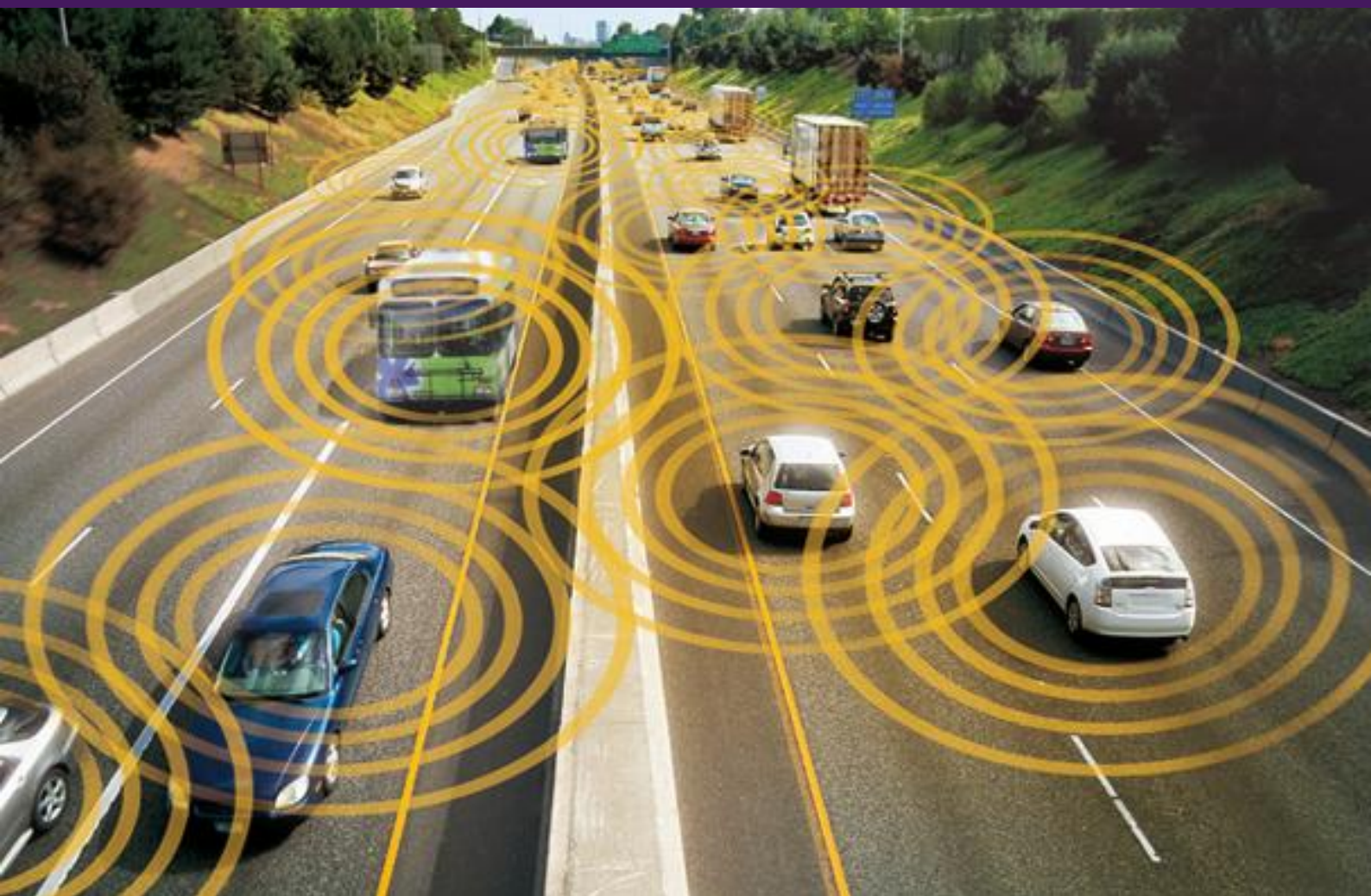
Connecting Mobility

Assessment of wireless connectivity options in support of ITS

An investigation into and assessment of ITS-G5 based and cellular communications for ITS infrastructure support

Combining strenghts for future mobility



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1 Management Summary

1.1 Background

Mobility of persons and goods is an essential factor in modern society, but it can be challenging to align the goals of individual travellers, who wish to conduct their trip timely, safely and as comfortably as possible, with collective goals such as avoidance of congestion and prevention of environmental pollution. Intelligent Transport Systems (ITS) concepts hold the promise of improving mobility and transportation processes, through the introduction of ICT and other technologies, and serving both individual (personal or business) as well as collective goals. ITS involves a transition of mobility as a system. With the introduction of ITS concepts for mobility inherently multiple stakeholders are involved, so desired changes in mobility as a societal system require alignment and cooperation amongst these players and tend also to introduce chicken-and-egg type of problems because costs and benefits of a system transition can be quite unbalanced for individual stakeholders during specific phases of such a transition.

Although ITS is already with us in various forms such as Connected Car services for navigation and traffic information services, this is not yet the case for Cooperative ITS (C-ITS). C-ITS is a concept in which mobile road users such as vehicles and the road side infrastructure get engaged in mutual information exchange to align their behaviours and intentions such that traffic conditions can be optimized. C-ITS aims to provide individual road users additional safety measures (via V2V warnings) and to provide the road operator with a traffic management instrument (via collection of real-time data (V2I) and via informing road users and steering their behaviour (I2V)). The C-ITS concept as envisioned in Europe is defined via the standardized ITS-G5 protocol stack, involving two connectivity options, i.e. IEEE 802.11p based wireless communications (the default option) and cellular connectivity. After many years of studies, demonstrations, pilots and standardization activities, the actual introduction of C-ITS seems near in Europe and in the US. In Japan, C-ITS is already a reality. In expected, future deployments of C-ITS applications throughout Europe, both car manufacturers (OEM's) and public road operators have an important role because investments are needed: firstly to get vehicles C-ITS enabled and secondly to deploy roadside infrastructure and systems via which C-ITS services can be delivered. The use of cellular networks in vehicular mobility is already established through Connected Car services.

1.2 Study request

Connecting Mobility is a specific part of Rijkswaterstaat and the Ministry of Infrastructure & Environment (Dutch: Ministerie van Infrastructuur en Milieu or Min IenM). It is assigned in 2014 to support all stakeholders in the transition to smart mobility in The Netherlands and the European context. Therefore it is involved in national and international expert discussions about the possible and preferred public role(s) during the launch and exploitation phases of C-ITS in the Netherlands. Rijkswaterstaat is responsible for the execution of national policies concerning national highways and roads and supporting facilities, and traffic management, amongst other fields. In this broader context, Connecting Mobility and Rijkswaterstaat seek guidance on evaluating ITS-G5 and cellular as possible communication technology options for C-ITS, since the availability of wireless network infrastructure is an important requisite to be able to provide I2V services to road users on local,

regional or national scale. The request of Connecting Mobility in 2015 was to provide:
a C-ITS assessment framework of wireless communication technologies which would assist in getting insights in the trade-off between different technologies, particular on non-technical aspects;
a first iteration of this assessment framework assuming the support of five C-ITS applications from the Day-1 list that was proposed by the Amsterdam Group back in 2013. These five represent C-ITS applications currently most relevant for the Netherlands: road works warning, probe vehicle data, in-vehicle signage, traffic light control and shockwave damping.

After the conduct of a quick scan on this topic, which led in 2015 to the publication of the report "Assessment Framework with technical and non-technical indicators for communication technology considerations in future C-ITS applications (v1.0)" (TNO report with reference R11354) this study has been prolonged in order to capture additional insights on developments relevant to C-ITS and to arrive at a more focussed and practical framework. This extended (phase 2) study resulted in this report.

This phase 2 report again addresses technical and non-technical aspects related to both network infrastructures based on (i) ITS-G5 and (ii) cellular (3G/4G) technology as options to support the information distribution for C-ITS applications which use I2V or V2I type of communication i.e. via a network infrastructure. The focus in this report has been on these two technologies only as they both support bidirectional wireless connectivity between cars and infrastructure in ITS and because they are most prominent in the current debate about wireless connectivity for C-ITS. The missing treatment of TMS (with TMC messages) and DAB(+) (with TPEG messages) in this study does not imply its irrelevance in the ITS landscape, since it is useful and is being used for I2V broadcast of traffic events and other traffic related information. The DAB-TPEG service piggy backs on existing operational DAB(+) services and infrastructure. The timeframe in scope of the study is 2016-2020.

Hence, this phase 2 report is a further developed and elaborated version of the phase 1 report. Various developments in the automotive and ICT domains, which are emerging and influence the further development and deployment of C-ITS, are included and should be taken into account in the infrastructure assessment question. Derived from the broad set of criteria which could be considered, this report now describes a more focused and more practical framework and presents the results of our first iteration with the 5 selected C-ITS applications. Based on our findings, more substantiated conclusions and recommendations have been formulated. In terms of available inputs, additional desk research has been conducted as well as a series of interviews. Also this renewed version is to be considered as only an enabler and trigger for such a discussion on this topic and not as an outcome of thorough scientific investigations. The report is intended to be used by Min IenM, Rijkswaterstaat and possibly others for national and international discussions on C-ITS.

1.3 Findings

Cooperative ITS is in essence part of the broader ITS concept, is based on the ITS-G5 protocol, focusses on V2X communications, and is designed to support a large set of (future) applications in support of travel comfort, road safety and traffic management. The *societal business case* is actually the main driver of C-ITS. Distinctive technical capabilities of ITS-G5 (Wi-Fi-p) are the ad-hoc distributed concept and very small latencies which can be achieved.

A lot of effort has been put into research and development, and international standardisation activities, now for more than two decades. Still, the ITS-G5 protocol and its supporting mechanisms like security have not sufficiently matured yet to allow for its *large scale* introduction in Europe. Also some principal issues in the concept remain to be investigated as described in this report, mainly dealing with scalability and privacy issues. C-ITS system components based on ITS-G5 are basically ready for deployment, but experience is still lacking about how C-ITS *as a whole system* works in real-life under different circumstances. To date, a relatively small set of envisioned ITS V2X use cases is sufficiently specified and developed towards small scale deployment. It has taken considerable time to get to this point due to necessary standardisation activities within ETSI and ISO/CEN. It is recognized in the ITS community that a full, Europe-wide interoperable system deployment requires fulfilment of C-ITS Deployment Platform recommendations which are of technical, organisational and legislative nature. Furthermore, it requires close (international) cooperation of the automotive industry, road operators, service providers and regulators and, last but not least, it needs to be accepted by the user. The Car2Car Communication Consortium, representing the European automotive industry, is determined on the use of ITS-G5 for Vehicle-to-Vehicle communications. However, their target date for large scale introduction of ITS-G5 based C-ITS in new cars is postponed to 2019, which they consider as the earliest possible date. This delay in large scale deployment does not imply that ITS-G5 cannot be deployed at all. Specific use cases such as C-ACC and truck platooning focussing on V2V communications in *closed user groups* could already be taken up on fairly short notice.

Road operators in Europe can play an important role in resolving the 'chicken-and-egg' problem in the C-ITS deployment. However, their collective involvement, particularly in standardisation activities, would have to be intensified to be able to establish their part of the C-ITS deployment in time. This involves a sufficient set of Day-1 applications ready to operate end-to-end. The current priority of road operators in the Netherlands is on I2V information services like road works warning, probe vehicle data, in-vehicle signage, shockwave damping and intelligent traffic light control. These applications are being piloted in C-ITS projects and the appropriate international standards are being profiled to meet national requirements. The issue with the priority use cases is that they do not really provide a convincing argument for the roll out of ITS-G5 technology.

C-ITS does also not possess (yet) a natural attraction to commercial service providers (due to lack of deployment of C-ITS capable nodes, and alternative Over-The-Top (OTT) solutions), and to road users (due to lack of clear direct user benefits), which results in the lack of demand (pull) from these stakeholders. This lack of demand makes it more difficult to establish fruitful public private co-operations which is a key policy objective in the Netherlands. The business case for C-ITS is complex. The case is positive, but the benefits emerge at the societal side but not equally distributed over the stakeholders involved. This applies just as well to the costs which have to be made for large scale introduction. The business case for the commercial sector is unclear and the government is careful on investments. Successful introduction requires more than a proper communication technology. The C-ITS Deployment Platform has proposed so called Day 1.5 applications which are targeted to specific user groups and could help to popularize ITS. In our opinion, these more appealing Day 1.5 applications such as information services on parking, city navigation and available E-charging stations will enlarge support for ITS in general, but will not change the situation for C-ITS *as such*.

The postponement of introduction of ITS-G5 into new cars to 2019 is an immediate delay factor for large scale deployment of C-ITS. Reaping the positive impacts by all stakeholders will take considerable time as the adoption of C-ITS would be related to the gradual renewal of the vehicle fleet rather than via a 'big bang' introduction scenario of ITS-G5 supporting devices. The support of the ITS-G5 protocol in popular smart phones would probably accelerate the adoption but this is not likely to happen due to an insufficient market perspective for such a feature. As stated before, deployment of ITS-G5 technology in selected scenarios for specific target groups (with direct benefits and based on flexible future proof configurations), seems a more viable strategy in the coming years (e.g. until 2019). Specific deployment examples are C-ACC and truck platooning (business case for transport & logistics companies; requiring no supporting infrastructure), and the application of ITS-G5 in urban areas where specific vehicle categories like emergency services, public transport busses, and cabs can interact with intelligent traffic light control installations (requiring locally supporting infrastructure). So, for the societal business case to become a reality to its *full extent*, enforcement via legislation would be necessary similar to the US and similar to eCall, legislation which then has to apply to the EU as a whole. Unlike some other countries, the introduction of tolling in the Netherlands is not supported in the current political constellation. A gradual and specifically targeted introduction of ITS-G5 technology is the most realistic scenario for the Netherlands in our view.

During the time the C-ITS concept has been under development and particularly during the last 3-5 years, various developments have taken place in society as a whole, comprising social/political (e.g. climate change and sustainability), economic (e.g. crises, changing business models) and technological changes (e.g. automated driving, IoT, app economy with OTT models). These developments have already impacted mobility needs, mobility patterns and mobility solutions to a certain extent but this impact is likely to become stronger, persistent in the coming years and most noticeable in urbanized regions. Hence, they are influential to ITS and to C-ITS in particular. In the same way, the societal debate on data ownership and privacy protection, and subsequent legislation also influences possibilities and limitations of ITS. In this study, developments in the vehicular mobility domain and in the ICT domain have been investigated in more depth in this study and will be elaborated further in the next two paragraphs.

In the *automotive domain*, the importance of the connected car concept, supported via cellular communications today, increases rapidly in the coming years. This is fuelled by innovations of OEMs and Tier-1 companies in Big Data based, sophisticated applications aimed towards driver assistance. The in-car system gradually develops into a dual faced platform, i.e. one side facilitating automotive functions (e.g. for automated driving, remote diagnostics, and over-the-air updates) and the other side facilitating in-car information and infotainment services for the driver. OEMs are under some policy pressure to further open up the in-car system to third parties, according to agreed standards. How this will play out exactly is difficult to predict but what can be stated with fair certainty is that in the coming 5-10 years a substantial part of the car fleet will be connected to and be part of vehicle-specific and generic cloud environments (see the next summary on ICT). Furthermore, automated driving technology is developing rapidly and seems to catch up and blend with the C-ITS roadmap. Experts in automated driving indicate that C-ITS is not considered a necessity for automated driving as such but is expected to provide added value. It is considered as a clear incentive for C-ITS support in cars, but it must be kept in mind that C-ITS is in essence not a driver for OEMs. Traffic management experts consider C-ITS services essential for guidance of automated vehicle traffic.

As stated before, C-ACC (also not a driver for OEMs) and truck platooning are specific use cases which do require the use of ITS-G5 (V2V) technology.

In the *ICT domain*, massive adoption of mobile data communications (3G/4G) is a fact in most countries in the world, and particularly in the Netherlands. Various OTT based ITS information services are being offered today to road users via cellular communications. Positive forecasts on further growth of demand in mobile data communications are driving innovations and investments in infrastructure and device technologies and subsequent standardisation in 3GPP and ETSI. International standards for 5G are announced to be ready in 2020. These standards will incorporate additional specifications to accommodate ITS services and applications which are more demanding than can currently be supported by 4G. Which service propositions actually will become commercially available via the networks of mobile operators, and when, is not entirely clear at this moment. It is also conceivable that *new roles* will emerge concerning exploitation of state-of-the-art 5G like networks which are specifically profiled towards ITS using Software Defined Networking and Network Function Virtualisation technologies. A full commercial exploitation model for ITS-only is probably difficult because the willingness to pay for safety critical applications is expected to be (very) low, although the authors have not found scientific evidence that supports this expectation. Other developments in ICT influential to ITS are OTT service platforms and Internet-of-Things (IoT). Both technological developments will create the situation in 5 to 10 years that at least in the first world countries *everyone* and *everything* gets connected. Both developments will facilitate flexible and sophisticated service/ application propositions on a large scale (Internet services economy), based on standardized abstractions of physical entities and hosted by cloud concepts. Standardisation and business driven IoT launches in various application domains will determine how far and deep this increased connectivity will go. In specific application domains like ITS, the ability to meet more demanding requirements latency, reliability) will determine how far the influence will actually go.

The developments described in this report have been depicted on a timeline, which is illustrated below.

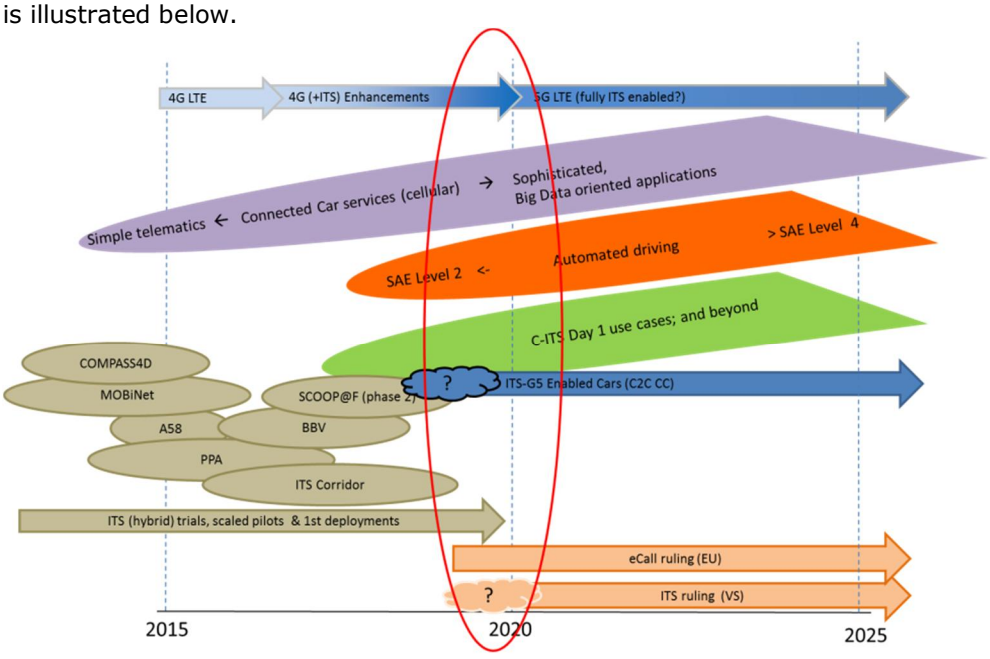

Figure 1-1: Developments plotted along 2015-2025 timeline.

The graphic depicts various important and both autonomous developments (Automated Driving, Connected Car) as well as dependent developments (C-ITS), all of them happening more or less simultaneously. C-ITS is influenced by these autonomous developments and has difficulties to keep up with these fast developments. From the graphic and particularly looking at the 2016-2020 timeframe, it can be concluded that the outcomes of these developments will be decisive regarding the future of C-ITS beyond 2020. At this point in time, there are simply too many uncertainties to already draw firm conclusions. Against this background, a strategy on valorisation of the societal business case associated with C-ITS is difficult and requires an understanding how these autonomous developments will evolve, how they can be leveraged to the maximum extent and which complementary interventions would then be needed. Given the nature of this matter, these interventions must be done in close cooperation with other countries in Europe.

The situation as developed to date and the uncertainties which apply, has initiated discussions about a *hybrid approach*, leveraging both ITS-G5 and cellular communications as supporting information channels for C-ITS applications. A hybrid approach would also allow, in time, to intelligently combine the strengths of both options. The C-ITS Deployment Platform proposes this approach, which is a policy also actively recommended by the Netherlands. However, the hybrid approach can have different interpretations with also different development trajectories associated. Hence, what hybrid *should mean* exactly ought to be determined soon, so all future (C-) ITS application developments can be based on that concept, and likewise the (C-) ITS architecture to be deployed.

In reply to the request of Connecting Mobility for an assessment framework to be able to conduct an effective assessment regarding ITS-G5 and cellular connectivity options, we have developed such a framework, building upon the work done in the preceding quick scan. The results may be useful in two ways. Firstly, it provides the "instrument" as such which has also been used within TNO to conduct a first iteration of this assessment. Secondly, this first iteration has generated a substantial and insightful elaboration of the issues associated with three infrastructure exploitation models and associated connectivity options, reflecting a substantial part of the solution space. The first iteration has been applied to the five priority use cases and is fully presented and documented in this report. The first exploitation model (Model I) represents a fully public-owned and public-operated ITS-G5 based infrastructure and service model. Model II represents a fully market driven, OTT/cellular based model where the public role is limited to information or data provider. Model III represents the hybrid approach in which an third party (a so-called ITS Communication Service Provider) uses both cellular and ITS-G5 technology to provide appropriate ITS connectivity services to road operators and to others.

1.4 Conclusions

ITS-G5 based C-ITS is to be considered as an important candidate to provide time critical warning services to road users and to support specific traffic management tasks, exploiting the ad-hoc concept and its inherent compliance with demanding timing requirements. With automated driving developments emerging, such more demanding requirements will become even more important in the future. Nevertheless, the process of completion of C-ITS solutions up and including their pan-European deployment is a long term process. In the meantime, alternative approaches have emerged and will continue to emerge, which forces us at some point to review the position of ITS-G5. Such a review is needed because these alternatives affect the initially perceived added value of ITS-G5 based C-ITS.

The success of autonomous developments in cellular communications and Internet, and the emergence of ITS services via OTT/cellular communications cannot be ignored. Straightforward ITS information services which were once thought to be delivered over ITS-G5, can be delivered via cellular communications. This is also the case for most of the five priority use cases in the Netherlands. An OTT/cellular oriented ecosystem exists today which shows promising levels of user acceptance and seem to contain viable business models. The massive adoption and the speed of technological developments in the cellular field, combined with the delayed introduction of ITS-G5 leads us to the conclusion that cellular communications and Internet are *de facto* part of any future ITS ecosystem of services and applications.

Looking further into the future, it remains to be seen to what extent cellular communications will be able to and will be offered to accommodate the technical requirements of more demanding (i.e. time-critical) ITS services which are expected to emerge. Although such claims exist, there is still too much uncertainty to draw firm conclusions already now. These uncertainties are expected to disappear in the coming years as the 3GPP standardisation process moves forward and mobile operators make up their minds concerning their role and proposition in (C-)ITS. These developments must at least be monitored closely. They will eventually determine how important ITS-G5 will become, but we expect now that both will play a key role in future C-ITS provided it offers clear added value in comparison with the cellular option. This pleads for 'thinking hybrid'. as of today. The main stakeholders i.e. OEMs, road operators, could facilitate such a transition.

The assessment framework developed in this study provides in a structured way an understanding of the pros and cons of C-ITS via three stylized exploitation models: the ITS-G5 centric approach (Model I), the OTT/cellular centric approach (Model II) and the hybrid approach (Model III). The assessment was scoped to only the five priority Day-1 cases which are relevant in the Netherlands today but do not represent the set of applications which is expected to emerge and which is expected to cover use cases which are (much) more demanding towards the supporting wireless connectivity solution. The exploitation models chosen in our analysis are not intended as suggestions for only discrete options to exploit ITS connectivity, but rather serve as 'lenses' for analysis and as such highlight elements that are of value in the anticipated and composed future exploitation model. The outcome of our first iteration conducted within TNO, on the basis of all insights gathered, supported our prejudgement that both the ITS-G5 and OTT/cellular exploitation models have different strengths and weaknesses. Neither candidate provides the perfect solution. It therefore supported our conclusion that a hybrid strategy is worthwhile to consider so that this complementarity can be exploited.

1.5 Recommendations

Recommendations stated below apply to the period 2016-2019/2020. By that time, it is expected that the developments described have played out sufficiently to allow further decision making regarding the strategy regarding infrastructure support of ITS and cooperative applications in particular.

The overarching recommendation is to focus on allowing and probably stimulating further development of the ecosystem around OTT based ITS applications which has already emerged and which has generated various "popular" applications. This development should however be done in such a way that connectivity solutions based on ITS-G5, which we still consider to be an important connectivity *option*, can be gracefully adopted as where and when appropriate. So, in our view, the hybrid concept is the targeted concept, until international developments would prove otherwise.

Hence, C-ITS pilot projects involving ITS-G5 technology as well specifically targeted deployments of ITS-G5 technology should be pursued in the Netherlands in the coming years in order for stakeholders to continue gaining experience and learning about it's possibilities and limitations. Such pilots should however be defined in a hybrid context (see also next paragraph). The pilots should be well scoped and be given limited durations in order to allow fast learning and frequent re-evaluation of leaning goals. In this way, the Netherlands can also continue their involvement in international standardisation and profiling activities. Specifically targeted deployments refers to smart deployment of ITS-G5 technology in selected scenarios for specific target groups that would benefit directly, based on flexible (future proof) configurations.

As stated, future development and piloting of ITS applications should be done - from a public road operator perspective - on the basis of a hybrid connectivity approach, where possible. This however requires stability regarding the exact interpretation of "Hybrid" and its architectural implications. Therefore, urgency applies to the specification, development and tests/experiments of this hybrid concept, most preferably in an international context (H2020, CEF and in ETSI, CEN) or in coordination with initiatives abroad. In the Netherlands, all relevant Dutch ITS Round Tables are advised to prioritize their work on C-ITS towards hybrid concepts in terms of architecture, interoperability, security and privacy protection measures, or at least take the hybrid approach into account. This involves also a number of organisational and business alternatives and implications, which should be pronounced. Identification and verification of (implicit) assumptions which apply to each of the options supporting a hybrid solution is deemed necessary because these options have different original contexts. An interesting question would be how to set up a Model III type of business model.

Road operators and associated public stakeholders in the Netherlands are advised to emphasize their efforts on the enablement of information for ITS applications / services offered in the market which leverage the existing OTT option (over cellular and/or default Wi-Fi connectivity). Without pretending to be complete, this includes for example establishing third party access to data (static and dynamic), introduction of provisions for IoT in future infrastructure and associated systems and providing communication operators access to passive roadside facilities (e.g. sites, portals, cabinets) under "appropriate" conditions. In this way traffic management goals on local, regional and national level suffer the least from the delay which is eminent with ITS-G5 based C-ITS. Also pro-active cooperation between road operators and

trusted organizations like the ANWB may lead to ITS service offerings (apps) which enjoy appreciation and popularity, in case the market would not develop well or fast enough on its own. The PPA project is important in this respect and the goals of the PPA program could be reused for ITS projects in other regions in the Netherlands.

The government runs the 'off line' campaign "Als ik ONderweg ben, ben ik OFFline" since 2015. Road safety should obviously not be compromised, but less stringent behavioural recommendations could emerge from an assessment of viable alternatives for in-car use of information and communication services. These alternatives would have to have a positive net safety benefit. Specific attention is needed on how information services for driver assistance can interact with the driver in such a way that they do not negatively affect traffic safety by distracting the driver's focus on the road, as is seen today with smart phones and social media apps. This could be done in co-operation with the smart phone industry.

In case local road operators in urban regions intend to equip their infrastructure facilities like traffic light installations and street light installations with ITS-G5 capabilities, they are advised to include requirements on easy system reconfigurability/upgradeability, non-proprietary interfaces and Internet connectivity in the procurement of such systems or system extensions.

The Ministry of Economic Affairs is advised to initiate a market consultation regarding the need for mobile services with QoS differentiation in different application domains and how the current regulatory framework accommodates such needs. In public mobile networks QoS differentiation is not allowed based on Net neutrality principles. The same Ministry is advised to promote R&D activities in the horizontal ICT roadmap of the Topsectoren beleid on the matter of applicability of beyond 4G/5G and Internet technology in specific application domains ("verticals"), including the ITS domain.

If not already in progress, the Amsterdam Group is advised to study the impact of various developments such as presented in this report, on ITS requirements and use cases to be supported, especially given the timelines involved to arrive at appropriate standardized solutions. Particularly, developments like automated driving (e.g. C-ACC) and the involvement of other types of road users (e.g. VRUITS) are relevant.

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