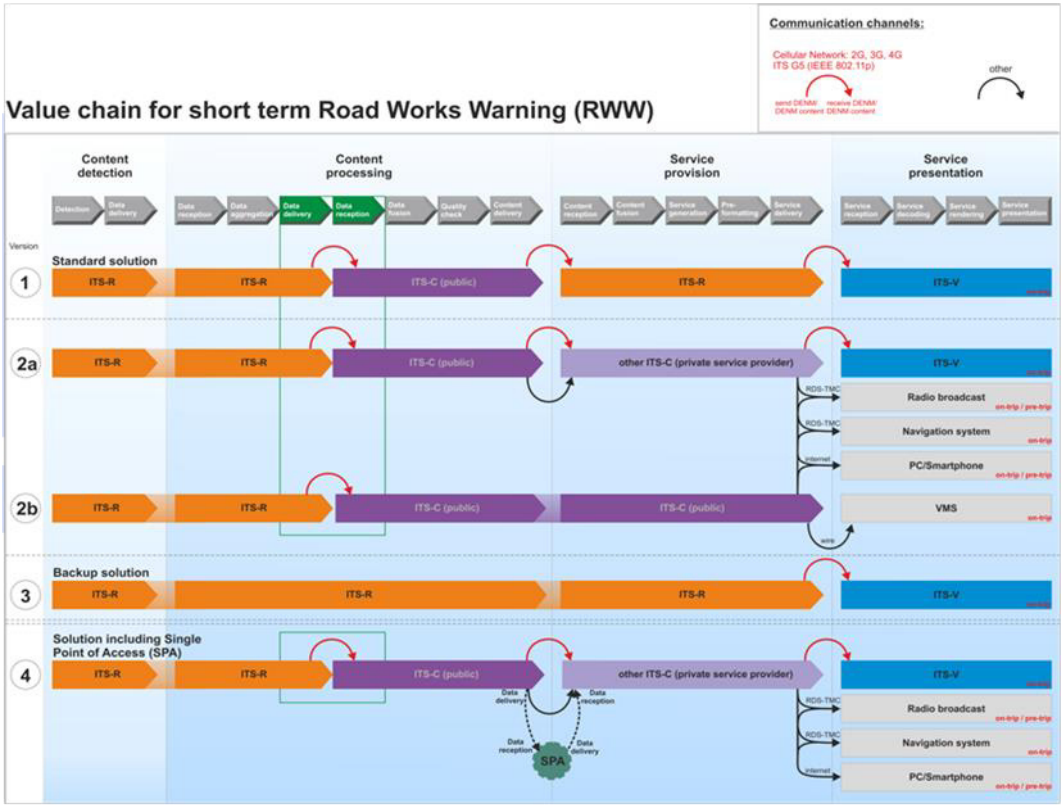

Figure 5. Value chain of traffic information for short term road works (Source: EIP+ White Paper)

As shown, there are different variants for such concepts, depending on the choice of system architecture, i.e. depending on which actors and communication flows are enabled. Sometimes, the communication flows include Nation Access Points (NAPs), which distribute C-ITS information via service providers to road user, as it is done today with

conventional SRTI/RTTI services. In other cases, direct communication to road users (via cellular or ETSI ITS G5) is deployed. This makes it difficult to find a “general” value chain concept, to which quality definitions could be related.

4. Concept of Data Use Cases

To avoid the above problem of complexity regarding data categories and data flows, as identified in the scoping section above, it is suggested to start with C-ITS quality definitions for selected, specific “Data Use Cases”. They describe parts of the system architectures of specific C-ITS deployments, i.e. they reflect partial data categories and data flows, and touch on specific elements of the Value Chain.

This way, quality definitions can be elaborated in a clear context of a single use case, and thus can be mapped to current C-ITS deployments. This makes it easier to define Quality Criteria, rather than looking at an entire data ecosystem or at any data use cases. In a next step, such definitions may be scaled up to final quality definitions, independent of a single use case.

A few initial Data Use Cases have been selected as a starting point for the C-ITS quality definitions. The selection is based on the following criteria:

- There is some “maturity” regarding the respective data flows, e.g. in concrete specifications of data flows with a C-ITS project.
- Road operators play an active role within the data flow (the quality definitions are mainly targeted to road operators, as done in the previous EU EIP Quality Packages).
- The data flows include some new data sources and/or communication techniques towards the traveller. (In contrast: there might be data from conventional SRTI/RTTI services contributing to C-ITS services. For these data, the previous SRTI/RTTI Quality Package is referenced.)

The initial Data Use Cases have been derived from current C-ITS deployments. One reference was the system architecture from the C-ITS-Corridor project in Germany, which fosters the Road Works Warning (RWW) service. Here, connected warning trailers inform approaching drivers about the status and location of the corresponding road works. Based on the system architecture, there are two different communication channels to the driver, resulting in two different Data Use Cases. The next figures illustrate these two Data Use Case, based on the C-ITS-Corridor project.

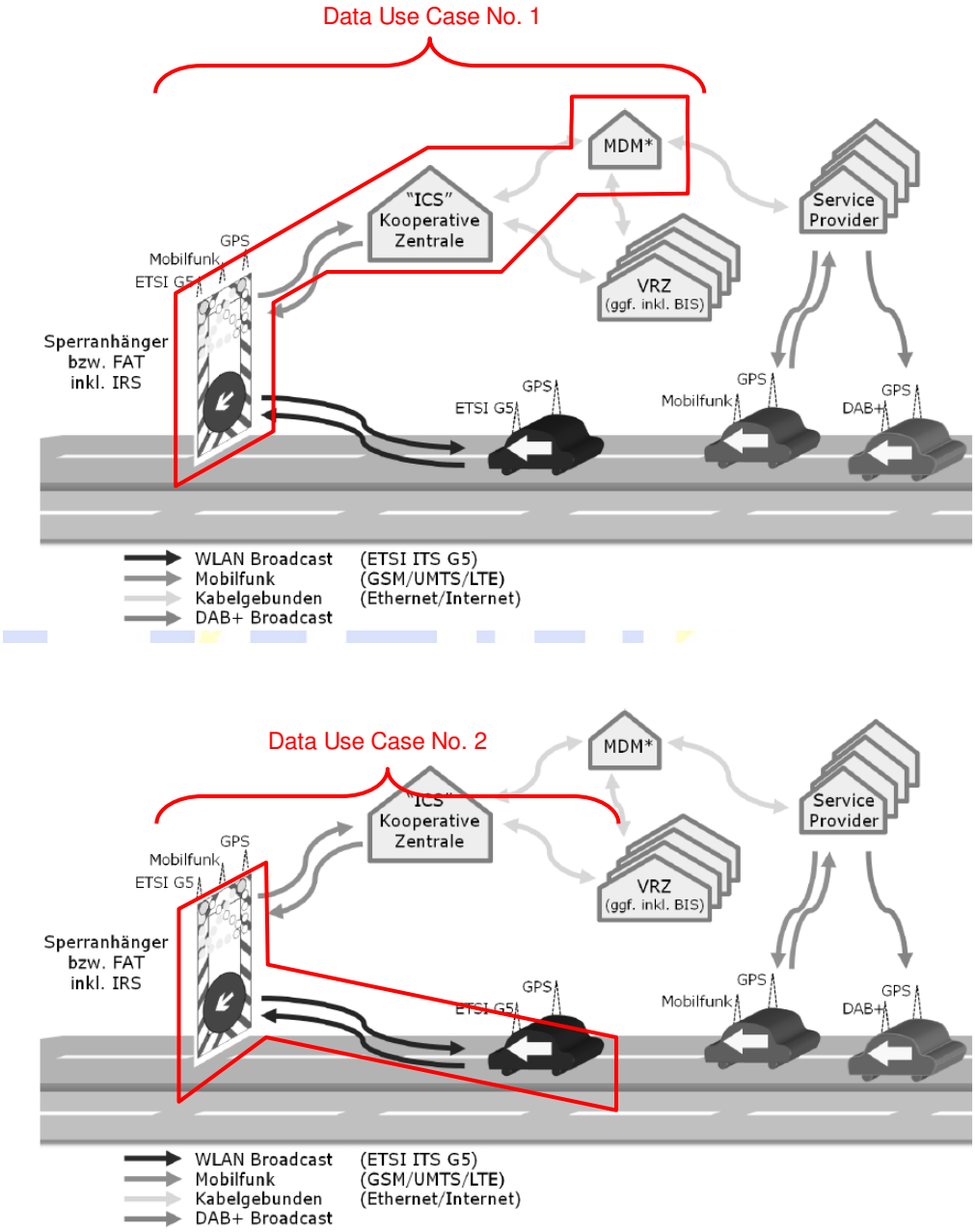

Figure 6. Definition of Data Use Cases no.1 and 2, based on the C-ITS-Corridor project in Germany[20]

[20] Cooperative ITS Corridor, Gesamtarchitektur, Version 2.2, Bundesministerium für Verkehr und digitale Infrastruktur, 2019

Further Data Use Cases no. 3 and 4 have been defined for Weather Conditions Warning (WCW) services.

All Data Use Cases handle events which are detected “live” within the traffic environment by so called ITS stations, i.e. vehicles or infrastructure elements, thus enabling a new, highly-granular information source.

In Data Use Cases no. 1 and 3, this information is eventually taken over via a TCC to a NAP, from where it is disseminated to information providers, as it is done today. In these cases, the Value Chain is covered up to the step “Content processing”.

In contrast, Data Use Cases no. 2 and 4 handle direct information between infrastructure elements and the vehicle, i.e. vehicles receive relevant information en-route via roadside units, thus enabling a new, short-distance way to communicate to travellers. Eventually, this information is presented via on-board units. In these cases, the Value Chain is covered up to the step “Service provision”.

The four initial Data Use Cases are summarised in the following table.

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Table 3: Four initial Data Use Cases

Data use case		C-ITS Service	Data Supplier	Data Receiver	Communi-cation Techno-logy	Data categories	Ref.	Elements of Value chain			
No.	Name							Content detection	Content processing	Service provision	Service presentation
1	Warning trailer status data to NAP	RWW	Warning trailer	NAP via C-ITS-S and TMC	Cellular, cable, proprietary format	Position of warning trailer, status of warning trailer, …	[21] [22]	x	x		
2	Road work information from warning trailer to vehicle	RWW	Warning trailer	Vehicle	WLAN, DENM	Same as above, optionally enriched by road work information from TMC	[23] [24] [25]	x	x	x	
3	Weather information from road side stations to NAP	WCW	Road side station (originating from passing vehicles)	NAP via C-ITS-R, C-ITS-S and TMC	Cellular, cable, proprietary format	Location and type of weather hazard	[26]	x	x		
4	Weather information from weather station to vehicle	WCW	Weather station	Vehicle	Cellular, cable, WLAN, proprietary format, DENM	Location and type of weather hazard	[27]	x	x	x	

European ITS Platform

[21] "Informationsweg 1" according to: Cooperative ITS Corridor, Gesamtarchitektur, Version 2.2, Bundesministerium für Verkehr und digitale Infrastruktur, 2019

[22] "basic service" or Version 1, 2a, 2b, 4 of Figure 11 according to: EIP+ White Paper on Cooperative ITS Services, Deliverable 1 of EIP+ Sub-Activity 4.1, Version 1.0, 2016

[23] "Informationsweg 2" according to: Cooperative ITS Corridor, Gesamtarchitektur, Version 2.2, Bundesministerium für Verkehr und digitale Infrastruktur, 2019

[24] Use Case "Road Works – Mobile" / „Standalone Mode" or „Augmented Mode" according to: C-Roads Platform Working Group 2 Technical Aspects: Common C-ITS Service Definitions, Version 1.4

[25] "standalone service" or Version 3 of Figure 11 according to: EIP+ White Paper on Cooperative ITS Services, Deliverable 1 of EIP+ Sub-Activity 4.1, Version 1.0, 2016

[26] Version 1b, 3a of Figure 14 according to: EIP+ White Paper on Cooperative ITS Services, Deliverable 1 of EIP+ Sub-Activity 4.1, Version 1.0, 2016

[27] Version 2 of Figure 14 according to: EIP+ White Paper on Cooperative ITS Services, Deliverable 1 of EIP+ Sub-Activity 4.1, Version 1.0, 2016

5. Quality Criteria

5.1. Introduction

The goal of this step is to set up relevant Quality Criteria and their corresponding definitions.

A first baseline is found in the EU EIP Quality Package for SRTI/RTTI (see section 2.1). This work contains a set of two quality criteria in the category “Level of Service” (describing the provision of data) and nine quality criteria in the category “Level of Quality” (describing the data as such).

In addition, quality aspects from existing specifications for C-ITS data exchange, namely ETSI standards, were taken into consideration. The quality concepts from both ETSI standards and the EU EIP Quality Criteria were compared. Based on this, overlaps and correlations between these two concepts were discussed.

Lastly, quality definitions for Automated Driving were reviewed, see the references in section 2.6. In these references, Quality Criteria have been introduced for various data types required for the operation of Automated Driving. However, it is noted that the data types for Automated Driving may extend the scope of current C-ITS applications[28].

The definition of Quality Criteria was elaborated in an iterative process with the EU EIP working group. In particular, several interactive sessions to discuss and to concretise the definitions of Quality Criteria were held. The goal was to find a conclusion on the definitions of each quality criterion, back up these definitions with graphical examples, and clear out open questions. As a result, a set of proposed Quality Criteria including their definitions, and some arguments behind such proposal, is introduced below. The definitions are established for the four predefined “Data Use Cases” (see section 4). Then, an aggregated, generic definition is given with a perspective on all possible C-ITS applications and data flows.

The definitions are accompanied with some illustrations for Data Use Case no. 1 (Road Works Warning use case), explaining how the introduced Quality Criteria can be applied in practice. The symbols used in these illustrations are explained in the figure below.

[28] For example, a high-definition (HD) map is an important support element for CAD, allowing e.g. precise positioning of automated vehicles. Such a map would contain various data contents about the road environment in high granularity. Thus, such data requirements are not comparable for C-ITS applications with conventional vehicles.

Figure 7. Symbols used in illustrations

Finally, some discussion items are summarised which came up during the definitions sessions with the EU EIP partners. Here, outstanding questions and a positioning from EU EIP partners on these questions are noted.

5.2. Availability

Availability has been previously defined by EU EIP as time percentage for which a (content provision) service is offered. This definition still makes sense for C-ITS, however it may be specified which elements of the service are actually offered. For C-ITS, it is proposed to relate Availability to the functionality of C-ITS system elements along the communication chain being assessed, in accordance to some predefined specifications, which in turn are defined somewhere else (e.g. as service levels for C-ITS deployments).

- **Definition for Data Use Case No. 1**

  Average availability for all operating* connected warning trailers, including the communication chain up to data input at a NAP.
- **Definition for Data Use Case No. 2**

  Average availability for all operating* connected warning trailers, including the communication chain up to passing, connected vehicles.
- **Definition for Data Use Case No. 3**

  Average availability for all operating* road side stations, including the communication chain up to data input at a NAP.
- **Definition for Data Use Case No. 4**

  Average availability for all operating* connected weather stations, including the communication chain up to passing, connected vehicles.

- **Generic Definition**

  Average availability for all operating* connected data senders, including the communication chain up to the data receiver.

Usage Notes:

The criterion may be expressed as e.g. “available during hours from x to z” or “available at percentage of the daily time”.

Whenever there are multiple data senders, e.g. many road works warning trailers, the calculation is to be calculated in two steps:

- Step 1: “Individual Availability” = operational* period for one single operating connected trailer, related to its deployment time on the road.
- Step 2: “Overall Availability” = average of the individual availabilities from Step 1

Only the result from step 2 is to be assessed for this criterion.

* Operational means in accordance to predefined technical specifications

Illustration:

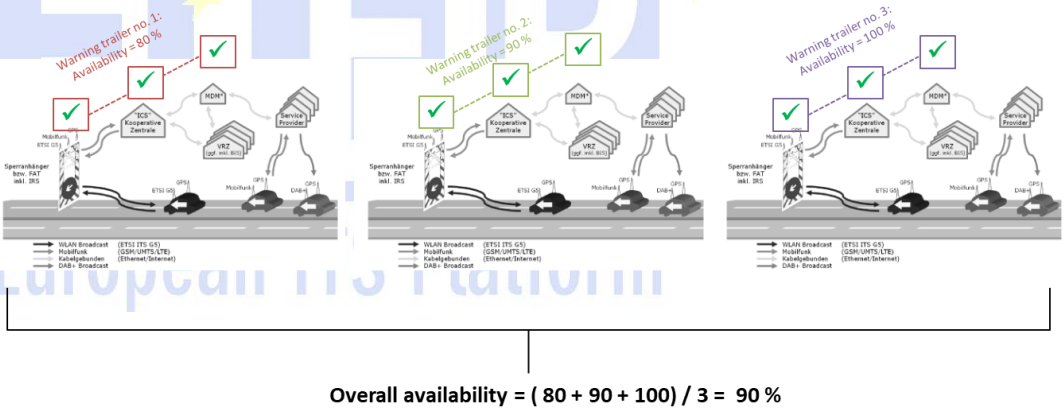


Figure 8. Illustration for Quality Criterion “Availability”

5.3. Latency

The SRTI/RTTI Quality Package contained two time-related criteria “timeliness” and “latency”, with a timeline reference to information processes (detection, acceptance validation, and dissemination via a NAP). However, this definition related to conventional ITS actors, such as police staff, traffic management centers and traffic information centers.

With a broader actor- and data-landscape in C-ITS, a description of time needs to be unambiguous and flexible. Thus, it is proposed to use one time-related criterion only, and to relate the time definition to two distinctive time stamps of communication flows within a C-ITS communication chain. Such time stamps are noted below with (a) and (b).

- **Definition for Data Use Case No. 1**

  Total time for communicating messages between (a) actual status change of a warning trailer and (b) data input at a NAP.

- **Definition for Data Use Case No. 2**

  Total time for communicating messages between (a) actual status change of a warning trailer and (b) sending out this status change by the warning trailer. This is part of the latency from Data Use Case No. 1.

- **Definition for Data Use Case No. 3**

  Total time for communicating messages between (a) receiving vehicle-generated data about weather conditions by a road-side unit and (b) data input at a NAP.

- **Definition for Data Use Case No. 4**

  Total time for communicating messages between (a) creation of a weather warning at a weather station and (b) sending out this weather warning by the weather station.

- **Generic Definition**

  Total time for communicating messages between (a) a timestamp at a C-ITS sender and (b) a timestamp at a C-ITS receiver.

Usage Notes:

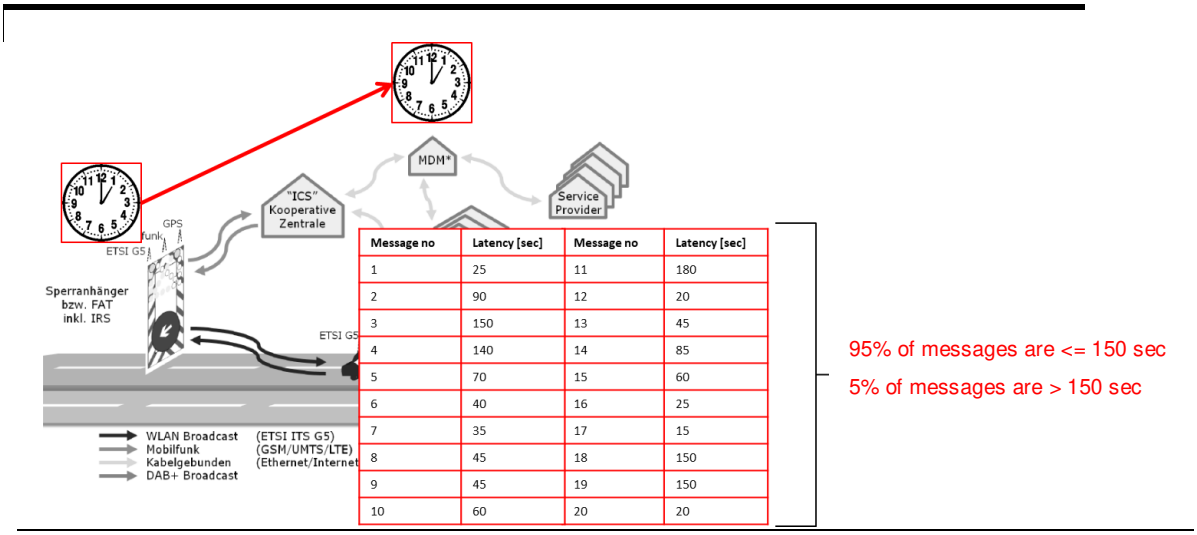
The calculation is referring to a percentual threshold of all sent-out messages. Example: “95% of all messages have latency below 5 minutes”. A proposal for such thresholds is given in the next chapter “Quality Requirements”.

Latency should be defined separately for different communication channels and also related to a specific time period, to be defined by the quality manager (e.g. one month).

Based on feedback from the InterCor project, the above definition may be rephrased to “The delay of sending a single message from the sender application to a receiving application”.

Based on feedback from the C-Roads Urban Nodes DE project, the above definition may be rephrased to “Time difference between a transmitted message at the C-ITS sender and a received message at the C-ITS receiver.”

Illustration:



Message no	Latency [sec]	Message no	Latency [sec]
1	25	11	180
2	90	12	20
3	150	13	45
4	140	14	85
5	70	15	60
6	40	16	25
7	35	17	15
8	45	18	150
9	45	19	150
10	60	20	20

95% of messages are <= 150 sec

5% of messages are > 150 sec

Figure 9. Illustration for Quality Criterion "Latency"

Discussion items:

A question was raised, how to consider technical issues when measuring different time stamps, e.g. regarding clock synchronization and the capability to store time stamps in the warning trailer? Our answer is that these are technical challenges to be tackled in the current C-ITS deployment projects. Any insights and best-practices from these projects will be compiled in the later section "Assessment methods".

5.4. Refreshment Rate

The SRTI/RTTI Quality Package contained a criterion "Reporting Period" for status-oriented information. The definition can be taken over for C-ITS use cases. However, it is proposed to rename the criterion to "Refreshment Rate", as this is a rather common wording in C-ITS.

- **Definition for Data Use Case No. 1**

  Time interval for refreshing / updating the status reports coming from a warning trailer.

- **Definition for Data Use Case No. 2**

  Same as for No. 1 (as this Criterion relates to warning trailers as such, not to the communication channel)

- **Definition for Data Use Case No. 3**

Time interval for refreshing / updating the status reports coming from a road-side unit.

- **Definition for Data Use Case No. 4**

  Time interval for refreshing / updating the status reports coming from a weather station.

- **Generic Definition**

  Time interval for refreshing / updating the status reports coming from a data sender.

Usage Notes:

It is noted that a trailer may send out the same information during longer periods, e.g. a week, and the last received information is stored in the NAP to be accessed at any time. This means a setting of “Refreshment Rate” with strict requirements, e.g. in the range of minutes or seconds, is only relevant, when there is an expected, frequent change of the message item.

We note that “Refreshment Rate” may be difficult to measure for implementations which only send an update when a change has occurred in the underlying event (this is e.g. the mechanism how DENM update is triggered at the originating ITS station). However, “Refreshment Rate” can be expected to applicable to C-ITS services involving CAM messages (that are generated and sent periodically) and to C-ITS service implementations in which the protocol layers under the C-ITS application layer transfer information at fixed intervals (e.g. some web service interfaces between servers behave like this).

Based on feedback from the InterCor project, the above definition may be distinguished by “repetition rate” (i.e., how often a message is sent) and “update rate” (i.e., how often a message is renewed).

Based on feedback from the C-Roads Urban Nodes DE project, the above definition may be rephrased to “Time interval for refreshing/updating the status and data messages coming from a data transmitter.”

Illustration:

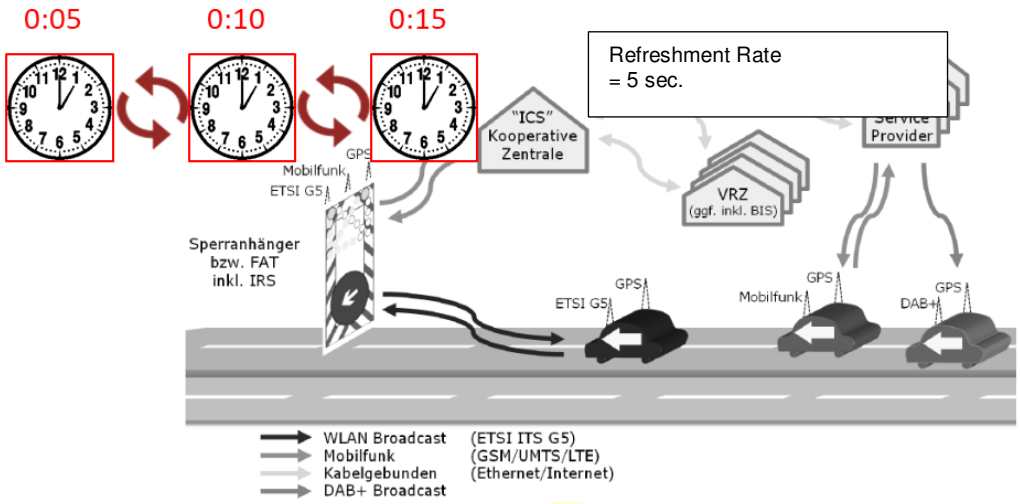


Figure 10. Illustration for Quality Criterion "Refreshment Rate"

Discussion items:

A first discussion in the EU EIP group was whether Refreshment Rate is a Quality Criterion at all, or rather a technical specification of the warning trailer. This resulted in a closer look at C-ITS specifications, namely ETSI standards. In fact, there is a DENM data element "transmissionInterval" (see details below) specified by ETSI, raising the general question how to deal with correlations between EU EIP Quality definitions and the ETSI standards, which define such DENM data elements.

We understand that EU EIP Quality Criteria are used to allow assessing data and service quality for specific use cases and information chains, while the ETSI standards relate to the contents of messages being provided via C-ITS channels. A content of a message may contain quality-related information, e.g. about the accuracy and repetition rates of the information items. However, the quality assessment according to EU EIP does not look only into the message content, but on the way how the message is provided, based on an external assessment.

For this reason, is was realised that the ETSI and EU EIP quality concepts differ substantially. However, for the sake of completeness, we decided to quote any ETSI definitions within this Quality Package that have a quality relevance, in particular considering any data elements by ETSI which talk about "quality", "confidence" and "accuracy". Further, we decided to denote evident correlations (and maybe overlaps or differences) with corresponding EU EIP Quality Criteria.

Correlation to ETSI standardisation:

Within ETSI standardisation, there is a DENM data element “transmissionInterval” with a similar character. It is defined as: “*Time interval for DENM transmission as defined by the originating ITS station. Informs the receiving ITS stations about the intended transmission interval of two consecutive DENM transmissions.*”[29]. It is used as an optional data element within a DENM management container and is expressed in milliseconds.

It is important to understand how DENM messages are handled. In case of an event, the ITS station that generated the DENM may send an update DENM if the underlying event has changed. A DENM may also be repeated by a C-ITS station, but this does not necessarily imply an update of the DENM content. This way, "transmissionInterval" seems to be in line with the former EU EIP criterion ""Refreshment Rate. However, there is a little difference with the word "intended" in the DENM definition. In the EU EIP Quality concept, Quality Criteria are used to assess REALISED quality, not to describe the INTENDED one.

Further, “Transmission Interval” is embedded into the message content, whereas “Refreshment Rate” allows external quality assessments.

It is concluded to note the correlation of “Refreshment Rate” with "transmissionInterval" with the remark above.

5.5. Location accuracy

The SRTI/RTTI Quality Package contained already this criterion, however only for “event-oriented” information. It is suggested to use it for any C-ITS messages, as C-ITS messages are usually accompanied with some geo-reference.

- **Definition for Data Use Case No. 1**

  The deviation of the reported horizontal location of a warning trailer, with respect to the actual location.

- **Definition for Data Use Case No. 2**

  Same as for No. 1 (as this Criterion relates to warning trailers as such, not to the communication channel)

- **Definition for Data Use Case No. 3**

  Not applicable, as weather information is coming from passing vehicles. The location accuracy of private vehicles is (so far) not in scope of EU EIP.

- **Definition for Data Use Case No. 4**

[29] Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 3: Specifications of Decentralized Environmental Notification Basic Service ; ETSI EN 302 637-3 V1.2.1 (2014-09) ; section B.53

The deviation of the reported horizontal location of a weather warning, coming from a weather station, with respect to the actual location

- **Generic Definition**

  The deviation of the reported horizontal location of an event information with respect to the actual location.

Usage Notes:

The concrete calculation of “Location Accuracy” is proposed to be based on the ETSI concept of the confidence ellipsoid (see below). It is calculated as follows:

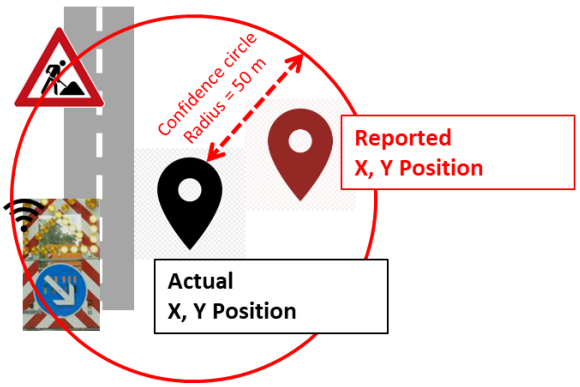
The confidence is expressed with a shape of circle with a predefined confidence level (e.g. 95 %). The centre of the circle shape corresponds to the reference position point for which the position accuracy is evaluated. Example: “The reported position of 95% of all messages falls within a circle of a radius of 50 metres, where the centre point is the ground-truth position of these messages.”

Another way of calculation was proposed int the MMTSI Quality Package as a “Mean value of positional uncertainties” (based on an INSPIRE concept). This is, however, not recommended for the C-ITS context.

Based on feedback from the InterCor project, the above definition may be separately considered for so-called “awareness zones” and “relevance zones”. This means that activation of C-ITS messages is affected by entering or leaving such zones. The location accuracy may be different for such zone concept.

Based on feedback from the C-Roads Urban Nodes DE project, the above definition may be rephrased to “Deviation of the reported horizontal location in relation to the actual location.”

Illustration:



Message no	Within circle?	Message no	Within circle?
1	yes	11	yes
2	yes	12	yes
3	yes	13	yes
4	yes	14	yes
5	yes	15	yes
6	yes	16	yes
7	no	17	yes
8	yes	18	yes
9	yes	19	yes
10	yes	20	yes

95% of messages within circle
5% of messages outside circle

Figure 11. Illustration for Quality Criterion "Location Accuracy"

Discussion items:

It was discussed if this Criterion is useful at all, looking at potential problems to establish the ground truth reference and have an efficient reference testing method. However, as positional accuracy of C-ITS messages, especially for mobile data senders (e.g. warning trailers) is relevant for the quality assessment of such messages, the Criterion is introduced. Potential issues with reference testing are discussed in the section on Assessment Methods (see section 7).

Another observation is the definitions above are only applicable for point-based Information, expressed with x,y coordinates. Positional accuracy could be also related to, e.g. links or areas. This case has to be further investigated and maybe the definitions above to be expanded.

Correlation to ETSI standardisation:

Within ETSI standardisation, there is a concept of a confidence ellipse with a similar character to "Location Accuracy". This is embedded within a DENM data frame "eventPosition" for detected events. It is used within a DENM management container and is referencing to further definitions from the ETSI common data dictionary, namely the data frame "DF_ReferencePosition", the data frame "PosConfidenceEllipse", and the data element "DE_SemiAxisLength"

The definitions of these data frames and elements are as follows:

- "eventPosition": *Geographical position of the detected event. The position of an event is determined by the originating ITS-S. Shall be presented as "DF_ReferencePosition".* [30]
- "DF_ReferencePosition": *The geographical position of a position or of an ITS-S. It represents a geographical point position. The data shall include the following information: (…) positionConfidenceEllipse: accuracy of the geographical position (…).*[31]
- "PosConfidenceEllipse": *Provides the horizontal position accuracy in a shape of ellipse with a predefined confidence level (e.g. 95 %). The centre of the ellipse shape corresponds to the reference position point for which the position accuracy is evaluated. The DF shall include the following information: semiMajorConfidence (…), semiMinorConfidence (…), semiMajorOrientation (…)* [32].

No examples or usage notes for the confidence ellipse within deployments, e.g. in C-Roads, are known yet.

As stated for "trasnmissionInterval" above, the accuracy of "eventPosition" is embedded into the message content, and is not compatible with the EU EIP concept of external quality assessments.

Nevertheless, the way how the accuracy is calculated for "eventPosition" seems to be applicable for the EU EIP Criterion "Location Accuracy". However, the confidence ellipse concept for "eventPosition" seems to be too complicated. For simplification, a confidence circle concept is proposed, i.e. "semiMajorConfidence" and "semiMinorConfidence" will have the same length and no "semiMajorOrientation" is needed. In the end, only one value for the radius remains. This way, the calculation is the concretised as indicated in the usage note above.

It is concluded to note the correlation of "Location Accuracy" with "eventPosition" with the remark above.

5.6. Error rate

[30] Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 3: Specifications of Decentralized Environmental Notification Basic Service ; ETSI EN 302 637-3 V1.2.1 (2014-09) ; section B.14

[31] Intelligent Transport Systems (ITS); Users and applications requirements; Part 2: Applications and facilities layer : common data dictionary; ETSI TS 102 894-2 V1.2.1 (2014-09) ; section A.124

[32] Intelligent Transport Systems (ITS); Users and applications requirements; Part 2: Applications and facilities layer : common data dictionary; ETSI TS 102 894-2 V1.2.1 (2014-09) ; section A.119

The SRTI/RTTI Quality Package contained the criteria “Classification correctness“ for event-oriented information, and “Error Rate” for status-oriented information, each with different relevance. For C-ITS, it is suggested to generally use “Error Rate” to describe the relative number of erroneous messages, as detected and/or reported by a specific C-ITS actor.

- **Definition for Data Use Case No. 1**

  Percentage of messages with wrong status, as reported by a connected warning trailer, out of the total number of messages from connected warning trailers.

- **Definition for Data Use Case No. 2**

  Same as for No. 1 (as this Criterion relates to warning trailers as such, not to the communication channel)

- **Definition for Data Use Case No. 3**

  Not applicable, as weather information is coming from passing vehicles. The correctness of information coming from private vehicles is (so far) not in scope of EU EIP.

- **Definition for Data Use Case No. 4**

  Percentage of messages with wrong weather information, as reported by a weather station, out of the total number of messages from weather stations.

- **Generic Definition**

  Percentage of messages with erroneous information, as reported by a data sender, out of the total number of messages.

Usage Notes:

If this Criterion is used for discrete information items (e.g. “status on” vs. “status off” ; or : “arrow showing to left” vs. “arrow to the right”), the “erroneous” is referred to falsely reported information. For continuous information items (e.g. visibility ranges), the “erroneous” is referred to excessive deviations of the reported information.

When calculating the share of messages with erroneous information, only unique C-ITS messages are relevant, e.g. repetitions of the same DENM message would not be counted as new messages.

Based on feedback from the InterCor project, the term „erroneous“ in the above definition may be seen in a different context. In InterCor, ”validity” of a C-ITS message is considered most-relevant. This may allow a redefinition of this Criterion to “reliability by calculating the percentage of valid activations of the Human Machine Interface (HMI) ”

Based on feedback from the C-Roads Urban Nodes DE project, the above definition may be rephrased to “Percentage of number of incorrect messages in relation to the total number of messages”.

Illustration:

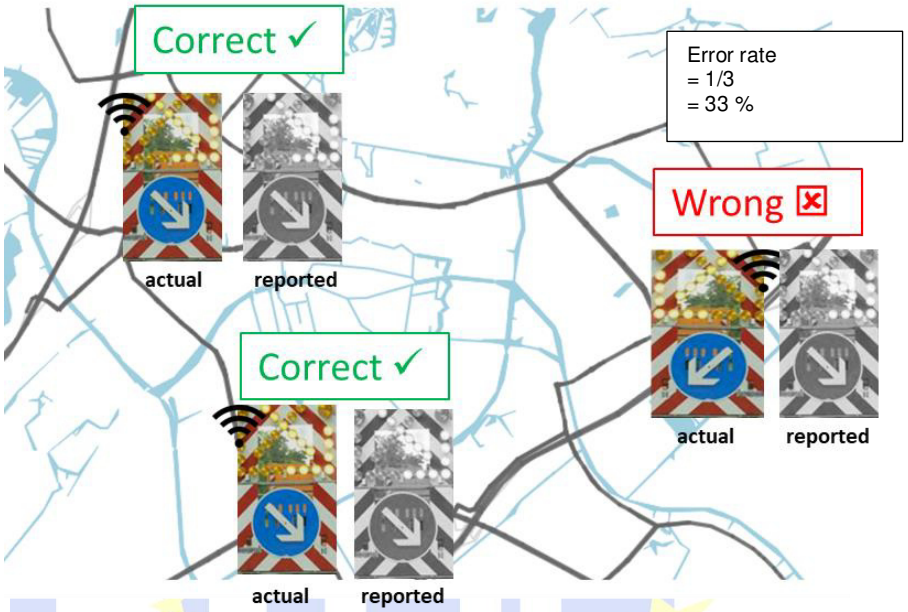


Figure 12. Illustration for Quality Criterion "Error rate"

Correlation to ETSI standardisation:

Within ETSI standardisation, there is a DENM data element "informationQuality" with a similar character. It is defined as: "*Quality level of the information provided by the ITS-S application of the originating ITS station. It indicates the probability of the detected event being truly existent at the event position.*" [33]. It is used as a data element within a DENM situation container.

The data element is filled with a value from lowest (1) to highest (7). The value 0 shall be set when the information is unavailable. C-Roads specifies how these values are to be set:

- value (2): one source of automated data e. g. CAM or a traffic sensor alerting the event

[33] Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 3: Specifications of Decentralized Environmental Notification Basic Service ; ETSI EN 302 637-3 V1.2.1 (2014-09) ; section B.23

- value (4): multiple sources of automated data in larger quantity per minute alert the event
- value (6): manual verification (i.e. by using CCTV or being on site) by road operator agent or other reliable source (e. g. police) or a verification system (e. g. detection by loops or radar, accumulation of CAMs) with a 99.9% safety guaranty.

It is understood that “informationQuality” rather relates to the confidence of a reported event, i.e. a level of likelihood that a reported event is really happening in reality, based on the applied detection and verification technique. Thus, “informatonQuality” only gives in indication on how much a data user can confide in the data source. It does not quantify individual qualities, e.g. as a correctness or error rate. The EU EIP criterion “Error Rate”, on the other hand, does quantify such qualities. In practice, there might be an interdependency between “informationQuality” and “Error rate”, e.g. better detection and verification techniques may result in a lower “Error rate”. Such independencies, however, have not been investigated yet.

It is concluded to note the correlation of “Error Rate” with "informationQuality” with the remark above.

5.7. Summary table

A summary table with all generic definitions, as elaborated above, is shown below.

It is noted that such definitions are not differentiated for different information types, as it has been done at the SRTI/RTTI Quality Package, where there used to be two categories of traffic information: “event-oriented” and “status-oriented”. It is suggested not to use such categories for C-ITS quality anymore, as they are ambiguous. (For road-work warnings, as an example, the status report from a warning trailer is obviously “status-oriented”, while the accompanying road work information is rather “event-oriented”.)

Further, the summary table adds three ETSI-based, quality-related data elements (“transmissionInterval”, “PosConfidenceEllipse” and “informationQuality”), together with the original definition and a correlation to EU EIP Quality Criteria.

Table 4: Proposed Quality Criteria for C-ITS Services and Data

Quality Criterion		
Based on	**Name**	**Definition**
EU EIP Definitions	**Availability**	Average availability for all operating connected data senders, including the communication chain up to the data receiver.
	Latency	Total time for communicating messages between a timestamp at a C-ITS sender and a timestamp at a C-ITS receiver.
	Refreshment Rate	Time interval for refreshing / updating the status reports coming from a data sender.
	Location accuracy	Deviation of the reported horizontal location of an event information with respect to the actual location.
	Error Rate	Percentage of messages with erroneous information, as reported by a data sender, out of the total number of messages.
ETSI Standardisation	**Transmission Interval** (DENM data element)	Time interval for DENM transmission as defined by the originating ITS station. Informs the receiving ITS stations about the intended transmission interval of two consecutive DENM transmissions. *Correlates with "Refreshment Rate": "Transmission Interval" is embedded into the message content, whereas "Refreshment Rate" allows external quality assessments.*
	Event Position / Position Confidence Ellipse (DENM data frame)	The horizontal position accuracy in a shape of ellipse with a predefined confidence level (e.g. 95 %). The centre of the ellipse shape corresponds to the reference position point for which the position accuracy is evaluated. *Correlates with "Location Accuracy": "Position Confidence Ellipse" is embedded into the message content, whereas "Location Accuracy" allows external quality assessments. Nevertheless, the way how the accuracy is calculated for "eventPosition" is also applied for "Location Accuracy".*
	Information Quality (DENM data element)	Quality level of the information provided by the ITS-S application of the originating ITS-S. It indicates the probability of the detected event being truly existent at the event position. *Correlates with "Error Rate": "informationQuality" relates to the confidence of a reported event, i.e. a level of likelihood that a reported event is really happening in reality, based on the applied detection and verification technique. "Error Rate", on the other hand, quantifies the adherence to reality in terms of erroneous messages.*

5.8. Note on “Geographical Coverage”

One of the quality criteria in the previous EU EIP Quality Packages was “Geographical Coverage”. We originally proposed the following definition for the C-ITS context:

“Percentage of the road network and/or selection of road classes, where stationary, connected C-ITS stations operate.”

During follow-up discussions of the EU EIP quality group, some deficiencies with such definition were found. In particular, we noted some ambiguity, when looking at the original definition proposal.

First, the definition could be interpreted in three different ways:

1. Percentage of the road network, where stationary, connected C-ITS stations operate
2. Selection of road classes, where stationary, connected C-ITS stations operate
3. Percentage of the selected road classes, where stationary, connected C-ITS stations operate.

Looking at the term “road network”, there is also some ambiguity. This term may cover a wide variety of roads. In various EC Delegated Regulations the addressed road networks are different. A percentage of an undefined road network is not useful. For example, road-works warnings may be especially safety-relevant along motorways with high speeds or along highways with much traffic, while they are not so interesting along urban roads. It is noted that special geographical classifications, such as the TEN-T road classification by the EC, do not play a role here.

Second, we realise that that such ambiguity makes it impossible to quantify the corresponding quality values, as the values can be expressed in very different quantities, depending on the understanding of this criterion. Besides this, a quantification of such values is, in general, difficult to define, due to the very different characteristics of each C-ITS use case. For example, for the GLOSA (Green Light Optimal Speed Advisory) use case, a mapping of “geographical coverage” to roadwork elements (as proposed in the definition) does not make sense.

Due to these deficiencies, we agreed to remove this criterion as an “official” EU EIP quality criterion. Instead, we propose how deal with “Geographical Coverage” in specific C-ITS project settings, as follows:

- “Geographical Coverage” might be laid down as a specification for an individual C-ITS application, in order to **describe the geographical environment of a C-ITS application.**
- Such application-specific specification should at least have a **description of the road network, where a certain C-ITS service is operational.**

- It is suggested to **define the relevant road network,** preferably using a map showing the covered roads.

5.9. Candidates for further criteria

Some candidates for further criteria have been identified during the work for this Quality Package, which have not been introduced as official EU EIP Quality Criteria. They might be further discussed and introduced in the future.

- **Penetration Rate** (Source: EU EIP discussion)

  Possible definition: Percentage of connected (C-ITS-equipped) elements in the traffic system out of all (connected and non-connected) elements.

  Example: The introduced EU EIP Quality Criteria apply only to C-ITS-equipped data senders. It may be interesting to compare these C-ITS-equipped data senders to comparable elements in the traffic system, which could potentially be data senders (maybe allowing looking at impacts of C-ITS introduction over a time span). An example is conventional (non-C-ITS) warning trailers for the Road Works Warning (RWW) service.

  Proposal: Discuss in the future

- **Variance** (Source: DIRIZON study, see section 2.6)

  Possible definition: Standard deviation from a mean value for some quantitative data element

  Example: “Availability may be calculated based on an average for all assessed warning trailers. In addition to this average, a variance could be assessed. separately (micro), and then calculated as “median” and “variance” numbers for all warning trailers (macro)

  Proposal:

  A variance can be calculated for any quantitative parameter, i.e. for any Quality Requirements as introduced in this Quality Package. It could therefore be potentially used as an additional measurement of variation, especially when the phenomena being measured remains stable and static. Definitions in terms of, e.g. “allowed variations” have, however, not been defined yet.

- **Predictability** (Source: DIRIZON study, see section 2.6)

  Possible definition: ?

  Proposal: Not applicable for RWW and WCW services. However, this is maybe applicable for GLOSA services, as predictability of signal phases (in case of actuated signal timing) is an important feature in the GLOSA use case. To be discussed when quality for C-ITS services other than RWW and WCW are defined.

- **Valid activation of the HMI** (Source: InterCor feedback)

Possible definition: The percentage of true positive activations of the HMI, regarding time, location and contents. An indicator that the warning message is correct and reaches the HMI in time, so that it can be shown at the right moment to the driver. A valid activation of the HMI ("true positive") is correct in time, location and contents. There might be also "false negatives" (a missed activation) and "false positives" (invalid activation - no relevant event). Avoiding false events is crucial for the driver's trust in the system.

Example: The corresponding values might be: basic > 92,5 %, enhanced >95 % and advanced >99%.

Proposal: Consider this criterion in addition to the "Error rate" in this document. The "Error rate" concerns the correctness of a message, however not the right timing of showing the warning in relation to the relevant location.

- **Packet Delivery Ratio (PDR)** (Source: InterCor feedback)

  Possible definition: An indicator to measure the communication reliability as the ratio of received messages over sent messages.

  Note:

  applicable for the evaluation of communication

- **Effective Communication Range (ECR)** (Source: InterCor feedback)

  Possible definition: An indicator to measure the range of distance where communication is effective and reliable.

  Note:

  applicable for the evaluation of communication

- **Service Interval** (Source: DRD feedback)

  Possible definition: Period of time between service/calibration of a road-side station.

  Note:

  There are European standards for winter maintenance equipment (e.g., EN 15518-3). For e.g., the temperature and for the snow depth, requirements for the following parameters are specified: Measuring range, resolution and accuracy. When a station is serviced, it is checked that all its sensors work within the required specifications and they are recalibrated if needed. The Service interval used in Denmark is 1 year.

6. Quality Values

6.1. Introduction

This section compiles quality values, i.e. quantitative requirements for C-ITS services. Such values specify at which (minimum) level the Quality Criteria, as defined in section 5, should be realised by an individual C-ITS service to meet certain quality expectations.

The values are expressed in a quantitative way where possible. They are understood as initial target values, which have to be further discussed and evaluated with C-ITS stakeholders at a later stage.

Following the "star" concept of the former Quality Packages, such quality expectations are described in three levels:

** Basic*

*** Enhanced*

**** Advanced*

The most important quality values are the minimum ones, denoted as the ** Basic* quality level. This level should be met by the services in all member states, because if the service would be provided at a lower level of service or quality, the user benefits would likely be negligible or even negative. There is an open discussion how to understand such a basic quality level. There are two possible ways:

- The definitions will "lift up" the minimum quality levels for conventional RTTI/SRTI services (as laid down in the SRTI/RTTI Quality Package), however using C-ITS as an "enhanced" information channel.
- The definitions will set minimum quality levels for various C-ITS applications as a whole, as "a minimum standard" for e.g. new services.

In the process of this work, no final consensus among C-ITS stakeholders on this understanding could be elaborated.

In addition to the ** Basic* level, tentative Quality Requirement recommendations are also given for an *** Enhanced* and an **** Advanced* level.

The quality values, as presented next in this paper, are based on expert judgement form the EU EIP group (noted as "proposed by EU EIP" in the following tables). In some cases, alternative judgements from experts in ongoing C-ITS deployments were identified (noted as "proposed by project xyz" in the following tables). These C-ITS deployments were consulted within the validation phase, see section 8.

The compiled values will give the reader an orientation on possible ranges of quality values from today's point of view of C-ITS experts.

Initial thoughts on the proposed quality values were based on previous quality definitions for SRTI/RTTI and parallel studies related to Automated Driving. In the SRTI/RTTI Quality Package, these definitions were related to status-quo technologies, i.e. conventional ITS. However, there were already some implications on C-ITS, by reserving a most-advanced requirement level (****) for "Future technologies", but without concrete definitions. Potential implications of C-ITS on Quality Requirements have been stated as follows:

*" (…) near-future technologies, such as C-ITS (…) most likely will have a significant impact on SRTI and RTTI services, e.g. by improving detection and communication of related data. As a result, we can expect significant potentials to improve achievable quality levels. (…) A quality level **** has been defined for Quality Requirements which will be related to near-future technologies, but it has not been specified with concrete values yet…".*

A similar level-based definition of Quality Requirements has been done for Automated Driving (DIRIZON project, see section 2.6). The question now is how to compare potential Quality Requirements for C-ITS with Requirements previously defined for SRTI/RTTI and Automated Driving.

It has been stated that C-ITS data quality should be higher than the SRTI/RTTI requirements. It has been further stated that data requirements for Automated Driving are rather stricter that those for C-ITS. It is thus concluded that Quality Requirements for C-ITS should be somewhat higher than those for SRTI/RTTI and lower than those for Automated Driving. The next figure explains this concept.

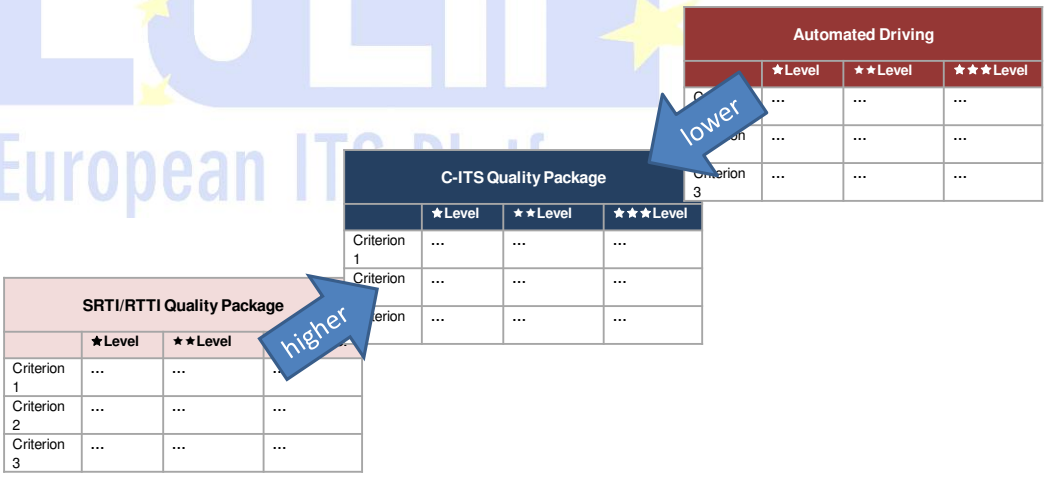


Figure 13. Relation of Quality Requirements for SRTI/RTTI, for C-ITS and for Automated Driving

In this sense, we expect that quality values should be placed above the highest requirements previously defined for SRTI/RTTI, and reaching towards at least the lowest requirements for Automated Driving.

An exception to this is made for the criterion “Availability”. For SRTI/RTTI, the numbers were already quite high (95%/99%/99,5%), so they have been taken over to C-ITS. (With many functioning actors necessary to operate an entire system, some downtimes or temporary failures should be acceptable, so a 100%-availability does not seem feasible.)

The approach above reflects quality expectations from an author’s perspective, i.e. what qualities SHOULD be achieved. In contrast, another approach may to look at achievable qualities from the practical standpoint, i.e. what qualities CAN be achieved. For this latter approach, quantitative evidence can be derived from existing C-ITS deployments. There are also some hints on achievable parameters on C-ITS operations form the automotive industry. The German automobile club ADAC conducted a survey among Germany car manufactures on existing C-ITS features in their car portfolios[34]. One question was *“What is the minimum, average and maximum time it takes for a hazard reported by a C2X vehicle from your house to be displayed on another C2X vehicle (end to end)?”.* The answers from this survey reveal “minimum times” in the range of 100 ms and 20 sec; and “maximum times” in the range of 200 ms and 2 min. It is suggested to use this range of numbers for the criterion “Latency” in Data Use Cases no. 2 and 4, which are most-comparable with the vehicle-to-vehicle-scenario in the survey.

6.2. Reference Table

In the next table, references of applicable C-ITS quality values are given.

In the table, definitions for Quality Criteria from section 5 are repeated, and quantitative expressions of quality values per Criterion are added.

As done for Quality Criteria, the definitions are established for the four predefined “Data Use Cases” (see section 4). This approach avoids the mentioned problem to find generic definitions for any C-ITS data ecosystems and any C-ITS data flows.

The Quality Requirements for the Criteria “Availability”, “Refreshment Rate”, “Error Rate” could be defined in the same way for all four Data Use Cases. For the other Criteria “Latency” and “Location Accuracy”, however, they vary for each Data Use Case, so the table gives four different definitions.

[34] « Welche Hersteller bieten bereits C2X an? » ; ADAC-Umfrage 6/2020 ; https://assets.adac.de/image/upload/v1594712609/ADAC-eV/KOR/Text/PDF/Umfrage_Hersteller_Car2X_dl45xm.pdf

Table 5: Requirements Table for C-ITS Quality Criteria

Quality Criterion	Data Use Case No.	Definition	★ (Basic)	★★ (Enhanced)	★★★ (Advanced)
Availability	1-4	Average availability for all operating connected data senders, including the communication chain up to the data receiver.	*Proposed by EU EIP:* 95% (347 days/ year) *Proposed by InterCor:* 95%	*Proposed by EU EIP:* 99% (361 days/year) *Proposed by InterCor:* 97,5%	*Proposed by EU EIP:* 99,5% (363 days/ year) *Proposed by InterCor:* 99% *Proposed by C-ITS Corridor DE:* 100%
Latency	1	Total time for communicating messages between (a) actual status change of a warning trailer and (b) data input at a NAP.	*Proposed by EU EIP:* 95% of all messages <10 minutes *Proposed by NordicWay3:* <10 minutes	*Proposed by EU EIP:* 95% of all messages <7 minutes *Proposed by NordicWay3:* <3 minutes	*Proposed by EU EIP:* 95% of all messages <2 minutes *Proposed by NordicWay3:* <1 minute
	2	Total time for communicating messages between (a) actual status change of a warning trailer and (b) sending out this status change by the warning trailer.	*Proposed by EU EIP:* 95% of all messages <2 minutes	*Proposed by EU EIP:* 95% of all messages <10 seconds	*Proposed by EU EIP:* 95% of all messages <1 second

Table 5: Requirements Table for C-ITS Quality Criteria (continued)

Quality Criterion	Data Use Case No.	Definition	★ (Basic)	★★ (Enhanced)	★★★ (Advanced)
Latency	3	Total time for communicating messages between (a) receiving vehicle-generated data about weather conditions by a road side unit and (b) data input at a NAP.	*Proposed by EU EIP:* 95% of all messages <10 minutes	*Proposed by EU EIP:* 95% of all messages <7 minutes	*Proposed by EU EIP:* 95% of all messages <2 minutes
	4	Total time for communicating messages between (a) creation of a weather warning at a weather station and (b) sending out this weather warning by the weather station.	*Proposed by EU EIP:* 95% of all messages <2 minutes	*Proposed by EU EIP:* 95% of all messages <10 seconds	*Proposed by EU EIP:* 95% of all messages <1 second
	5*		*Proposed by InterCor:* Stricter values needed	*Proposed by InterCor:* Stricter values needed	*Proposed by InterCor:* Stricter values needed
	6*				*Proposed by Talking Traffic:* "matter of milliseconds"
	7*		*Proposed by DGT3.0:* 95% of all messages <2 minutes	*Proposed by DGT3.0:* 95% of all messages <1 minute	*Proposed by DGT3.0:* 95% of all messages <30 sec.

** Line 5: Additional data use case from validation response: IVS (dynamic signs)*

Line 6: Additional data use case from validation response: Intelligent Traffic Light Data

Line 7: Additional data use case from validation response: luminous beacon with geolocation

Table 5: Requirements Table for C-ITS Quality Criteria (continued)

Quality Criterion	Data Use Case No.	Definition	★ (Basic)	★★ (Enhanced)	★★★ (Advanced)
Refreshment Rate	1-4	Time interval for refreshing / updating the status reports coming from a data sender.	*Proposed by EU EIP:* <5 minutes *Proposed by DRD (weather stations)*: <15 minutes	*Proposed by EU EIP:* <3 minutes *Proposed by DRD (weather stations)*: <10 minutes	*Proposed by EU EIP:* <1 minute *Proposed by DRD (weather stations)* <5 minutes
Location accuracy	1	Confidence for the horizontal position accuracy of the reported location of the warning trailer with respect to the actual location.	*Proposed by EU EIP:* 95% of all messages within tolerance circle <10m	*Proposed by EU EIP:* 95% of all messages within tolerance circle <1m	*Proposed by EU EIP:* 95% of all messages within tolerance circle <10 cm
	2	Confidence for the horizontal position accuracy of the reported location of the warning trailer with respect to the actual location.	*Proposed by EU EIP:* 95% of all messages within tolerance circle <10m	*Proposed by EU EIP:* 95% of all messages within tolerance circle <1m	*Proposed by EU EIP:* 95% of all messages within tolerance circle <10 cm

Table 5: Requirements Table for C-ITS Quality Criteria (continued)

Quality Criterion	Data Use Case No.	Definition	★ (Basic)	★★ (Enhanced)	★★★ (Advanced)
Location accuracy	3	Not applicable.			
	4	Confidence for the horizontal position accuracy of the reported weather warning, coming from a weather station, with respect to the actual location	*Proposed by EU EIP:* 95% of all messages within circle <10km *Proposed by DRD (GPS coordinates of weather stations)*: < 20 m	*Proposed by EU EIP:* 95% of all messages within circle <5km *Proposed by DRD (GPS coordinates of weather stations)*: < 10 m	*Proposed by EU EIP:* 95% of all messages within circle <500m *Proposed by DRD (GPS coordinates of weather stations)*:< 5 m
	5*		*Proposed by DGT3.0:* 95% of all messages within tolerance circle <15m	*Proposed by DGT3.0:* 95% of all messages within tolerance circle <10m	*Proposed by DGT3.0:* 95% of all messages within tolerance circle <5m
Error Rate	1-4	Percentage of messages with erroneous information, as reported by a data sender, with respect to the reality.	*Proposed by EU EIP:* <15% *Proposed by InterCor:* <7,5%	*Proposed by EU EIP:* <10% *Proposed by InterCor:* <5%	*Proposed by EU EIP:* <1% *Proposed by InterCor:* <1%
** Line 5: Additional data use case from validation response: luminous beacon with geolocation*					

7. Quality Assessment Methods

7.1. Methods from previous EU EIP Quality Packages

In the previous EU EIP Quality Package for Safety-related traffic information (SRTI) and Real-time traffic information (RTTI), potential methods for quality assurance and assessment were introduced. Besides describing the concrete methods, their applicability for different uses and their feasibility for studying different quality criteria were noted.

These methods include:

- Continuous monitoring of equipment performance and availability
- Manual verification of events or conditions
- Reference testing of data collected
- Time-space oriented reference test methods
- Monitoring of data completeness and latency
- Regular sampling of message or data content completeness and correctness
- Verification and calibration of traffic or weather conditions prognosis
- Surveys of perceived quality by users
- Collection of direct user feedback
- Monitoring of service use statistics

These methods are based on academic foundations and on years-long experience of road operators in the field of RTTI and SRTI. Some of these methods were also tested in dedicated validation phases for the EU EIP Quality Packages, by assessing real-life SRTI/RTTI data and services.

We understand that some generic concepts and principles of these methods can be transferred to the C-ITS domain. This means that potential approaches to capture Quality Criteria and compare them to (minimum) Quality Requirements, as introduced in the chapters before, can be derived from the methods listed above.

However, we realise that we cannot just recycle the methods from the SRTI/RTTI Quality Package for the C-ITS domain. This due to the fact that information dissemination is different to SRTI/RTTI, and that the technical side is more complex. For example, the Criterion “Latency” may be affected by the clock synchronisation of different communication partners in C-ITS, while this is usually not an issue in the rather simple SRTI/RTTI communication chains. Consequently, a careful adoption of the introduced methods to the C-ITS domain is needed.

7.2. Deriving assessment methods from evaluation activities of C-ITS projects

A promising starting point to identify assessment methods suitable for C-ITS is to look on evaluation methods applied in current C-ITS deployment projects.

The following example is based on the evaluation report from the InterCor project[35]. The evaluation in this project relates to different topics, including a technical evaluation. This evaluation touches on, among others, the communication performance, proving "the technical maturity of the road side units and in-vehicle systems to provide the service to drivers using ITS-G5 and Cellular communication". According to the report, some typical communication delays were quantified in the ranges of milliseconds.

It is obvious that this kind of evaluation relates to an assessment of the EU EIP Quality Criterion "Latency" (see section 5.3).

In fact, latency measurements for communication chains in C-ITS data ecosystems, recorded as time stamps, seem to be a common evaluation technique. However, such measurements need to be put in the right context when talking about C-ITS Quality. For example, there might be different definitions of "time stamps" in C-ITS: they can be noted inside a C-ITS message, or they can be noted outside a message in form of a logfile.

The following figure shows other possible correlations between evaluation items and the EU EIP Quality Criteria, based on the InterCor context.

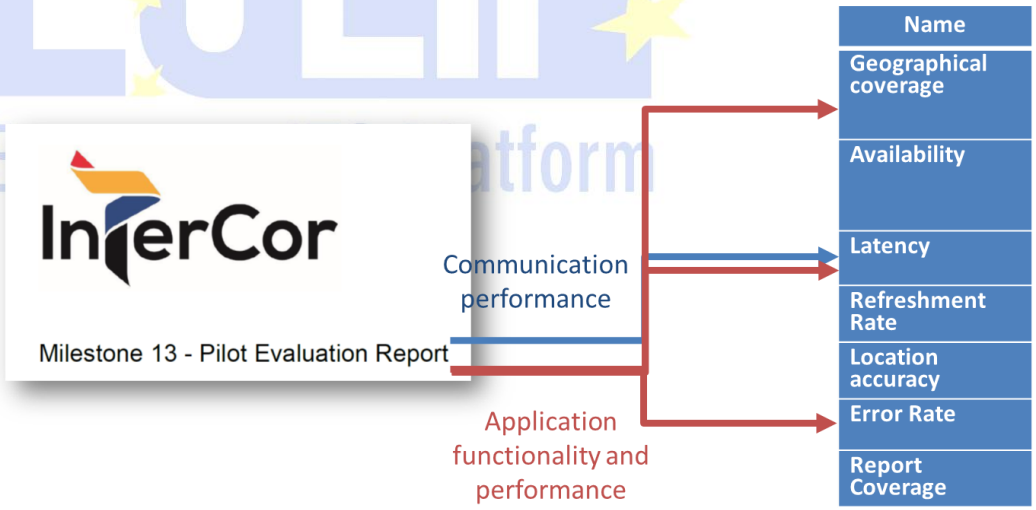


Figure 14. Converging path for quality values in the C-ITS domain

[35] Gary Crockford et al.: InterCor Milestone 13 - Pilot Evaluation Report (2020); https://intercor-project.eu/wp-content/uploads/sites/15/2020/03/InterCor_M13-Pilot-Evaluation_v1.0_INEA.pdf

Eventually, the identified evaluation techniques and the affected Quality Criteria need to be carefully correlated.

8. Validation of the quality definitions

The quality definitions, as presented in the previous chapters, have undergone a dedicated validation procedure.

Here, structured feedback from C-ITS stakeholders about the previous version of this Quality Package was collected via a questionnaire. Questions were asked on the clarity of the proposed quality definitions, the fitness of the proposed quality levels, and learnings from recent and ongoing C-ITS deployments. The questionnaire template is attached as an Annex II.

Responses were received from:

- RWS (InterCor project)
- RWS (Talking Traffic project)
- RWS (Dutch Data Top 15)
- Danish Road Directorate (weather stations application)
- Autobahn GmbH (C-ITS Corridor project)
- Autobahn GmbH (C-Roads DE Urban Nodes)
- DGT (DGT3.0 – Use Case Signal V-16)
- Vegvesen Norway (NordicWay3)

As an outcome from this questionnaire activity, some quality criteria could be reframed and revised, i.e. quality wordings were changed and explanatory notes were added, where necessary (see chapter 5).

For the quality values, i.e. the quantitative qualitative requirements, however, no converging could be identified from the questionnaire responses. In many cases, a response was given that a concrete value cannot be given yet, but needs further research or validation. In the few cases values could be suggested, though these seemed to be quite heterogenous and very much related to the individual project setting of the responder.

This required some reframing of the “requirement tables”, as laid down in chapter 6. Instead of considering such tables as “final, agreed values”, which was done in previous other Quality Packages, e.g. for SRTI/RTTI, we decided to only cite any values as references from analysed C-ITS environments. This will give the reader an orientation on possible ranges of quality values from today’s point of view of C-ITS experts, but will not declare any values that must be reached as basic/enhanced/advanced values, as suggested by the previous Quality Packages.

Another argument for such reframing is that quality values cannot be considered fixed on a time scale, as the evolution of a C-ITS application likely will lead to increased values over time.

Further, we were able to absorb some key issues from the questionnaire responses, which were added to the conclusions chapter (see chapter 9).

9. Conclusions and recommendations

The presented “Quality Package” presents initial quality definitions and concepts for the domain of C-ITS, as proposed and agreed by EU EIP partners for the use in Europe:

- A set of Quality Criteria to assess individual C-ITS services → see chapter 5
- References to possible Quality Values or Requirements to be met by individual C-ITS services → see chapter 6
- Advice about possible Quality Assessment Methods → see chapter 7

The main lesson learned from the elaboration of this Quality Package is that the variability of data categories and complexity of data flows in C-ITS deployments make a generic description of C-ITS Quality quite challenging. As a consequence, a concept of “Data Use Cases” was introduced, where quality definitions are elaborated for specific, isolated data environments. As a starting point, four Data Uses Cases have been defined, covering selected data flows of two day-1 C-ITS services (Road Work Warnings and Weather Condition Warnings).

One important baseline for defining Quality Criteria was the former Quality Package for safety-related traffic information (SRTI) and real-time traffic information (RTTI). However, it became evident that previous quality definitions for SRTI/RTTI do not always seem applicable for the C-ITS domain. Thus, some redefinitions and additions have been made. Eventually, seven EU EIP Quality Criteria have been proposed.

Besides many agreements on the Quality Criteria, some open questions and uncertainties remain. For example, we learned that quality can be defined differently, depending on how the information chain looks like, and which elements of such chain are considered.

Further, some reframing of the definitions, and even proposals for additional criteria were suggested in the validation phase, based on responses from ongoing C-ITS deployments. For example, one response was that Quality Criteria should be more distinguished, depending on the consequences of “wrong” data. This again shows the challenge of high variability and complexity in our context.

Also, parallel quality-related definitions within C-ITS data standards (ETSI DENM+CAM specifications) were explored. We decided to cite such definitions within this Quality Package, and correlate them with the elaborated EU EIP Quality Criteria, when applicable. This way, the final list of EU EIP Quality Criteria adds three ETSI-based, quality-related data elements (“transmissionInterval”, “PosConfidenceEllipse” and “informationQuality”), together with the original definition and a correlation to EU EIP Quality Criteria. However, some overlaps and conflicts between the ETSI and EU EIP quality concepts could not be resolved entirely. There was neither a further elaboration on the ETSI elements, e.g. on quality requirements (i.e. minimum levels), as such requirements are currently established in ongoing projects like C-Roads.

For quality levels, i.e. quantitative Quality Requirements, it was again challenging to define common expressions for all possible C-ITS services, data categories, and data flows. This is again due to the heterogeneous data applications across all C-ITS services. In the validation phase, very often no concrete values could be derived from C-ITS deployments, or, in a few cases, some heterogenous, project-specific numbers were given. Consequently, our quality levels have not been formulated explicitly as finally agreed Quality Requirements (basic / enhanced / advanced), but rather as reference values, giving an orientation on possible ranges of quality values from today's point of view of C-ITS experts.

Future research needs to explore Quality Requirements in a wider scope, looking at other data applications and C-ITS services. Further, the quantitative expressions of Quality Requirements are often based on a personal assessment, and need to be validated in future steps.

In summary, we realize that not all open questions, when defining Quality Criteria and Requirements, can be solved for now. So, this paper is seen as a first approach to capture and describe applicable C-ITS Quality definitions, which need to be further discussed and validated.

To back up the theoretical character of this Quality Package with practical perspectives, expert knowledge from C-ITS deployment stakeholders, as well as evidence from pilot deployments was considered . To do so, C-ITS projects were consulted via questionnaires at the beginning of the project (see section 2.2), as well as at the validation phase, where our first attempts for C-ITS quality definitions were reviewed and partially revised (see section 8).

The recent validation phase made also apparent that piloting emerging technology such as C-ITS may require temporarily a wider range of values for quality, partly also of definitions of quality criteria. This phase precedes a converging phase - when having collected more experience also in the transition towards regular operation – to a narrower bandwidth of values as it has been the case for the services covered by the first Delegated Regulations (SRTI/RTTI). In other words, we found that the range of possible quality values is on a path from "wider" to "narrower", by collecting more experience and by transition to regular operations in the C-ITS domain, see the following figure.

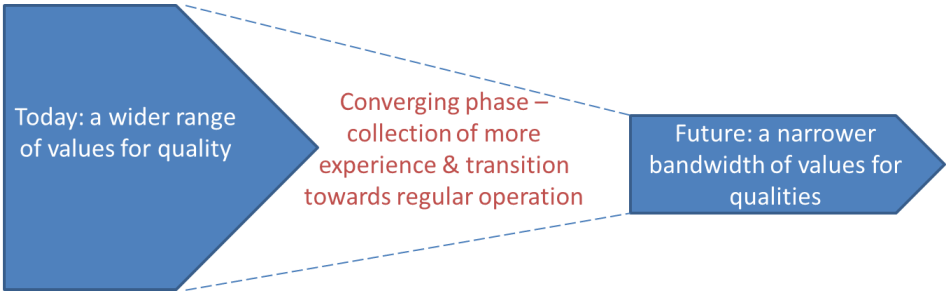


Figure 15. Converging path for quality values in the C-ITS domain

With this key finding from the validation activity, we conclude that the present C-ITS Quality Package cannot (yet) serve as „tabular look-up“ with fixed quality values, as such values are not mature yet and cannot be established on a generic, cross-deployment level.

However, we were able to formulate the following recommendations for future C-ITS project in terms of quality aspects:

- Considering the specificity of each C-ITS deployment and use case, we recommend to elaborate an individual Quality Framework.
- The present C-ITS Quality Package can be used as a baseline for such individual Quality Framework, but must be detailed out and tailored to the project environment, e.g. by setting up individual Quality Criteria.
- In particular, each C-ITS deployment project could tackle quality aspects as follows:
    - Establish quality management as an explicit work package, with own resources and personnel,
    - Integrate quality criteria in the development phase of the project, and/or
    - Integrate quality criteria in the evaluation phase of the project.

Doing so, there might be more evidence on quality aspects on a cross-deployment level, eventually leading to a Europe-wide agreement and consolidation of C-ITS quality criteria.

As a final conclusion, this work is considered a pioneer step to capture quality aspects of C-ITS services in a broader context. This way, it adds a “quality layer” to existing and ongoing standardisation, harmonisation and legislature attempts to design C-ITS services. Whereas this work has some preliminary and awareness-raising character, we assume that such quality aspects will get some momentum when C-ITS services step into regular

operations in a large scale, and when efficiency, reliability and acceptance of such services get more attention. EU EIP and potential follow-up projects will continue to address the quality aspects in this manner.

Lastly, we refer to the ongoing, EU-cofunded NAPCORE project, where a follow-up quality activity ("Working Group 3, Task 3.2 "European NAPs data quality") will take over any remaining quality harmonisation issues, also in the C-ITS context.

10. References

References are shown as footnotes throughout this report.

11. Annexes

ANNEX 1

C-ITS project liaison questionnaire

ANNEX 2

Validation Questionnaire about C-ITS Quality Package

ANNEX 1

EU EIP 4.1. Sub-Task "Defininining C-ITS Quality"

C-ITS project liaison questionnaire (Draft July 24,2019)

Dear C-ITS project partner,

EU EIP SA 4.1 is working on a framework for data quality in C-ITS.

As an input for our work, please answer the following questions.

General questions:

1. Name of your project?

2. What Day 1 C-ITS service do you develop? *(road work warnings, weather conditions, …)*

3. What is your role in the project? *(project coordinator, consultant, technical developer, …)*

4. In general, what are your expectations towards characteristics of the data? *(on a range from 1 "not relevant" to 5 "highly relevant"; please mark below))*
   - Data must be accessible ☐1 ☐2 ☐3 ☐4 ☐5
   - Data must be understandable ☐1 ☐2 ☐3 ☐4 ☐5
   - Data must be processible ☐1 ☐2 ☐3 ☐4 ☐5
   - Data must be reliable ☐1 ☐2 ☐3 ☐4 ☐5
   - Data must be consistent ☐1 ☐2 ☐3 ☐4 ☐5
   - Data must be complete ☐1 ☐2 ☐3 ☐4 ☐5
   - Data must be re-usable ☐1 ☐2 ☐3 ☐4 ☐5
   - Data must be relevant ☐1 ☐2 ☐3 ☐4 ☐5
   - Data must provide some added value ☐1 ☐2 ☐3 ☐4 ☐5
   - Data must have the right level of detail ☐1 ☐2 ☐3 ☐4 ☐5

Questions for a specific data use case* in your responsibility:

**If you have multiple data use cases, please repeat questions 5-12 for each use case!*

5. What kind of data is processed? *(e.g. road work messages)*

6. What is the data sender? *(vehicle, road-side station, central station?)*

7. What is the data receiver? *(vehicle, road-side station, central station)*

8. Does that data relate to some standard? *(DENM, CAM, …?)*

9. Do you represent the role a data sender or receiver or both?

10. Are you using the following quality criteria in your data use case? If yes, have you defined (minimum) quality levels? *(please mark below)*

• Availability	□ applied, no level defined	□ applied , with (minimum) quality level: _____	□ not applied
• Geographic coverage	□ applied, no level defined	□ applied , with (minimum) quality level: _____	□ not applied
• Timeliness	□ applied, no level defined	□ applied , with (minimum) quality level: _____	□ not applied
• Location accuracy	□ applied, no level defined	□ applied , with (minimum) quality level: _____	□ not applied
• Error rate	□ applied, no level defined	□ applied , with (minimum) quality level: _____	□ not applied
• Event coverage	□ applied, no level defined	□ applied , with (minimum) quality level: _____	□ not applied
• Completeness	□ applied, no level defined	□ applied , with (minimum) quality level: _____	□ not applied
• Other:_____	□ applied, no level defined	□ applied , with (minimum) quality level: _____	□ not applied

11. Are any of the criteria above assessed? If yes, how? *(Quantitative measurements, e.g.?)*

12. Who is in charge for the data quality assurance? *(Data sender, data receiver, nobody, other)*

<u>General questions (continued):</u>

13. In your particular project, do you think data quality has been considered sufficiently? *(please mark below)*

    □ No

    □ Yes, but only for my project

    □ Yes, for large-scale roll-out of the C-ITS service

14. Do you have any further quality-related insights from your project?

15. Can you provide us with empirical data from your data use case? *(in order to enable EU EIP SA 4.1 to do some evaluation studies on data quality)*

Your Name: _____

Your Email: _____

Thank you!

Members of EU EIP SA 4.1

ANNEX 2

EU EIP 4.1. Quality of ITS

Questionnaire about C-ITS Quality Package (draft)

Dear C-ITS project representative,

EU EIP SA 4.1 has published a framework for data quality in C-ITS, called the "C-ITS Quality Package":

https://www.its-platform.eu/highlights/quality-package-c-its-information-quality-introduced-eu-eip-online-workshop

The purpose of this questionnaire to gain feedback on the suitability and practicability of the "C-ITS Quality Package".

Please answer the following questions.

1. Name of your project?
2. What Day 1 C-ITS service do you develop? *(road work warnings, weather conditions, …)*
3. What is your role in the project? *(project coordinator, consultant, technical developer, …)*

Questions for a specific data use case* in your responsibility:

**A data use case is one form of data exchange in a C-ITS architecture. If you have multiple data use cases, please repeat questions 4-9 for each use case!*

4. What kind of data is processed? *(e.g. road work messages)*
5. What is the data sender? *(vehicle, road-side station, central station?)*
6. What is the data receiver? *(vehicle, road-side station, central station)*
7. Does that data relate to some standard? *(DENM, CAM, …?)*

8. One item of the “C-ITS Quality Package” is a set of generic **Quality Criteria**, to describe data and service qualities in any C-ITS project.
   See a summary table below (more details: see section 5 of the “C-ITS Quality Package”).

Quality Criterion	Definition
Geographical coverage	Percentage of the road network and/or selection of road classes, where a stationary, connected C-ITS stations operate.
Availability	Average availability for all operating connected data senders, including the communication chain up to the data receiver.
Latency	Total time for communicating messages between a timestamp at a C-ITS sender and a timestamp at a C-ITS receiver.
Refreshment Rate	Time interval for refreshing / updating the status reports coming from a data sender.
Location accuracy	Deviation of the reported horizontal location of an event information with respect to the actual location.
Error Rate	Percentage of messages with erroneous information, as reported by a data sender, out of the total number of messages.
Report Coverage	Percentage of connected working C-ITS data senders out of all connected C-ITS data senders.

For each Quality criterion, please indicate your reaction in the next table. *(please mark, multiple answers are allowed)*

Quality Criterion	Reaction
Geographical coverage	☐ this criterion is not applied in our use case ☐ we have a different wording or context in our use case, my comments see below ☐ we understand and agree with the definition ☐ we don't understand or don't agree with the definition, my comments see below ☐ this criterion has been covered by the evaluation of our project, see report/resource below Comments, further resources: _____
Availability	☐ this criterion is not applied in our use case ☐ we have a different wording or context in our use case, my comments see below ☐ we understand and agree with the definition ☐ we don't understand or don't agree with the definition, my comments see below ☐ this criterion has been covered by the evaluation of our project, see report/resource below Comments, further resources: _____
Latency	☐ this criterion is not applied in our use case ☐ we have a different wording or context in our use case, my comments see below ☐ we understand and agree with the definition ☐ we don't understand or don't agree with the definition, my comments see below ☐ this criterion has been covered by the evaluation of our project, see report/resource below Comments, further resources: _____
Refreshment Rate	☐ this criterion is not applied in our use case ☐ we have a different wording or context in our use case, my comments see below ☐ we understand and agree with the definition ☐ we don't understand or don't agree with the definition, my comments see below ☐ this criterion has been covered by the evaluation of our project, see report/resource below Comments, further resources: _____
Location accuracy	☐ this criterion is not applied in our use case ☐ we have a different wording or context in our use case, my comments see below ☐ we understand and agree with the definition ☐ we don't understand or don't agree with the definition, my comments see below ☐ this criterion has been covered by the evaluation of our project, see report/resource below Comments, further resources: _____
Error Rate	☐ this criterion is not applied in our use case ☐ we have a different wording or context in our use case, my comments see below ☐ we understand and agree with the definition ☐ we don't understand or don't agree with the definition, my comments see below ☐ this criterion has been covered by the evaluation of our project, see report/resource below Comments, further resources: _____
Report Coverage	☐ this criterion is not applied in our use case ☐ we have a different wording or context in our use case, my comments see below ☐ we understand and agree with the definition ☐ we don't understand or don't agree with the definition, my comments see below ☐ this criterion has been covered by the evaluation of our project, see report/resource below Comments, further resources: _____

9. Another item of the "C-ITS Quality Package" are **Quality Requirements**, which define (minimum) levels for each of the Quality Criteria, to be met by individual C-ITS services. They are distinguished as a ** Basic, ** Enhanced and *** Advanced* levels.

   See an example table below for the use case "Road-work warning trailer status data to NAP" (more details: see section 6 of the "C-ITS Quality Package").

Quality Criterion	★ (Basic)	★★ (Enhanced)	★★★ (Advanced)
Geographical coverage	95 % of road network and/or all Motorways/National Roads	97% of road network and/or all Motorways/National Roads +Main Roads/ connectors	100%, and/or whole road network, including local roads
Availability	95% (347 days/year)	99% (361 days/year)	99,5% (363 days/year)
Latency	95% of all messages <10 minutes	95% of all messages <7 minutes	95% of all messages <2 minutes
Refreshment Rate	<5 minutes	<3 minutes	<1 minute
Location accuracy	95% of all messages within tolerance circle <10m	95% of all messages within tolerance circle <1m	95% of all messages within tolerance circle <10 cm
Error Rate	<15%	<10%	<1%
Report Coverage	> 80%	> 90%	>99%

For each Quality Criterion, please indicate your reaction in the next table. *(please mark, multiple answers are allowed)*

Quality Criterion	Reaction
Geographical coverage	□ criterion not applied/measured/specified in our use case □ we propose the following value for * Basic Level: _____ ** Enhanced Level: _____ *** Advanced Level: _____ □ we don't feel such values can be determined yet, but need further research or validation Comments, further resources: _____
Availability	□ criterion not applied/measured/specified in our use case □ we propose the following value for * Basic Level: _____ ** Enhanced Level: _____ *** Advanced Level: _____ □ we don't feel such values can be determined yet, but need further research or validation Comments, further resources: _____
Latency	□ criterion not applied/measured/specified in our use case □ we propose the following value for * Basic Level: _____ ** Enhanced Level: _____ *** Advanced Level: _____ □ we don't feel such values can be determined yet, but need further research or validation Comments, further resources: _____
Refreshment Rate	□ criterion not applied/measured/specified in our use case □ we propose the following value for * Basic Level: _____ ** Enhanced Level: _____ *** Advanced Level: _____ □ we don't feel such values can be determined yet, but need further research or validation Comments, further resources: _____
Location accuracy	□ criterion not applied/measured/specified in our use case □ we propose the following value for * Basic Level: _____ ** Enhanced Level: _____ *** Advanced Level: _____ □ we don't feel such values can be determined yet, but need further research or validation Comments, further resources: _____
Error Rate	□ criterion not applied/measured/specified in our use case □ we propose the following value for * Basic Level: _____ ** Enhanced Level: _____ *** Advanced Level: _____ □ we don't feel such values can be determined yet, but need further research or validation Comments, further resources: _____
Report Coverage	□ criterion not applied/measured/specified in our use case □ we propose the following value for * Basic Level: _____ ** Enhanced Level: _____ *** Advanced Level: _____ □ we don't feel such values can be determined yet, but need further research or validation Comments, further resources: _____

10. Do you have any further quality-related comments from your project or use case?

Your Name: _____

Your Email: _____

All details and information you provide will only be used for the purposes of the "EUEIP SA 4.1 Quality of ITS" and will be securely stored. We will not share your data with any third parties.

Thank you!

Members of EU EIP SA 4.1