Work towards Optimum Quality of ITS

Final report

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European ITS Platform

1. Executive summary

The presented paper compiles results from the “Optimum Quality” task of EU EIP sub-activity 4.1.

The level of quality of traffic information services is a significant parameter that affects how users perceive the information service and how they use it in real life. The quality of information affects how often drivers use the information service, and how much the information affects drivers’ decision-making. If a driver experiences bad quality, the information does not have any effect on decision-making, thus no benefits for the society are achieved. Furthermore, low quality information leads to wrong decisions, leading to costs for society in the form of decreasing traffic safety and flow. Actions that improve information quality usually come with a cost – typically so that quality improvement to the basic quality level is cheaper than improving the quality to the higher quality levels, e.g. to the “Advanced level”, according to the EUEIP quality framework. Research has proved that once a certain quality level has been reached, further quality improvements do not yield significant benefits to the drivers nor the society. Therefore, it can be assumed that an optimum quality level for traffic information services does exist in which the benefits acquired per invested Euros is the highest. This is the theoretical optimum quality level.

The goal of this task has been to analyse and assess the optimum quality levels for selected services. In addition, the goal was to collect experiences of different quality improvement actions and give recommendations to road authorities of EU Member States on options to improve quality of the different quality criteria. Also, the goal was to analyse the whole value chain in the wider context and recommend action and best practices how to maximise societal benefits of the services.

In order to quantitatively analyse optimum quality of ITS services, one would need quantified data on costs of service production, the quality level reached with certain amount of investments, as well as estimates on societal benefits on different EUEIP quality levels. In the first stages of the project, a literature study and stakeholder consultation was accomplished in order to get an overview of the empirical data available that could be used for defining the optimum quality. The outcome of this analysis was, that the amount of quantitative quality information is very limited and it is difficult to compare the results of different evaluation studies. While there are quality and impact evaluations as well as cost/benefit analyses, they tend to either focus on very specific aspects (e.g. specific quality parameter such as latency) or consider impacts of a service on, for example, safety without addressing the relevance of the different quality parameters. Similarly, the cost/benefit aspect is hard to pinpoint on even specific services, let alone quality aspects, as they often relate to comprehensive traffic management systems where the investments benefit not only quality of information services, but also traffic management measures. Thus, it was concluded that a quantitative analysis and definition of optimal quality is extremely difficult and a more practical approach is needed. The focus was set on more realistic and practical results that should benefit the Member States in their ITS related investment and quality improvement activities.

The main research objectives identified for the Optimum Quality task are:

- to identify different use cases and significant impact mechanisms in achieving societal benefits of selected information services;

- to identify the importance of different quality criteria for the realisation of the significant impact mechanisms;

- to recommend a “target quality level” or an ”optimum quality range” for the critical quality criteria using the EU EIP Quality Package framework (Kulmala et al., 2019);

- to recommend road operators’ actions by which to improve the critical quality elements efficiently, considering ongoing technical developments, and

- to recommend road operators’ role and actions in the service side of the Value Chain for Traffic Information, for different service types in order to maximise societal benefits.

The working group decided to focus on selected services, which were safety related information services (weather related, other events), road works information services and travel time information services. Also, multi-modal traveller information services (MMTIS) were considered partly, but no recommendations for optimum quality levels were given due to its complexity.

Looking at the impact mechanisms of information services, and their linkage to the levels of different quality criteria, an expert assessment was performed including review of existing literature. For each of the selected services, the most significant user outcomes (e.g. mode choice, route choice etc.) were identified, following an assessment of the consequential impacts to the societal benefits of information (e.g. safety and accident risk, comfort and stress etc.). Also, the significance of different EUEIP quality criteria in the realization of these effects and benefits was successfully performed. To sum up the results from this phase, the often very relevant criteria for all information services were identified as follows:

- Service criteria
  - **Geographical coverage**
- Quality Criteria
  - **Timeliness (event-based information) / Reporting period (status information)**
  - **Latency**
  - **Classification correctness (event-based information) / Error rate (status information)**

Furthermore, in the working group discussions it was identified that some other quality criteria were deemed important or critical for some services, such as Location accuracy for SRTI warnings.

Based on the above-mentioned analysis, followed by an analysis of potential improvement methods related to different quality criteria (and their rough cost indication), the working group was able to present an expert judgement, what is likely to be the optimum or target quality level (the level to which organisations should currently strive for) of different quality criteria for the selected services. The presented optimum quality levels or optimum quality ranges are purely based on expert judgement, which must be kept in mind when using the results.

The analyses are based on initial work of dedicated experts which were further elaborated in a broader group of experts in a workshop. The following results refer to the quality levels **Basic**, **Enhanced** and **Advanced**, as established in the EU EIP Quality Package.

The results on target quality levels for event-based information, produced with technologies and processes currently in wide-spread use in the Member States, were as follows:

- **Geographical coverage**:
    - for travel time information and weather related SRTI information, optimum is **100 %** of the regularly affected TEN-T network, and **Advanced** (95%) for the whole TEN-T network
    - for other SRTI events: **Advanced** (95%) with a note that actual target should be 100% of all road works in the responsibility of the road authority.
- **Timeliness:**
    - **Enhanced for all selected services** (For 95 % of all events: Time between event occurrence and first detection: Best effort; Acceptance after first detection < 10 min)
- **Latency:**
    - for all SRTI events except SRTI short term road works: **Advanced (**For 95% of all events < 5 min) and **Enhanced** (For 80% of all events: < 5 min) for SRTI short term road works. Different target level may be set due to the prioritization of other events over road works information in the traffic information centres.
    - for travel time information **Advanced (**95 % of all reports < 2 min)
- **Location accuracy:**
    - for SRTI events: **Advanced** (<5 km)
- **Classification correctness:**
    - for all SRTI events **Advanced** (>95%)

The results on target quality levels for status-type information were as follows:

- **Reporting period**: **Advanced** (1 min) for the congested or incident-prone operating environments and **Enhanced** (5 mins) for less congested operating environments.
- **Timeliness (update)**: **Advanced** (95 % of all reports < 2 min)
- **Error rate:** depending on the OE **Enhanced** (5%/20%) or **Advanced** (5 %/10%)

As assumed, a Basic quality level was not estimated to be optimum level for any of the services, and road operators are suggested to strive for more improved quality levels. This result is an indication that the quality requirements in the EUEIP Quality Package have been set to feasible levels addressing the current status in different member states. An important but not surprising finding from the analysis was also that the optimum quality level depends on the operating environment. The proposed optimum quality levels do apply only for the operating environment (OE) “Main highways with 2 separated carriageways and congestion and/or safety problems”, if not stated otherwise. In contrast, in certain operating environments the likelihood of events may be small and therefore it is not worthwhile to invest in roadside instrumentation, meaning that the optimum quality level is lower than in heavily trafficked environments. For some services, such as travel time information services, there may be further OE’s where the service is not needed at all, at least not in ‘normal’ conditions or 95 % of time. The connection between optimum quality levels and OE’s should be analysed in more detail in future projects.

Regarding the most cost-efficient quality improvement methods, based on experiences collected from the working group and further experts analyses, the following key findings can be made:

- **In the recent years** actions have been based mostly on non-scalable actions (road instrumentation, human resources, road inspectors), as well as system integration (specifically with traffic management systems and with Emergency Response Centres)
- **Currently and in the next two years** mobile technologies are lowering the unit costs (€/km) and automatization and data fusion are likely to improve the (quality) efficiency of the existing instrumentation and systems
- **In the near future (3-5 years)** the development and market penetration of C-ITS will make information more precise, more current and more dedicated to the individual road user and her current situation on the road.

To sum up, an organisation must know first what quality level is currently reached, to be able to define the steps towards further improvements. That is a prerequisite for cost-efficient quality work in the longer term. Another important aspect for the sake of cost-efficiency is the mapping of quality interdependence, i.e. exploring how different changes in systems/processes affect quality in different content types and quality criteria. Many improvement methods, such as adding road instrumentation, affect various processes, so a holistic view needs to be taken in the assessment of the overall cost-effectiveness. Many road authorities use multiple actions simultaneously. For example, Rijkswaterstaat in the Netherlands invests simultaneously in personnel, road inspector vehicles, smart camera systems (with automatic detection) and optimization of processes (e.g. Charm).

The performed analysis reveals, that especially due to developments regarding vehicle data, data fusion, system intelligence and automatization, and in the near future the roll-up of C-ITS systems, the cost-efficiency of quality improvement methods and actions is likely to increase. This development will shift the point of optimum quality to higher quality levels. Thus, the presented recommendations of the optimum quality levels apply only in current circumstances and widely used technologies. The recommendations should not be used to hinder possible quality development beyond the current target levels.

The analysis so far has considered mostly the quality of information from the start of the event until the information is available in the national access point (NAP), i.e. the content side of the Value Chain of Traffic Information, following the traditional scope of the EU EIP Activity 4.1. However, it is known that the benefits of traffic information, and therefore also the point of quality optimum, does not rely merely on the quality of data when provided at the NAP, but also on the quality of the end-user services. The more road users access and utilize information in their trip and driving decisions, the more benefits will be realized for the society, and the better is the utilization rate of the quality improvement investments. In the last work phase the working group completed the picture of the Value Chain of Traffic Information, looking at actions available for road operators and authorities affecting the service side of the Value Chain, reaching from the NAP to the end-user. Even though the service part of the Value Chain is mainly in the responsibility of public and private service providers, the road operators have different means to facilitate better use of the available data. The actions can be summarized as follows:

- Improvement of data richness by using all relevant data fields of the standard data models
- Development of data fusion methodologies and provision of more value-added datasets in addition to the basic ones
- Development of easy-to-use APIs to the NAP to raise interest among local service providers

- Introduction of national or regional actions that foster vehicle fleet renewal
- Streamlining the functioning of the value chain by building cooperation between road operators and service providers
- Development of clear national regulation for questions that require rules for the game

The role of service channels is gradually changing, as traditional traffic announcements within radio broadcasts lose users for the in-vehicle communication services and mobile applications. However, the change will happen rather slowly during the next couple decades. During the transition period, road operators should strive to maintain good quality and uniform message content in all the service channels. Given the importance of transmissions in the traffic information value chain, it is also necessary to take into account the evolution of communications networks. Capacity of networks may increase, but their usage may increase as well, which can have an impact on the quality of the information on some occasions.

To crystallize the most important findings from the study, the main take-aways for different road operators in Europe are as follows:

1. **Know your data quality.** Use the EU EIP Quality Package to design the local quality framework and identify the most feasible quality assessment methodologies.
2. **Set quality targets.** Consider the current quality level and the recommended optimum/target quality levels and consider the different needs in various operating environments.
3. **Assess the expected quality improvement from the ongoing development projects.** Analyse how the technological development (monitoring systems, vehicle data, development of IT systems and automation) will affect the data quality of different information services.
4. **Define and implement the needed complementary actions to reach targets.** Identify the complementary actions needed to reach the targeted quality levels using the recommendations in this report.
5. **Engage in the collaboration and regulation work with the local and global value chain stakeholders.** Facilitate active and continuous collaboration with the global and local service providers and agree about actions that streamline the information flow in the whole value chain.
6. **Evaluate quality improvement.** Build a local quality monitoring system for continuous quality measurement and use a wide range of incremental quality improvement actions.

The quality framework developed by the EU EIP project is validated and tested and therefore mature enough to support all quality improvement activities within the European road operators' organisations. However, quality of information services may be lacking from the strategic KPIs of the organisations, and therefore quality management receives insufficient funding independent of other development projects. Institutional challenges are rarely easy to overcome. If the quality effect of investments or other actions is not evaluated systematically, the European community cannot develop new knowledge of the effects and benefits, and the situation remains. Based on the analyses and discussions in the working group, the European Commission should either consider clear incentives for road operators to implement the Quality Framework or consider stronger regulation to support deployment in the revision of the ITS Directive.

2. Introduction

2.1. Context

The level of quality of traffic information services is a significant parameter that affects how users perceive the information service and how they use it in real life. The quality of information affects how often drivers use the information service, and how much the information affects drivers' decision-making. If a driver experiences bad quality, the information does not have any effect on decision-making, thus no benefits for the society are achieved. Furthermore, low quality information can lead to wrong decisions, leading to costs for society in the form of decreasing traffic safety and flow. In the U.S. Shah and Wunderlich (2005) have concluded, based on a simulation study, that an error in the measured quantity can be at maximum 9-21 % to allow net benefits for the society from the use of information. The same study concluded that once the error has been decreased to the level of 5 %, no significant benefits can be reached for further quality improvements. As there usually are some costs involved in the improvement activities of quality, it can be concluded based on the mentioned research results, that an optimum quality level is likely to be found for traffic information services.

The Grant Agreement of EU EIP-project sets the initial scope for this Task 4 "Work towards Optimum Quality for ITS":

> *"The optimum quality is determined on the basis of what is the most cost-efficient in terms of socio-economic benefit-cost ratio in different operating environments. This is important in order to prevent member states from over- or under-investing in service coverage and quality. It requires a sufficient number of quality assessments accompanied with benefit and cost information from national studies or corridor projects so that widely deployed services such as different types of real-time information services represent likely candidates of study. The optimum may change in time due to introduction of new technology solution, and this needs to be addressed specifically."*

2.2. Goal of the Optimum Quality Task

The goal of the task is to analyse the mechanisms for acquiring societal benefits from selected ITS services and to build a link between data and service quality and the societal benefits. This analysis will be further used to assess different investment and process development options in the improvement of the quality, in order to give guidance to the Member States on which quality level should be targeted for selected services from a cost-efficiency's perspective.

The Optimum Quality Task serves as additional elaboration to the EU EIP Quality Package on Safety-Related and Realtime Traffic Information, also published by EU EIP sub-activity 4.1. (Kulmala et al., 2019). The reader is suggested to familiarise themselves with the Quality Package first, in order to understand the Quality Framework referenced in this report, in particular with respect to quality criteria and criteria levels.

3. Theoretical framework of Optimum Quality

Based on the pre-study of this Task, optimum quality of traffic information services is a topic that has not previously been very thoroughly researched. However, many organisations have some sort of inherent optimum quality approach in the planning of their ITS investment programs, even though the optimum quality level is not usually quantitatively set. Even though limited ITS specific literature on optimum quality could be found, optimum quality is a topic that has been widely researched under other domains, such as production industry (for different consumer goods). Juran (1951) presented his famous and classic theory on optimum quality already in 1951, after extensive research in production industry. Juran's classic model for optimum quality costs addresses the following common phenomena:

- Increasing conformance (of quality targets) reduces economic losses due to defective products.
- The cost of quality improvement and control increases geometrically as perfection is approached.
- Due to the above-mentioned common laws, the optimum quality is always short of perfection, i.e. the optimum level is < 100 % quality.

These phenomena are illustrated in Figure 1*. Model for optimum quality costs (Juran 1951).*.

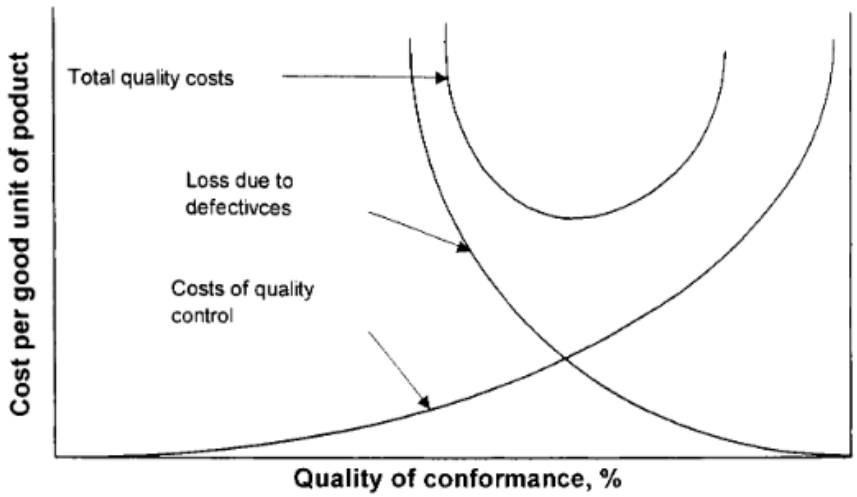

Figure 1*. Model for optimum quality costs (Juran 1951).*

Analysing Juran's theory from the perspective of ITS information services, it can be argued that at least the phenomena regarding increasing costs for quality improvement usually applies. However, technological changes and new concepts may significantly alter the form of the cost curve and thus change the location of the optimum quality point.

Analysing the cost of defectives-curve, one must think about the right way to apply the theory in the field of ITS. Instead of economic losses due to decreased sales or increased amount of reclamations, one must consider lost socio-economic benefits due to incomplete information quality. Lost socio-economic benefits may occur when consumers make travel or driving decisions based on false information, and loose time or increase accident risks or congestion because of that. The smaller the errors in information quality, the smaller the possibilities for such adverse effects.

With these small adjustments to the original theory it can be argued that Juran's classic theorem gives a reasonably good ground for further inspection in the field of ITS.

In the following illustration Juran's theory is applied to the world of ITS and further to the EUEIP Quality Framework. Instead of using the function of socio-economic losses (due to incomplete quality), we apply so called Capital Budgeting Theory and estimate the function of socio-economic benefits acquired with different quality levels. According to Capital Budgeting Theory, there is an economic inflection point, beyond which available quality improvement action no longer yields socio-economic benefits to the same extent that investments costs arise. This point in the quality scale is the Optimum Quality level in the EUEIP Quality Framework. The application of Capital Budgeting Theory in the scope of EUEIP's information quality activities is illustrated in Figure 2*. Illustration of the development of service improvement costs and societal benefits.* .

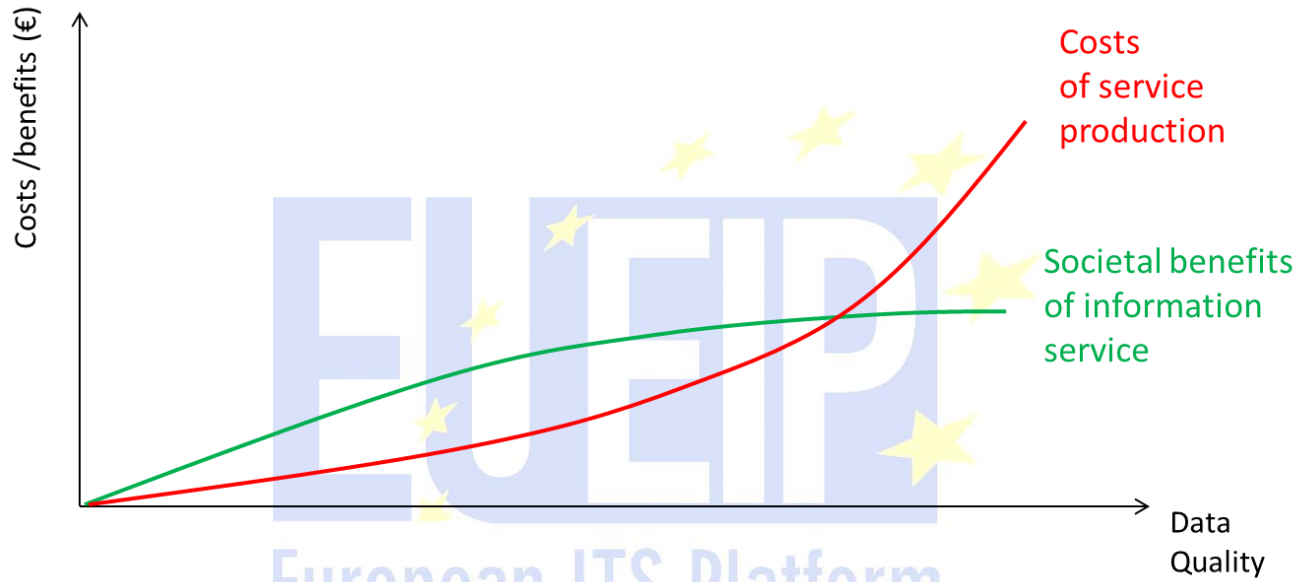

Figure 2*. Illustration of the development of service improvement costs and societal benefits.*

The above explained approach forms the theoretical background in this Optimum Quality Task. In order to quantitatively analyse ITS services, one would need quantified data on costs of service production as well as estimates on societal benefits on different EUEIP quality levels. It should however be noted that it is acknowledged that it is very difficult to study real services in quantitative manner following this theory. In the following chapters, it is explained what kind of approach can be used from the practical perspective.

The term "societal benefits" deserves further explanation. In this task, we are studying the economic and environmental impacts that occur when users use the information services in trip planning and execution (e.g. driving behaviour). These changes in users alter the outcome of travel in the traffic system (traffic flow, safety etc.). The changes in the traffic system in turn present the societal impacts i.e. impacts on households and companies as well as consequences of traffic system impacts on environment, health and overall satisfaction.

The societal impacts of the information services industry as well as the effects of the use of information in operational traffic management are excluded from this study.

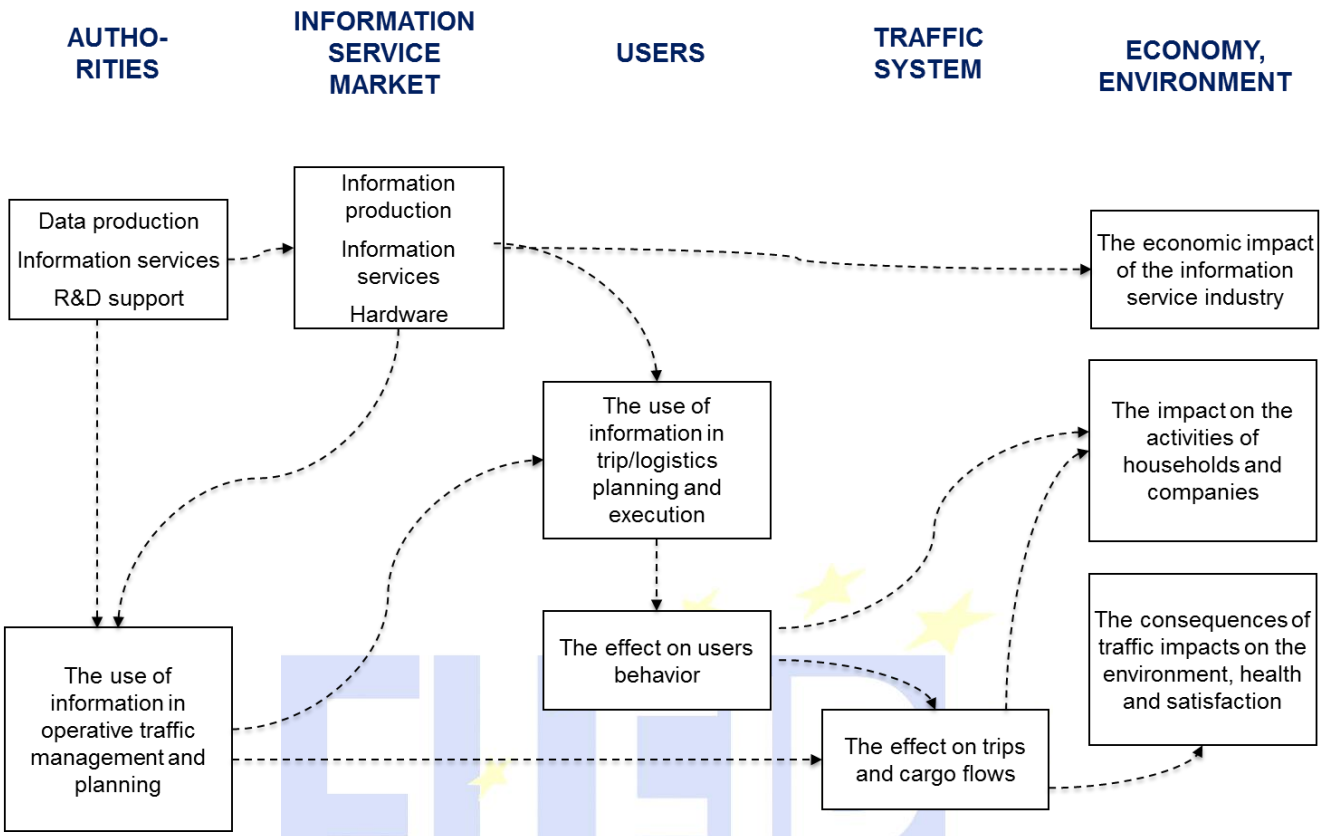

Figure 3. *Illustration of the chain of impacts for traffic information services (Laine et al. 2013)*

4. Revised research objectives

The ambitious goal of defining optimum quality meant that there was a need for quantified data. It would be necessary to understand what are the quantifiable investment and operating costs as well as socio-economic benefits of the different services at different quality levels. During late spring and summer of 2018, a literature study and stakeholder consultation was done in order to get an overview of the empirical data available that could be used for defining the optimum quality. The round of collecting inputs indicated how limited the amount of quantitative quality information is and how difficult it is to compare the results of different evaluation studies. While there are quality and impact evaluations as well as cost-benefit analyses, they tend to either focus on very specific aspects (e.g. specific quality parameter such as latency) or consider impacts of a service on, for example, safety without addressing the relevance of the different quality parameters. Similarly, the cost-benefit aspect is hard to pinpoint on even specific services, let alone quality aspects, as they often relate to comprehensive traffic management systems. Road operators' investments typically improve their traffic management as a whole, not specifically traffic information services.

In conclusion, quantitative analysis and definition of optimal quality was deemed extremely difficult and a more practical approach necessary. Based on the findings from the initial study phase, it was decided to fine-tune the research objectives. The focus was set on more realistic and practical results that should benefit the Member States in their ITS related investment and quality improvement activities. The main research objectives identified for the Optimum Quality task were:

- **to identify** different use cases and significant impact mechanisms in achieving societal benefits of selected information services
- **to identify** the importance of different quality criteria for the realisation of the significant impact mechanisms
- **to recommend** a "target quality level" or an "optimum quality range" for the critical quality criteria using the Validated Quality Package framework
- **to recommend** road operators' actions by which to improve the critical quality elements efficiently, considering ongoing technical development
- **to recommend** road operators' role and actions in the service value chain for different service types in order to maximise societal benefits

The information services selected into the analysis were 1) SRTI weather related events (Spain), 2) SRTI other events but not Wrong Way Drivers (the Netherlands), 3) SRTI short-term road works information (Germany) and 4) RTTI travel time information (Finland). The selection was based on the interest and familiarity of the active participants in the Activity.

5. Working towards the optimum quality range of the selected services

5.1. Identifying impact mechanisms and adding the quality aspect

5.1.1. METHODOLOGY

The challenge identified during the initial literature study and stakeholder consultation (see section **Error! R eference source not found.**) was that the existing impact evaluations are incomparable due to varying context and different considerations as well as lacking relation from overall systems to specific services and their impacts. The first task is to better understand the impact mechanisms from investments to services to outcomes and impacts.

To understand how new improvements (investments, i.e. costs) result in socio-economic impacts, we have first defined what outcomes (i.e. changes in user behaviour) the selected services result in. Then, the outcomes (i.e. direct impacts the services have on users) will be connected to the expected societal impacts (e.g. improved safety or traffic flow). The process can be described as *Input → Output → Outcome → Impact (IOOI).* The investment (i.e. Input) enables the solution to be implemented, creating e.g. an information service (i.e. Output), which in turn results in a direct change in user behaviour e.g. slowing down or choosing an alternative route (i.e. Outcome), which more broadly will affect e.g. the overall traffic flow and safety (i.e. Impact). This logical model makes the connections from systems to impacts more explicit as well as clarifies assumptions and what is appropriate to evaluate (see e.g. PHAO Toolkit[1]).

The impact mechanisms will be identified for selected services based on expert interviews and available evaluation data in the literature identified in the pre-study or during this task. Each participant is advised to seek expertise in their own organisation in case the participants do not personally have the required experience for the task. All literature will be collected to an online repository to be shared with all participants.

Once the impact mechanisms have been identified, the most relevant outcome types (most strong effects for the impacts) will be analysed for the services in question. That is, in a similar construct as in the previous step, the effect of each quality criterion (corresponding to the EU EIP Quality Framework) to the direct behaviour change (i.e. Outcome) will be identified. This has been done through literature review and expert opinions.

Once the relevance of the quality criteria for the outcomes has been identified, the connection from quality can be made to the broader impacts.

To narrow down the scope of the work, it was decided to concentrate first on on-trip information delivered to e.g. navigation system or mobile application, and if time allows, continue analysis to pre-trip use cases and channels. It should be noted that on-trip information has different effect mechanisms than pre-trip information (as the user is already on the road).

5.1.2. RESULTS

In the following illustrations, we have defined the linkage between the information service output to different outcomes that realise when drivers and travelers actually use information services. Green arrows stand for significant linkage and yellow arrows less significant but notable linkage. From the different outcomes (i.e. changes

[1] PHAO Toolkit: Logic Model. https://www.okintheknow.org/wp-content/uploads/2016/11/Logic-Model-Compiled-Toolkit.pdf

in user behaviour or choices) we have also drawn a link to societal level impacts, following the same logic in arrows and their colouring. The linkages have been built using expert judgements within our working group, but also earlier research documented in literature have been used to some extent.

In addition, in the following service-specific illustrations it has been assessed which EU EIP quality criteria are significant for the realisation of the societal impacts. The significance has been presented using colour green for significant criteria and yellow for less significant but notable criteria. Blue colour means no significance. The evaluation has mostly been done by the experts participating in our working group, but also some external experts have given their input to some of the services. For most of the services, both pre-trip and on-trip use cases were analysed.

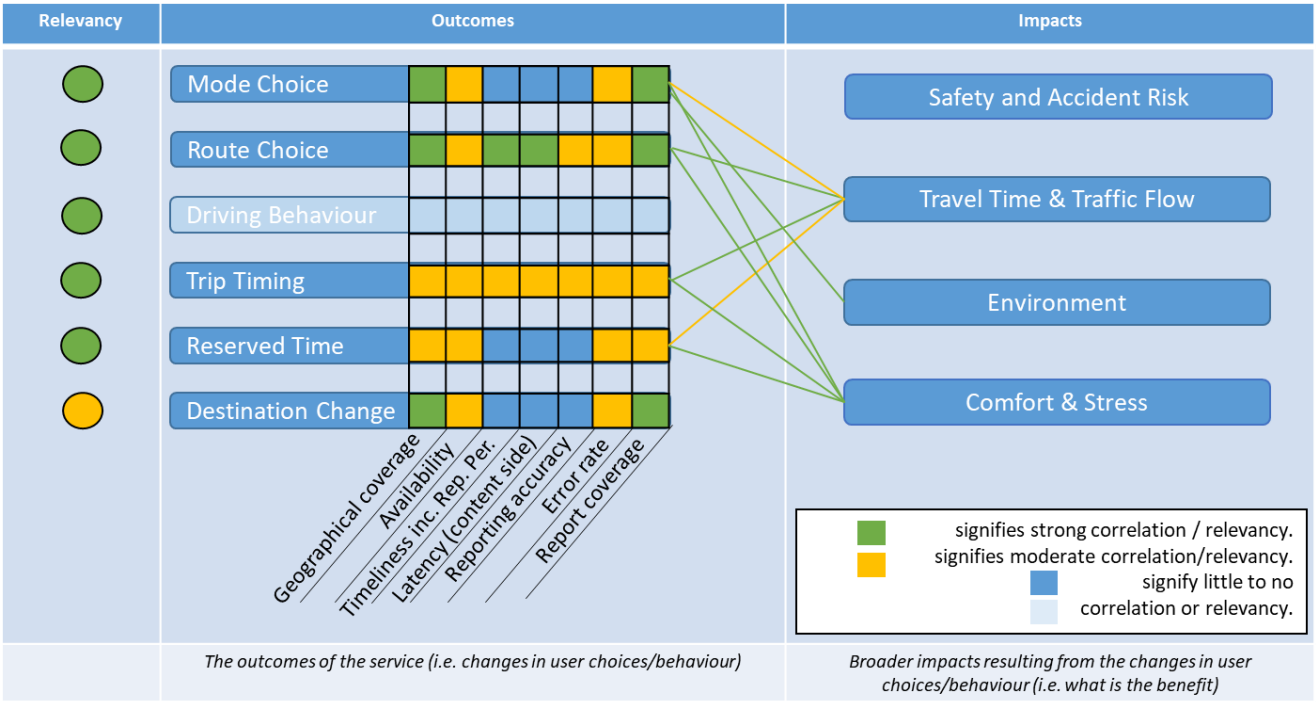

Figure 4. The impact mechanisms and critical quality criteria of travel time information services.

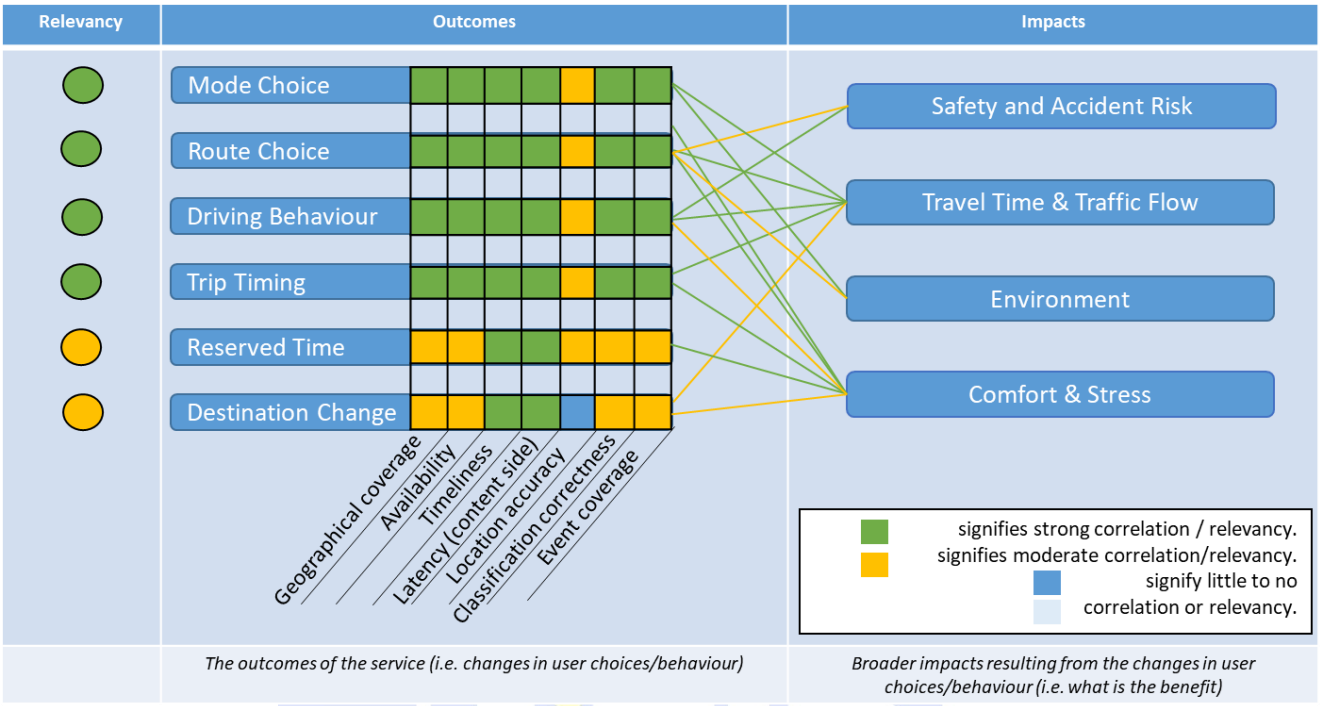

Figure 5. The impact mechanisms and critical quality criteria of weather-related safety warnings (SRTI)

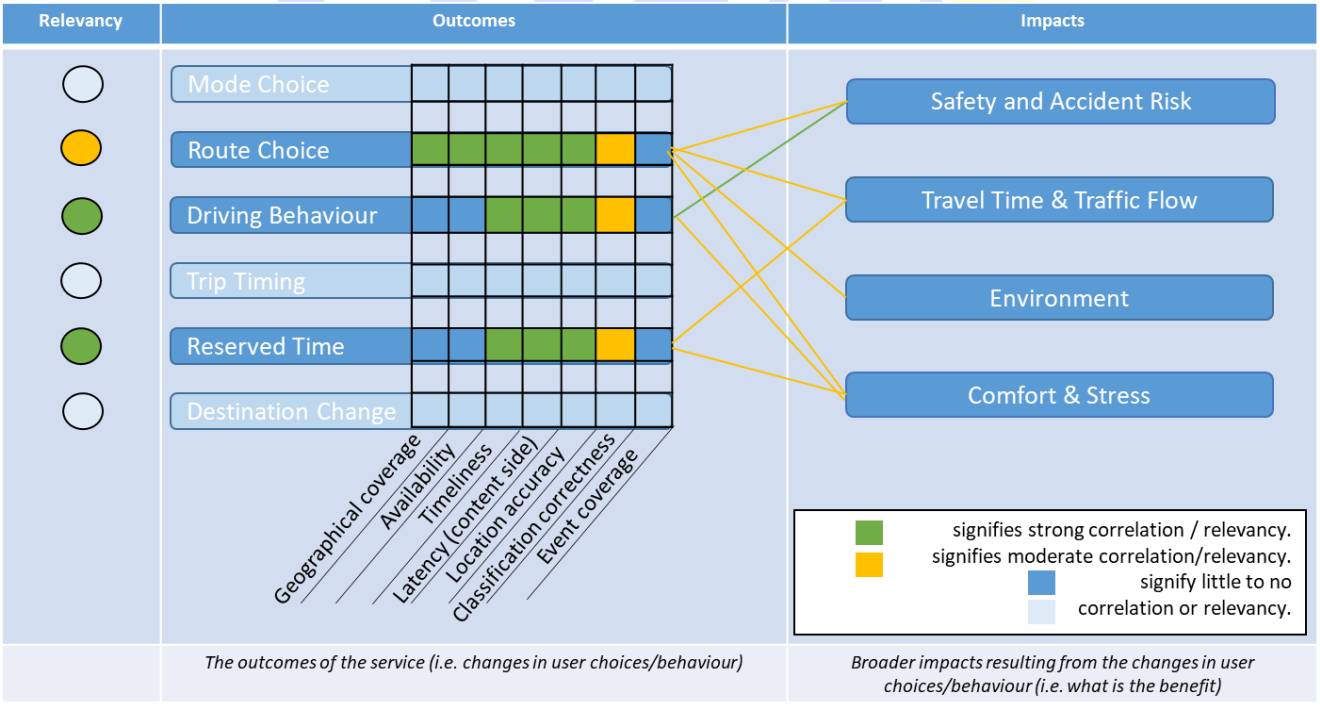

Figure 64. The impact mechanisms and critical quality criteria of safety-relevant event information (all SRTI except weather related and wrong-way driver), on-trip use case.

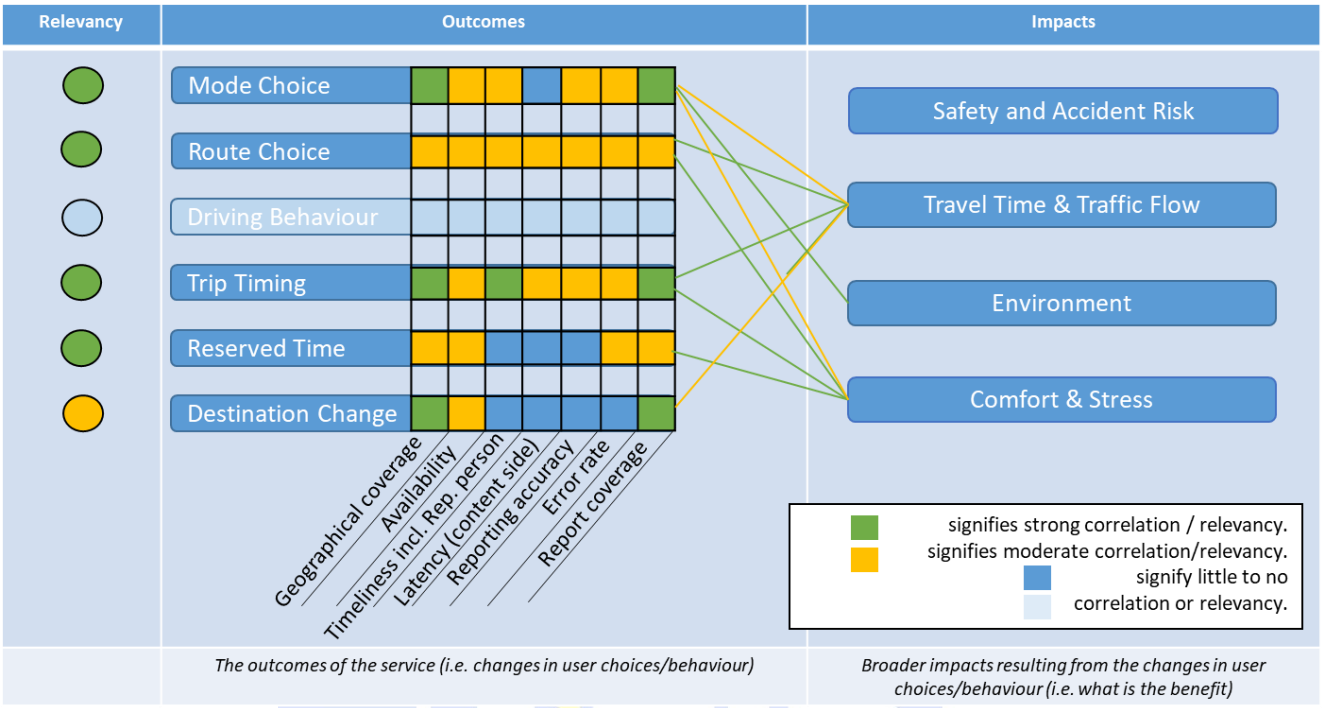

Figure 7. The impact mechanisms and critical quality criteria of pre-trip road works warnings.

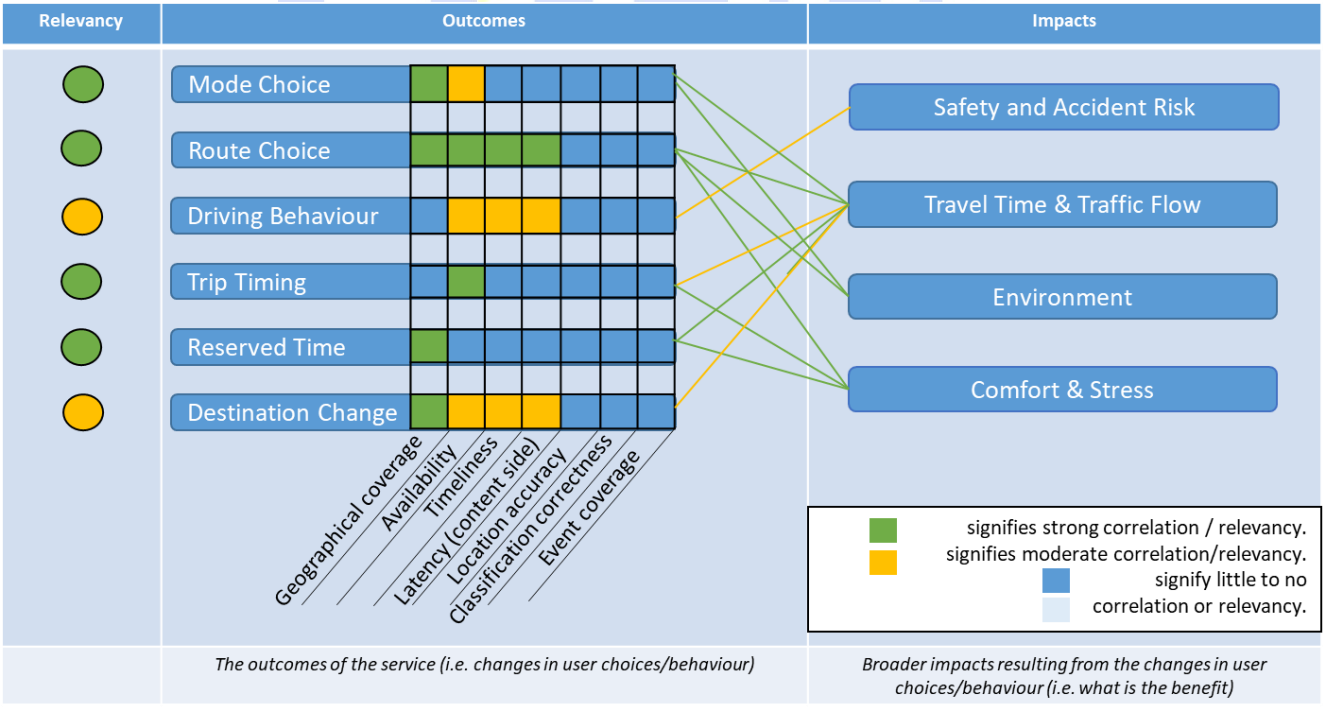

Figure 8. The impact mechanisms and critical quality criteria of MMTIS, availability of parking services.

For on-trip information, in addition to route choice, driving behaviour is influenced a lot as well. For pre-trip information it is quite different, as could be expected, with especially trip timing coming into picture. There is a clear difference in the importance and effect of different quality criteria and impact mechanisms when comparing

pre-trip and on-trip information. However, looking at the big picture, the combined effects and benefits of all use cases are what matters most. This highlights the relevance of considering the whole value chain to some extent. That is, when considering the cost or effort for improving quality and the impact that can be achieved, it's relevant to think about what channels and means are the most efficient - which improves impacts more, quality or quantity (reaching users)?

Looking at the combined mechanisms of pre-trip and on-trip information, the most significant outcomes (driver responses) that create most of the societal benefits are **changes in trip timing, route choice, reserved time and mode choice**. Changes in driving behaviour seems to have a bit less significance, and destination change has the least significance. In terms of impacts, travel time and traffic flow were indicated a lot - as well as the harder-to-quantify comfort and stress. And, of course when it comes to safety-related information, safety impacts are central as well. Environmental impacts are much less direct as it tends to be the result of changes in *traffic flow & travel time* (e.g. vehicle miles travelled).

To summarise which are the most significant quality criteria over all analysed information services, the criteria with green significance were given value 2 and criteria with yellow significance were given value 1. After that the values were summed up over all five services. As a result, the often very relevant criteria for all information services are

- LOS criteria
  - **Geographical coverage**
- Quality Criteria
  - **Timeliness (event-based information) / Reporting period (status information)**
  - **Latency**
  - **Classification correctness (event-based information) / Error rate (status information)**

It appears that different criteria have different reasons for importance: for example, affecting the value of the service itself or the trust towards it - and therefore the likelihood of reaching the users and having an effect into their behaviour. Because of this rather complicated analysis framework the results must be considered indicative.
Furthermore, in the working group discussions it was identified that some other quality criteria were deemed important or critical for some services, such as Location accuracy for SRTI warnings. Therefore, experts were advised to use all the criteria that were relevant for the service they were analysing in the following steps of the analysis of optimum quality.

5.2. Assessing the optimum Quality Range for selected services

5.2.1. METHODOLOGY

In the previous phases, it has been identified how the service type in question affects user behaviour, and how that further links to overall societal impacts of the service. In addition, it has been analysed, how critical each quality criterion (corresponding to the EU EIP Quality Framework) is for the users' behavioural changes and therefore for the consequent societal impacts. Before proceeding to assessing the potential optimum levels, it has been analysed how individual elements of the "input side" influence each quality criterion i.e. how different improvement efforts may improve the quality and what is their cost indication. It should be kept in mind that a

quantitative analysis of cost-efficient quality improvements was deemed very difficult in the initial study in summer 2018, therefore the cost-side analysis is only indicative.

Once all the relevant quality criteria have been analysed, attention should be given to whether the "optimum quality range" lies in the same quality levels for all relevant criteria, as defined before in the EU EIP Quality Package, or whether there is a difference. This will give us input for further elaboration of the Quality Package.

Based on the above-mentioned preparations, the members of the working group discussed and defined, what could be the optimum quality level for the critical quality criteria. The exact task for participants defining the optimum quality ranges was defined as follows:

- Concentrate on the most important use case for the selected services: **on-trip**
- Concentrate on TEN-T operating environment[2]: **Main motorways with 2 separated carriageways and congestion and/or safety problems**
- Discuss and answer based on earlier work
    - **Can the basic level be the optimum quality level** so that there is no need to strive for better quality? (quality level is high enough to lead into realisation of the identified user outcomes and societal impacts)
    - **What is likely to be the optimum quality level** (~the level that organisations should currently strive for), of the presented three levels, or is the optimum clearly higher?

The version 2.0 of the EUEIP Quality package (Kulmala et al., 2019) was used in the analysis.

The presented optimum quality levels or optimum quality ranges are purely based on expert judgement, which must be kept in mind when using the results. The analyses are based on initial work of dedicated experts which were further elaborated in a broader group of experts in a workshop (September 2019).

5.2.2. RESULTS

Optimum quality is dependent on both societal benefits and the costs impelled to improve quality and further acquire the increase in the societal benefits. Therefore, the working group first looked at the potential quality improvement methods and the costs related to them. Summarising the cost-side elements of the services, the following findings were made:

- Regarding **network coverage**, improvement costs are dependent on instrumentation or data purchase coverage, which are both more or less directly subject to road length covered. Instrumentation and maintenance of roadside systems is expensive and usually the instrumentation should serve also traffic management operations, not only traffic information processes.
- **Timeliness** of event-based services is currently dependent on the amount of instrumentation or probes on the road. Costs come directly per kilometre/probe, but future technologies such as C2C C-ITS applications may disrupt these investments.
- **Latency** is usually dependent on the overall IT system used in the local service production (or global if looking at FCD travel time information services). Improvement of IT, for example in a Traffic Information Centre (TIC), is an ongoing process that usually does not initiate from a need of one particular information

[2] Operating Environments are defined as part of the Deployment Guidelines by EU EIP (EU EIP, 2015)

service, and is therefore usually a slow process. The costs related to IT investments can be high but as they affect a large variety of processes, it is difficult to show which part of the costs would be related to information quality improvements.

- **Classification correctness/error rate** is dependent on the amount of instrumentation or probes on the road (clear situational awareness), but also (manual) processes and their quality control play a role in this (i.e. training of TMC staff for producing correct information). Development of TIC processes and quality control procedures may be among the cheapest methods to improve information quality. Adding automation (or semi-automation) into manual processes may be an efficient means for decreasing the possibility for human errors.

Based on expert judgement and group working, taking into consideration the above-mentioned cost impact considerations and the potential for the increase of societal benefits, the group has produced a proposal for optimum quality levels for the selected services. It should be noted that the proposal only applies for technologies and services that are currently in active and widespread use in the Member States. The identified optimum quality levels are presented in the following table.

Table 1. Proposal for optimum or target quality levels for the selected information services.

	RTTI Travel time information	**SRTI Weather related**	**SRTI events (other than weather & WWD)**	**SRTI short term road works warnings**
Geographical coverage	Optimum coverage may be 100 % of the regularly congested TEN-T network and network where exists regular travel time fluctuation due to road works and incidents.	**Enhanced** (80%) for the whole main road network and **Advanced** (95%) for TEN-network. **100 %** or roads that have local recurrent weather problems.	**Advanced** (95%) or 100% of network even though detection infra does not cover the same network.	**Advanced** (95%) However, target should be 100% of all road works in the responsibility of the road authority.
Timeliness (start)		**Enhanced** (For 95 % of all events: Time between event occurrence and first detection: Best effort Acceptance after first detection < 10 min)	**Enhanced** (For 95 % of all events: Time between event occurrence and first detection: Best effort Acceptance after first detection < 10 min^)	**Enhanced** (For 95 % of all events: Time between event occurrence and first detection: Best effort Acceptance after first detection < 10 min^)

Reporting period	**Advanced** (1 min) for the congested or incident-prone OE's. **Enhanced** (5 mins) for less congested OEs.			
Timeliness (update)	**Advanced** (95 % of all reports < 2 min)			
Latency (content side)	**Advanced** (95 % of all reports < 2 min)	**Advanced** (For 95% of all events < 5 min)	**Advanced** (For 95% of all events < 5 min)	**Enhanced** (For 80% of all events: < 5 min)
Location accuracy		-	**Advanced** (< 5 km)	-
Classification correctness		**Advanced** (> 95%)	**Advanced** (> 95%)	**Advanced** (> 95%)
Error Rate	Depending on the OE **Enhanced** (5%/20%) or **Advanced** (5 %/10%)			

A presumption for the results was, that generally 'best effort' cannot be defined as an optimum quality level for the quality criteria that have been identified as critical for the societal benefits. This presumption was also validated in the expert work. Another finding is that basic level was not identified as optimum level for any of the criteria or services. This indicates that the scale of the requirements has been set and fine-tuned correctly – to justify investments for Enhanced and Advanced levels.

The proposed optimum quality levels are for many parts identical for all three event-based services (see the SRTI columns in Table 1) that were selected for the analysis. For *geographical coverage* the optimum quality level is highly dependent on the operating environment in question. The optimum quality seems to be higher for TEN-T network, Advanced (95%) for most analysed services. However targeted quality was set to 100% of the network where traffic/weather related problems reoccur. For travel time information services, the optimum was set to 100 % of the TEN-T operating environment *Main motorways with 2 separated carriageways and congestion and/or safety problems,* meaning also that the service may not be very beneficial in other operating environments without congestion problems.

The optimum level for *Timeliness (start)* is Enhanced for all three services, meaning that acceptance should happen within 10 minutes from the first detection.

Regarding *latency*, the optimum quality level was proposed to be Advanced for three services and Enhanced for SRTI short term road works. The reason for the deviated results for short term road works is, that Traffic

Information Centres do prioritise accident information over road works, and also because sending out short term road works information usually requires more manual work. Therefore, the Advanced level can be costly to reach.

Regarding *classification correctness* the recommended quality level is Advanced for all services. The correctness of the content is seen critical for the trustworthiness and effectiveness of the information services.

Looking at the recommended quality levels for the criteria relevant only for status type of information (see the RTTI column in Table 1), namely *reporting period, timeliness (update) and error rate*, the recommended level is Advanced. For less congested operating environments, the targeted quality level for travel time information services can be Enhanced, since the Advanced level may be expensive to reach in all environments. One notion was made regarding the criteria definition of the timeliness (update) for travel time information services. The way how timeliness for status-type of information is defined (="the average age of the sensor data used in the most recent reporting period") brings us to a conclusion that Timeliness is not an actual quality criterion, because it is fixed to a certain system and does not dynamically change in time. Therefore, it could rather be handled as Level-of-Service criteria, just like Geographical coverage regarding status type information.

Regarding the used methodology (i.e. expert judgement) it should be noted that different experts responsible for analysing different services may have had slightly different approach in their work. This may have some effect on the results. For example, some initial analyses were more focused on the question how realistic it is to reach certain quality level with current technology, whereas some analyses were more focused on the user need for quality in different use cases. A principle used as an advice for the analysts was, that if a certain level is currently reachable with standard set-up/state-of-the-art technology and the level is clearly more beneficial from the user perspective, we can state it as "Potentially optimum" or "Target Quality". One conclusion from the exercise is, that rather than speaking about 'optimum' quality we should name the results as 'recommended quality' or 'target quality'.

It is clear that when cooperative and connected automated driving becomes operable in the TEN-T network the requirements for information quality will change and we will need to tighten the quality requirements for the data production significantly. At this stage it is too early to attempt to define the future requirements, as the CCAM technologies are developing fast and there are no standard requirements for the Operational Design Domain (ODD) of the autonomous vehicles and their applications. Also, in the future detection technologies will be totally different and automation in the information value chain much more commonplace.

An important finding from the analysis was, that the optimum quality level depends on the operating environment (OE). The proposed optimum quality levels do apply only for OE **Main motorways with 2 separated carriageways and congestion and/or safety problems.** In certain OE's the likelihood of events may be small and therefore it is not worthwhile to invest in roadside instrumentation, meaning that the optimum quality level is lower than in heavy traffic environments. For some services, such as travel time information services, there may be OE's where the service is not needed at all, at least not in 'normal' conditions or 95 % of time. The connection between optimum quality levels and OE's should be analysed in more detail in future projects.

Assessment of whether the optimum is lying on the Advanced Level (***) or way beyond that is very difficult because there is no exact knowledge of the improvement costs between any levels. Therefore, the scope of the analysis is limited to the presented 3 quality levels. A general final conclusion is that quality above the Advanced Level (***) may become optimum with future technologies, but that depends on the costs of the technology.

6. Discussion and recommendation on road operators' actions to improve the critical quality elements efficiently

6.1. Methodology

The aim of this work phase was to analyse and identify, which are the most recommended (cost-efficient) methods to improve the quality of information towards the recommended quality levels. The analysis has been done mostly using the expertise available in the Activity 4.1. working group complemented by some amount of expertise from the organisations of the working group members. Also, attention was paid to past experiences of the organizations to improve quality of the selected services. The analysis is fully qualitative and is focusing on the TEN-T road network.

The presumption in this phase was that the basic quality level can be reached by all member states.

6.2. Results

The most recommended methods to strive for the optimum/target quality are summarised in the following table per quality criteria over different service types (status/event types). The travel time information service is analysed from the viewpoint of procuring FCD service from the commercial service providers. The best practices regarding SRTI (other than WWD) were collected from SRTI services regarding weather related events, short-time road works and other hazardous events.

Table 2. Various methods to improve the quality of the EUEIP quality criteria for different service types.

	Status type information (travel time information)	**Event information (SRTI information services especially)**
Geographical coverage	Use of market dialogue to find out the network where most providers can provide good quality data	Instrumentation of the road network (cameras and other sensors) Human resources (road inspectors) and their location optimization
Timeliness (start)		System integration (specifically with Emergency Response Centres) Process optimization and development of automatic incident detection (e.g. Charm in the Netherlands, smart cameras) Instrumentation and human resources for monitoring in the Traffic Management Centres Mobile human resources (Road inspectors) Development of weather-related event prediction models

Reporting period ”refresh rate of status reports”	Setting of the desired refresh rate of the data in the tender specifications	
Timeliness (update) ”average age of sensor data”	Setting of the desired limit in the tender specifications (though this cannot be verified or measured)	
Latency (content side) “processing delay”	Fixed to the system set-up (mobile devices sending location) and software side (processing data). Improves according to long-term IT development plans.	System integration and automatization (e.g. pre-filled event information template) Use of vehicle data integrated to other data sources Measure and display latency towards operators and set a quality target
Location accuracy		Physical road markers every 100 m to improve accuracy of the first detection (usually manual call to 112 or similar service) Use of smart cameras and data analytics to detect/verify the exact location of an event
Classification correctness		Human resources continuous training
Error Rate	Set the desired minimum quality limit to specifications and use of quality testing before contract is signed	

Regarding FCD-based travel time information, most of the quality criteria depend on the fleet size (amount of probes) the provider has in the market in question. Also, the quality of the processing algorithms, and how they handle certain known challenges in FCD calculation (e.g. traffic lights, traffic stopping completely due to queues, speed differences between lanes) pay a big role in the overall quality. In the tendering process, the road operator as a client can require that the provider to show how they plan to grow the fleet size during the contract period and what development programmes the provider has in the pipeline to increase the algorithmic quality during the contract period. In Finland, the Road authority organized, during the first phase of the tendering, an open market dialogue to find out what technologies were available on the market and what are their maturity level and outlook. Based on the market dialogue the actual tendering was limited to technologies which were estimated to provide best quality for money. Setting of the quality requirements to a level that will ensure competition (several providers can reach the limit based on dialogue) was used to lower the costs side.

Regarding the SRTI event information, there are various quality improvement methods available, each of them touching the quality from a different perspective (or quality criteria). Based on the data collected from the working group member organisations, **in recent years** many quality improvement actions made are based on non-scalable actions such as adding road instrumentation (cameras) and human resources (TIC staff, road inspectors). In addition to those, monitoring of Quality KPI's of Traffic Information Centre staff is likely to be a cost-efficient way to improve accuracy of manual work. In addition, integration of ITS systems (such as 112 feed into the IT system of Traffic Information Centre) has proven efficient to improve latency and event coverage. Furthermore, improving the user-friendliness of National Access Points (NAP's) is likely to lead to wider market penetration of the provided data feeds and is also judged as an efficient means to increase societal benefits of information.

Currently and in the next two years the ongoing research and first practices on the use of mobile technologies (e.g. FCD) is likely to realise in improved quality with lower unit costs (costs per km). Using the current guidance of quality criteria and requirements in the tendering processes of the new data sources is recommended to foster quality development among relevant service providers. Also, the automatization of processes (such as identification of incidents from data fusion or from video image recognition) is likely to improve e.g. timeliness and overall cost-efficiency of quality improvement work, since it can provide more effectiveness using the existing road instrumentation. Event classification is currently executed usually by visual confirmation. Location accuracy is currently depending mostly on digital mapping, location descriptions and location databases (such as TMC). Further use of satellite-based positioning (GPS, Glonas, Galileo) will improve the location accuracy in the following years and new type of services.

In the near future (3-5 years) the development and market penetration of cooperative systems will lead to pushing SRTI event messages to cars and trucks by several private service providers, besides information from the road authority. Information will also be shared in real-time between vehicles on the network. Information will be more precise, more current and more dedicated to the individual road user and their current situation on the road. In this ecosystem, the road operator's role may be smaller than earlier, mainly acquiring the C-ITS data and pushing it to the NAP for wider utilization among all service providers.

To sum up, first one must know what quality level is currently reached to be able to define the steps towards further improvements. That is a prerequisite for cost-efficient quality work in the longer term. For this, we encourage road operators to apply some of the quality assessment methods, as defined in the EU EIP Quality Package (Kulmala et al., 2019). Another important aspect for the sake of cost-efficiency is the mapping of quality interdependence, i.e. looking on how different changes in systems/processes affect quality in different content types and quality criteria. Many improvement methods such as adding road instrumentation affects various processes and a holistic view needs to be taken in the assessment of the overall cost-effectiveness. Many road authorities use multiple actions simultaneously. For example, Rijkswaterstaat in the Netherlands invests simultaneously in personnel, road inspector vehicles, smart camera systems (with automatic detection) and optimization of processes (e.g. Charm).

7. Discussion and recommendations on road operators' role and actions in the service value chain for maximizing societal benefits

7.1. Methodology

As stated in the previous sections, an analysis of optimum quality levels is focusing on two aspects: the societal impacts and benefits that can be realised with a certain quality level, and the costs involved in developing an information service that reaches that quality level. The optimum level lies where the societal benefit-cost ratio is the highest. That is in principle all true, but it does not consider other aspects that affect the societal benefits. The benefits side is not only affected by the quality of information, but many other features and actions have an effect on that. The more road users access and utilize information in their trip and driving decisions, the more benefits will be realized for the society. In this chapter such actions, where the road operators may have a role in, are discussed.

The scope of EUEIP quality work is limited to the first half, i.e. the content half of the Value Chain for Traffic Information (TISA, 2012), i.e. from detection of an event until the information is placed in the NAP for further distribution. This first half of value Chain is usually partly or fully in the responsibility of the road operator, whereas the latter part of the value chain, i.e. the service half from NAP to the end user, is in the responsibility of the (public or private) service providers.

In this last work phase, we completed the picture of the actions available for road operators and authorities to maximise the utilization of quality improvement investments and the data that is available in NAPs. The focus is put on other actions than pure quality improvement programmes or investments in the content half of the Value Chain, but also on actions affecting the service half of the Value Chain, thus maximising the societal benefits achieved by the information service.

The qualitative analysis of the potential actions has been made by the active participants of activity 4.1. The separate findings have been discussed and elaborated together in the working group by all the participants.

7.2. Results

In the table below is a summary of the identified actions, by which road operators may improve the efficiency of the information value chain. The potential actions have been presented in different phases of the value chain and separately for status type and event type information services.

Table 3. Various methods for road operators to improve the efficiency of the different phases in the information value chain.

	Content detection	**Content Processing**	**Service Provision**	**Service Presentation**
Status type information services (e.g. travel time information)	Competition on the market and connected vehicles development keeps developing the services (no actions identified for road operators)		Use of reliability index in the service provision Provision of easy-to-use JSON interfaces in parallel to the DatexII/XML interfaces	Use of graphical route displays on road-side services Investments in HMI research and development of guidelines National legislation of efficient and safe HMI of in-vehicle services
Event type information services	Developing business models for acquiring vehicle data from OEMs for traffic information purposes Development of data fusion methodologies (roadside and vehicle data) for improved detection	Use of all relevant data fields of the standard data models e.g. DatexII Reduction of the used event codes for process streamlining	Standardisation of content transmission over all channels Use of push-type data interface in the NAP to increase interest among app developers.	Improving the reliability of TMC network in certain regions Design feature that enables the user to filter events by type to minimize distraction Investments in HMI research and development of guidelines National legislation of efficient and safe HMI of in-vehicle services

To maximize the societal benefits of information services, it is crucial to also discuss and identify actions by which it is possible to increase the market penetration of the most important service channels. The connected vehicle

development, meaning that the vehicle system is constantly connected to the internet and gets real-time information of travel times and events from the service provider, increases significantly the utilization of information services, compared to the situation where the user is required to open a mobile phone application. To foster this development, national or regional actions that speed up car connectivity, e.g. by fleet renewal or expanding wireless communication coverage, are crucial. Regarding the likelihood for using a mobile phone application provided by many road authorities, it is clear that the greater the information content is, the higher the data quality and usability are, the higher the user penetration is.

Many participants of this working group have underlined the importance of establishing good contacts and relationships with the commercial service providers, who are operating under the delegated regulations of the ITS Directive. If both the public and private parties share the same goals (e.g. strive for network optimum instead of individual optimum), the easier it is to agree on action on a concrete level. A good model is also to organize a close exchange e.g. via an annual meeting with the organizations who use the data provided in the NAPs, highlight the importance of compliance of all parties, and discuss the possible challenges from the business perspective. In practice, it is known that not all service providers reuse the information content from NAPs as the delegated regulations require. Also, there are many known practical difficulties, e.g. the fact that RTTI and SRTI type events are many times provided through the same services, but are regulated by two different delegated regulations. In addition, not all service providers have equal readiness to comply with European regulations. Many global companies have been acting as stakeholders during the preparation of the regulations and have therefore better readiness to fulfil their part of the requirements. However, in some countries there are local service providers that may have created a service that attracts many local users. Such players typically have smaller organizations and less capabilities in following European regulations if they do not bring them direct benefits. Consequently, there is a need to foster the functioning of the entire Value Chain of Traffic Information. Some road operators have indicated that there is a need to improve quality control over the value chain – the data quality that is present in the data provided by the NAP should be present in the data provided by the end-user services.

As described above, it is possible to streamline the information value chain and improve reliability by building cooperation between road operators and service providers. However, it must be said that there may be certain questions that require clear direction and rules of the game that can only be provided by national legislation. The first experiences from the Delegated Regulations of the ITS directive have shown, that the compliance is not 100 % and not all requirements have been met, neither by the road authorities nor different service providers.

As a further safety-related aspect, it has also been evaluated a risk that some content on hand-operated devices (be they smartphone or some other) may create unnecessary distractions for the driver and this decreases overall safety and thus the usefulness of the safety-related information. Such aspects need to be further investigated.

Looking at the relevance of different service channels in the future, it is likely that within 5 years' time the traditional service channels will lose users to the newer ones. This change has been presumed by all the agencies interviewed. The younger generation drivers have grown up with social media and various mobile internet services and may see traditional services such as RDS-TMC too limited and not as attractive. It is also likely that the role of spoken traffic announcements within radio broadcasts will diminish over time. That is mainly because there are competing entertainment channels available that are based on streaming content over the mobile internet network (4G, 5G). Audiobook services, music services such as Spotify enable the user to choose exactly the content they like, instead of listening to the content the broadcaster has chosen to present. In the future there will be less drivers that are listening to FM broadcasting while driving. The rising service channels of the future seem to be in-vehicle devices connected to the internet as well as smartphone applications. Both channels were seen as of equally high importance in 2025 by the agencies' estimations. To sum up, the changes in the usage of different channels,

however, is likely to happen rather slowly over the years. During this period, it is necessary for the road operators to maintain the good service quality of all the existing channels in order to provide reliable and uniform content via multiple channels. When a driver receives the same event information from radio, roadside unit and mobile phone application, they are more likely to alter their behaviour than based on just one information channel. Thus, the multiple channel strategy is likely to create more benefits for the society.

Table 4. Various methods to improve the quality of the EUEIP quality criteria for different service types.

	Importance of the delivery channel		**Limitations and characteristics of the delivery channel**	**Most relevant service providers**
	Currently	**In 2025**		
Mobile navigation devices and car in-dash systems	Medium	High	RDS-TMC based services have limited capacity 4G based services have good capacity and network coverage on TERN, but in-car connections are not yet widely common	Tomtom, Garmin, other European private companies
Smartphone applications	Medium to high	High	Internet access and battery power or charging outlet required for the device used. There are various service providers who can also limit what information gets sent to the driver. Risk of distraction exists.	Google maps, Waze, Maps (iOS), TomTom, Here, Inrix
Spoken traffic announcements (TA)	Low to high, depending on country/service type	Low (High importance estimated in NL)	Announcements from the authorities are only periodical covering only most unusual travel time changes or events. Not all radio channels distribute the information. Lower risk of distraction as there is no visual data presented.	Radio channels, DAB+, public road authorities
Internet services	Low to high depending on the service type	Low to medium	Information is pre-trip only and needs internet access. On-trip use creates a large distraction risk.	Google maps, Here, Inrix, ANWB, Apple, routenet, online map services by road authorities
Roadside information panels (VMS)	Medium	Medium	Only suitable for small area information, costly to install and maintain.	Local road authorities

8. Recommended actions for the Member States

To crystallize the main take-aways for European road operators, the working group defined the following logical steps to work your way towards optimum information quality and maximised societal benefits. The recommendations were discussed in an internal workshop, and some additional experience-driven advice can be given to support in the implementation of the actions.

1. **Know your data quality**

   Use the EUEIP Quality Package to design the local quality framework and identify the most feasible quality assessment methodologies. Reach for the European community on advice on best practises, since some quality criteria may be harder to measure.

2. **Set quality targets**

   Consider the current quality level and the recommended optimum/target quality levels and consider the different needs in various operating environments when setting the quality targets. The EU EIP Quality Framework provides a validated and agreed baseline for organisations for target setting. Remember, that the EU EIP quality criteria and requirements may serve as a basis for service agreements regarding different companies developing systems for the road operators. Also, knowing the quality requirements and targets on the service side is a good starting point for defining the quality targets in the first part of the value chain, i.e. the content side.

3. **Assess the expected quality improvement from the ongoing development projects**

   Analyse how the technological development (monitoring systems, vehicle data, development of IT systems and automation) will affect the data quality of different information services. This may prove a difficult task since there is a lack of evidence and knowledge to what extent different actions will affect quality locally. Nonetheless, an assessment should be made about which quality criteria will be affected (improved) by the ongoing projects and roughly how much, and which criteria will most likely remain untouched, and need further attention. Many organisations have ongoing investment projects that will lead to "jumps" in the quality levels. From the viewpoint of quality management, it would be beneficial to build in a practise of pre-assessment of potential quality effects at least to the major investment programs and plans.

4. **Define and implement the needed complementary actions to reach targets**

   Identify the complementary actions needed to reach the targeted quality levels using the recommendations in this report. Target especially those of the critical quality criteria that seem to be lacking most behind the targets. Prepare a pre-assessment of the expected quality improvement to overcome the internal hindrances for funding and human resources. Utilise the published evaluation reports from the European community in the pre-assessment.

5. **Engage in the collaboration and regulation work with the local and global value chain stakeholders**

   Facilitate active and continuous collaboration with the global and local service providers and agree about actions that streamline the information flow in the whole value chain. The wide-spread use of European NAPs, based on the ITS Directive, will cater for cross-border collaboration between parties. Participate in the TISA collaboration forums. As authorities have limited resources, regulation is seen as a secondary means whereas ecosystem building and voluntary collaboration that

benefit all parties as the first priority. The revision of the ITS Directive may bring new regulations that will further institutionalise the EU EIP Quality framework and also bring more funding for quality assessment and related research.

6. **Evaluate quality improvements**

   Build a local quality monitoring system for continuous quality measurement and use a wide range of incremental quality improvement actions. Evaluate systematically the quality improvements achieved by the projects and actions. Evaluate both the content side (data quality) and service side (may be covered by user satisfaction survey) and compare the findings to the users' needs. Document the used evaluation methods and datasets. Share knowledge to the European community to strengthen learning effect on the effectiveness of different actions.

The quality framework developed by the EU EIP project is validated and tested, and therefore mature enough to support all quality improvement activities within the European road operators organisations. A slightly discouraging observations is, however, that during the many years of developing the framework, rather few organisations have built their own systematical quality management schemes and many are still struggling to fill in the action no 1 (Know your data quality). Some quality criteria have been seen as too hard to measure, but the main reason for the non-action may be more of institutional in nature. Quality of information services may be lacking from the strategic KPIs of the organisations, and therefore quality management receives insufficient funding independent of other development projects.

Institutional challenges are rarely easy to overcome. If the quality effect of investments or other actions is not evaluated systematically, the European community cannot develop new knowledge of the effects and benefits, and the situation remains. How to incorporate the quality aspects to the strategic management and investment processes? Based on the analyses and discussions in the working group, the European Commission should either consider clear incentives for road operators to implement the Quality Framework on a policy level, or consider stronger regulation to support deployment in the revision of the ITS Directive.

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Appendix 1. Analysis of the optimum quality levels for the selected services

TRAVEL TIME INFORMATION SERVICES (RTTI)

	Quality improvement		Quality requirements			Analysis	
Criteria	**Method(s)**	**Cost indi-cation of method(s)**	*** Basic**	**** Enhanced**	***** Advanced**	**Analysis of level ***	Recommended (optimum) level
Geographical coverage	Purchase larger network from service provider	Immediate price increase per km	**Best effort**	**80%**	**95%**	Level * sub-optimal.	Optimum coverage may be 100 % of the regularly congested TEN-T network and network where exists regular travel time fluctuation due to road works and incidents. **Therefore, optimum cannot be defined as any of the presented quality levels.**
Reporting period	Fixed to a system and cannot be altered without system renewal	Cannot be negotiated by a single client	**Best effort**	**5 mins**	**1 min**	Level * and ** clearly sub-optimal, better frequency does not increase costs significantly.	**Level is *** optimum for the congested or incident-prone OE's. Level ** is optimum for less congested OEs.**

Timeliness (update)	Fixed to a system and cannot be altered without system renewal	Cannot be negotiated by a single client	**Best effort**	**95 % of all reports < 5 min**	**95 % of all reports < 2 min**	Level ** refers to using 10 minute sliding average…likely to be suboptimal as service reacts to changes too slowly.	Use of 5 minute sliding average presents state-of-the-art in the market. Some averaging is necessary for good user experience. **Optimum level is estimated to be ***.**
Latency (content side)	Fixed to a system and cannot be altered without system renewal	Cannot be negotiated by a single client	**95 % of all reports < 10 min**	**95% of all reports < 5 min**	**95% of all reports < 2 min**	Both *…** are Clearly sub-optimal, improvement not very expensive (IT infra).	Level *** presents state-of-the-art in the market. **Optimum level is estimated to be ***, because improvement from ** to *** is not seen as expensive.
Error Rate	Service provider negotiates contracts with FCD data providers	Adding more probes increase cost of service provision → pressure for higher price	**Max. 10% of reports with deviation > 20 %**	**Max. 5% of reports with deviation > 20%**	**Max. 5% of reports with deviation > 10%**	It may be expensive to get to the higher quality levels than * or ** using FCD with the current FCD penetration rate. Other means than FCD increase costs significantly.	Optimum depends on variety of things; Operating environment, the distance of the individual trip as well as the situation. **Optimum is likely to be **…*** depending on the case. Reduction of the share of erroneous data to less than 5 % is important for user trust and usage of the services.

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WEATHER RELATED WARNINGS (SRTI)

	Quality improvement		Quality requirements			Analysis	
Criteria	**Method(s)**	**Cost indication of method(s)**	*** Basic**	**** Enhanced**	***** Advanced**	**Analysis of level ***	**Recommended (optimum) level**
Geographical coverage	Install new equipment on the road network, data from vehicles and/or drivers	Costs are directly subject to network km's	**Best effort**	**80%**	**95%**		**Level ** (whole main road network) and Level *** (TEN-network). 100 % or roads that have local recurrent weather problems.**
Timeliness (start)	Better prediction of the events in question (very difficult)	Not known	**Best effort**	**For 95 % of all events: Time between event occurrence and first detection: Best effort Acceptance after first detection < 10 min**	**For 95 % of all events: Detection & acceptance < 5 min after event occurrence**	Sometimes the road has worse visibility than the signalized on VMS and sometimes the road has better visibility than the signalized.	**Level ** may be optimum** because at the moment when the visibility is worse than the signalized, it leads a reduction of driver´s safety. Otherwise, since the protocol started, no major accidents have been recorded.
Latency (content side)	Better prediction of the events in question (very difficult)	Not known	**For 80% of all events: < 10 min**	**For 80% of all events: < 5 min**	**For 95% of all events : < 5 min**	Nowadays the automated detour is activated manually by the operators of the Traffic	**Level *** is optimum.**

						Management Center of A Coruña.	
Classification correctness	Increase the number of equipment installed on the affected sections or use vehicle based data,	Direct increase of costs (~50 000 euros/station). Vehicle data has different cost structure.	**> 85%**	**> 90%**	**> 95%**		**As it is a very sensitive issue and affects a lot of road safety, the optimum is likely to be ***.**

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OTHER SAFETY-RELEVANT EVENTS THAN WEATHER-RELATED AND WRONG-WAY DRIVER

	Quality improvement		Quality requirements			Analysis	
Criteria	**Method(s)**	**Cost indication of method(s)**	*** Basic**	**** Enhanced**	***** Advanced**	**Analysis of level ***	**Recommended (optimum) level**
Geographical coverage	More cameras and road-inspectors. eCall and C-ITS may replace.	Direct cost increase per km. Gets cheaper in the future.	**Best effort**	**80%**	**95%**	Level is sub-optimal, no exact values defined	**Optimum is *** Advanced or 100% of network even though detection infra does not cover the same network.**
Timeliness (start)	More cameras and more road inspectors for earlier observation of incidents.	High structural costs.	**Best effort**	**For 95 % of all events: Time between event occurrence and first detection: Best effort Acceptance after first detection < 10 min**	**For 95 % of all events: Detection & acceptance < 5 min after event occurrence**	Level is sub-optimal, no exact values defined	**Optimum is **.** An enhanced level is the most realistic given the current IT infrastructure and (im)possibility to detect the ground truth for every event.

Latency (content side)	Optimization of the IT architec-ture and imple-mentation of newer and more sophisticated systems	Continuous improvement of IT environment is ongoing and has costs…	**For 80% of all events: < 10 min**	**For 80% of all events: < 5 min**	**For 95% of all events : < 5 min**	This level is with current techniques reachable	**Optimum is ***.** Immediate transmission of safety-relevant event is easily possible.
Classification correctness	More road side cameras and roadinspectors for an increasing number of own/first observation and acceptance.	High structural costs.	**> 85%**	**> 90%**	**> 95%**	85% seems (under todays circumstances) easy to reach	**Optimum is *** Advanced**
Location accuracy	Cameras, road inspectors, higher implementation of eCall and C-ITS	Cameras and road inspectors are expensive. eCall is cheap. C-ITS costs mostly for users except ITS-G5.	**Link between intersections**	**<10 km or link between intersections**	**< 5 km**	Level is too low, easy to reach	**Optimum is *** Advanced.**

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SRTI SHORT TERM ROAD WORKS WARNING (NOT INCLUDING LONG TERM ROAD WORKS KNOWN IN ADVANCE)

	Quality improvement		Quality requirements			Analysis	
Criteria	**Method(s)**	**Cost indication of method(s)**	*** Basic**	**** Enhanced**	***** Advanced**	**Analysis of level ***	**Recommended (optimum) level**
Geographical coverage	Make sure mobile detection is available on each road work vehicle	Installation costs of vehicle equipment, not very expensive compared to road works costs	**Best effort**	**80%**	**95%**	Not enough for ”optimum” , to reach acceptance / trust of the information service	**Optimum is *** advanced.** However target should be 100% of all road works in the responsibility of the road authority.
Timeliness (start)	Characteristics of the local IT system	Not known	**Best effort**	**For 95 % of all events: Time between event occurrence and first detection: Best effort Acceptance after first detection < 10 min**	**For 95 % of all events: Detection & acceptance < 5 min after event occurrence**	Not enough for ”optimum” , to reach the safety effects of the information service	**Optimum is ** Enhanced.** Fast and reliable detection is costly to implement because there are also unplanned events.
Latency (content side)	Characteristics of the local IT system	Not known	**For 80% of all events: < 10 min**	**For 80% of all events: < 5 min**	**For 95% of all events : < 5 min**	Not enough for ”optimum” , to reach safety effects the information service	**Optimum is ** enhanced.** Reporting of accidents is prioritised in the TMCs over short-term road works, this may cause

							delay occasionally and would be costly to avoid.
Classification correctness	Characteristics of the local IT system	Not known	**> 85%**	**> 90%**	**> 95%**	”False-positive” rates should be minimized, to reach acceptance / trust of service	**Optimum is *** Advanced.**

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