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Traffic Management of the future and Road Automation

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Abstract

Automation along the whole chain of road transportation and services will play a key role in future transport systems. Traffic Management should be prepared to accommodate the circulation of automated vehicles. A survey conducted among the members of the TM2.0 ERTICO Platform, including consultation by external stakeholders, reveals that road automation is expected to enable the provision of more reliable, effective and efficient Traffic Management services, which will increase road safety and efficiency and enhance environmental protection. High quality, detailed data of the current status of the road network and of the whole transport system should be always available, covering the whole road network. The traffic environment should be harmonised, while data privacy and security should be also safeguarded. New communication means with the automated vehicles should be conceptualised and designed, replacing the traditional communication means with human drivers, and this may require changes in the physical infrastructure.

Keywords:

Traffic Management, Road Automation, Connectivity

Introduction

Automation in road transport is expected to contribute to the key objectives of the EU transport policy, namely to increase safety, improve traffic efficiency and minimize pollutant emissions. It is also expected to maximise the comfort of the end users considering also societal aspects e.g. the needs of elderly and impaired people. Automation in this context is envisaged as automated and autonomous driving applications actively interacting with intelligent environment. For this to happen, intelligence and automated applications should reside on all actors of the transportation network, the driver, traveller, vehicles, infrastructure, road / Public Transport (PT) operators, Traffic Management Centres (TMC)s, etc. All major automotive manufacturers and tier-1 suppliers are investing a lot in research and development in automation and several highly and fully automated technological advancements are being demonstrated in numerous events. It is commonly accepted that automation will become a reality sooner or later and that it will play a key role in future transport systems.

The whole chain of the transport infrastructure should prepare itself to initially host mixed and later fully automated traffic flows, to manage and regulate the circulation of automated vehicles, supporting when needed their interaction and communication with their surroundings, thus increasing the road safety and efficiency in an orchestrated manner. On the other hand, the automated vehicles will greatly benefit from the possibility of high level communication, not only with the infrastructure and with other vehicles but also with the rest of the road users like pedestrians, cyclists and human drivers. For this, the whole transport network, cities and highways, has to be prepared to host and inter-link to this new transportation means. Indeed, one of the conclusions of the Ministerial Round Table at the ITS World Congress in Bordeaux in 2015 was: "Managed deployment will be needed for highly automated driving". It becomes evident that Traffic Management should be prepared to accommodate the circulation of automated vehicles in real traffic and to support the transition period where both automated and legacy vehicles will co-exist in mixed traffic environments.

Traffic Management and how it may answer the needs of mixed and fully automated environments is one of the topics being discussed within the TM2.0 ERTICO Platform [1]. The Platform originated in 2011 and was formally established on 17 June 2014 during the ITS Europe Congress in Helsinki. It now comprises more than 25 members from all ITS sectors, focusing on new solutions for advanced interactive Traffic Management, and aims to agree on common interfaces, principles and business models which can facilitate the exchange of data and information between the road vehicles and the Traffic Management Centres, improving the total value chain for consistent Traffic Management and mobility services as well as avoiding conflicting guidance information on the road and in the vehicles.

The work presented in this paper was conducted by members of the TM2.0 ERTICO Platform working under the TM 2.0 Task Force (TF) on "*TM 2.0 and Road Automation"*. The main objective of this TF was to assess how the gradual road presence of automated vehicles, at automation level 3 and above, will affect the current Traffic Management practices. Another objective was to analyse how new Traffic Management practices can facilitate the smooth integration of automated vehicles in real traffic, while gaining the maximum benefits from this introduction. Moreover, the TM 2.0 TF aimed to explore the interaction between Traffic Management, automated vehicles and human drivers. The TF worked under the principle that in order to establish an efficient and valuable interaction, "both ends" of the Traffic Management chain need to be prepared to communicate not only in the same language but also on the basis of similar technical and functional quality levels.

Current scene

Automation in road transport is a reality. Numerous prototypes are driving safely in countries all over the world. Since June 2011 five US states have adopted legislation that allows driverless cars on the road network. In June 2015, Google driverless cars had driven more than 1 million miles [2]. In January 2015, the Netherlands was the first European country to approve large-scale testing of self-driving cars [3]. In March 2015 an Audi Q5 drove from San Francisco to New York City. In April 2015 the city of New York signed a contract with Google for 5,000 driverless taxis by 2016. On 2 October 2015 a PSA autonomous car drove from Paris to Bordeaux while in November 2015 it crossed the French border to complete a loop of around 3,000 km running from Paris to Madrid via Vigo. Within the CityMobil2 project [4] fully autonomous mini buses are currently operating in real traffic conditions in five European cities. It is a matter of time until autonomous vehicles (in level 3 of automation and above) are massively driving in real roads.

On the other hand, the transport infrastructures and Traffic Management across Europe are very heterogeneous in terms of quality and availability of: i) systems, whether located at central stations, at the road side, or for communications, ii) services, for example incident management, traffic information, road works, etc., iii) content itself, e.g. Traffic Management data and Plans, and iv) processes, e.g. governance and Traffic Management operations. Moreover, the traffic environments in Europe are very diverse themselves, i.e. urban, motorways or regional networks, and equally diverse are the various domains and use cases, addressing private traffic, VRUs, parking, public transport, etc.

Some efforts towards harmonising the infrastructure and Traffic Management, and thus preparing for the road automation reality, are already in place. For example, the Austrian-German-Dutch project "Cooperative ITS-corridor" [5] deals among others with upgrading Traffic Management so as to support cooperative ITS use cases, and as such it entails a significant level of automation. Specifically, the Austrian part of the corridor project, the European Corridor – Austrian Testbed for Cooperative Systems (ECo-AT) project aims to jointly create harmonised and standardised cooperative ITS applications with partners in Germany and the Netherlands. The German part of the corridor project focuses on harmonised road works warning services via TPEG and ETSI G5. In the Netherlands, the project focuses initially on two services, road works warning and probe vehicle data.

Moreover, road authorities and traffic information service providers in the Netherlands have agreed to make data from Traffic Management systems open and available for service providers as regards road works, location reference, maximum speed, requested time to solve an incident, Traffic Management plans, parking data, data from traffic light controllers, data from bikes, blue wave (bridges) [6].

Other projects relevant to Traffic Management and road automation include: LENA4ITS, a project which investigated the interoperability between public Traffic Management and individual navigation services and proposed a 4-level model for cooperation of private and public partners in Traffic Management; TRAMAN21 (Traffic Management for the 21st Century), whose aim is the development of fundamental concepts and tools that will pave the way towards a new era of future motorway Traffic Management research and practices; and UR:BAN, a cooperative ITS project with the goal of developing advanced driver assistance and Traffic Management systems for cities. The current CHARM programme [7] aims at the "Next Generation of Traffic Management System". The innovation track includes the development of an "Advanced Distributed Network Management" module that provides automated support for management of large, nationwide traffic networks. The module will be a multi-layered, self-learning engine that will be able to manage large networks and balance between different types of goals.

However, although there is some progress as regards road automation and Traffic Management, the developments have until now mainly focused on the vehicle side. The members of the TM 2.0 platform expect that the evolution in Traffic Management practices and procedures, so as to effectively host the automated vehicles, will be a main challenge in the following years.

Stakeholders' needs and requirements

Previous work by members of the TM 2.0 platform [8] has identified the following main stakeholders in Traffic Management services provision, the Road Infrastructure Owners, the Road Side Service Providers, the Content Service Providers, the In Car Service Providers and the Service Consumers.

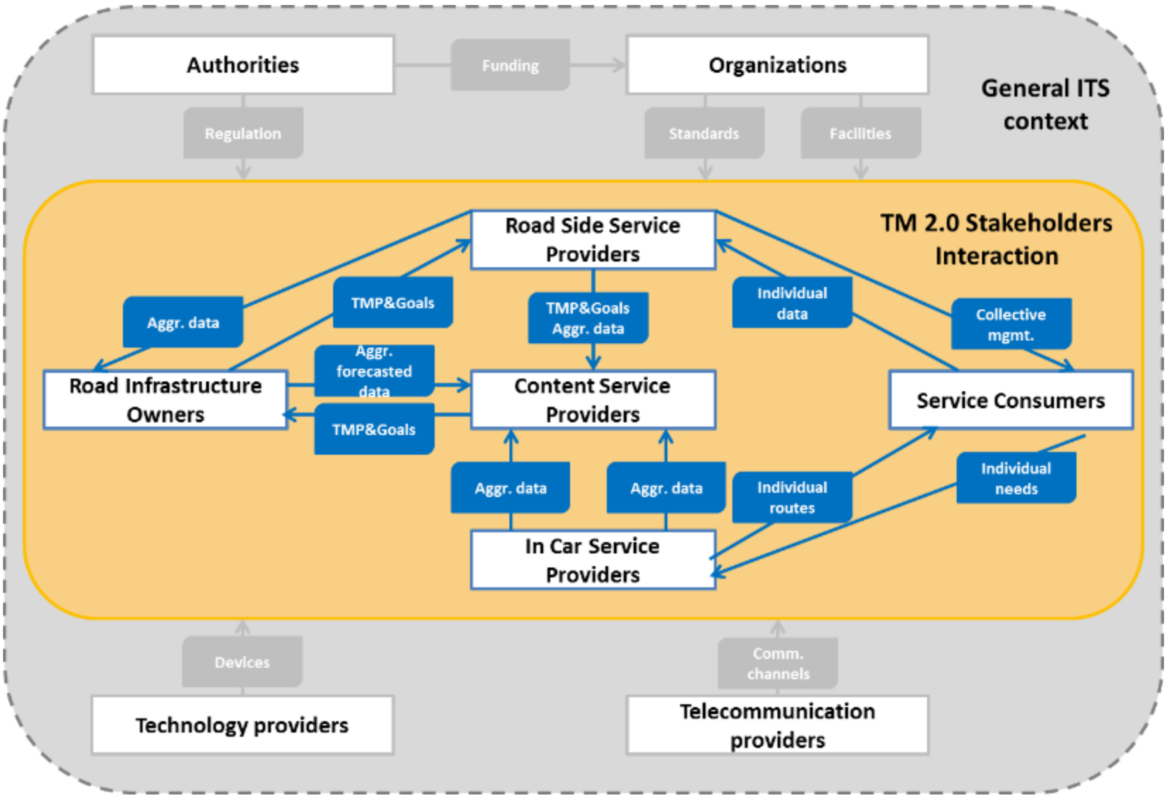

Figure 1 - TM 2.0 organisational reference architecture

The TM 2.0 TF on "*TM 2.0 and Road Automation*" has analysed the high-level requirements of the above-mentioned stakeholder groups as regards the gradual integration of road automation in the road network for the purposes of its work, via internal discussions and interviews with external entities, and these are presented below.

In-Car Service Providers, such as the navigation, location and mapping industry, including those Vehicle Manufacturers who do not use third-party providers but invest in a dedicated production line on these services and products, are primarily competing on the Quality and Timeliness of their service. The real-time traffic information (road-network status) provided as a service, has to be both 'true' (valid) and well-timed in reaching the driver. As the level of road automation increases, the more vital these services will become for the road safety, and the more acute these requirements will become. In an automated environment, information rendering the journey safe and comfortable should be accessible by both the vehicle and the user, if he /she so wishes. The required data and Traffic Management Plans should be made accessible by all road operators or relevant authorities, to Service Providers. More to that, this information should cover the entire road-network, not only highways but also low class roads, including their inter-connection points, it should be available at the same level of detail and it should be consistent. The latter, is an even more pressing requirement for automated vehicles, since such vehicles may rely completely on such data and information, as they operate without a human-in-the-loop, who could intervene, if needed.

Moreover, as the level of road automation increases the Quality and Timeliness of data, traffic information and services need to be guaranteed in both ends of the real time traffic information and mapping service chain. This requires a certain speed of exchange in the information (traffic and mapping) channelled between Traffic Management Centres (TMC) and Content Service Providers. In this respect, Traffic Management Plans should be available at all times, i.e. the TMCs should maintain an open channel for their Traffic Management Plans and related information for those Content Service Providers who wish to make use of them in their fusion engine when enhancing their real-time traffic information. As a result, when the real-time traffic information reaches the vehicle via the In-Car Service Providers, the Traffic Management Plans will be already integrated with the traffic information on the road network status. This requirement is even more pressing for automated vehicles.

Service consumers on the other hand, is a stakeholder category that includes entities such as the automated vehicles themselves, the Drivers, Fleet Operators or Transportation companies. They may also include Other Traffic participants, for example pedestrians, since a Traffic Management service may provide them with information about the behaviour or the intentions of an automated vehicle. Both the automated vehicles and Other Traffic Participants should be able to intuitively interact with each other, anticipate each other's intent and predict each other's behaviour, thus safely planning in common their future trajectories. For this, the automated vehicles status and intent should be explicitly communicated to Other Traffic Participants, while automated vehicles should be able to anticipate the intent of Other Traffic Participants and integrate it in their own manoeuvring planning.

The Road Infrastructure owners stakeholder category aims towards the safety and security, environmental sustainability and efficiency of the infrastructure. In order to achieve these goals, and especially the optimisation of throughput, during the gradual integration of road automation, new traffic control techniques should be conceptualised and designed for mixed traffic (automated and non-automated vehicles on the road network). Examples of such techniques may include a combination of Variable Message Signs for non-automated vehicles and highly reliable C-ITS links for automated vehicles. To meet these new needs, information gaining and processing should move from classic methodologies to more modern technologies.

Road Side Service Providers deliver traffic information services to their clients and this is often also based on Traffic Management Plans. The Traffic Management data and Plans need to be made available and accessible to all Service Providers in a secure manner using standard interfaces. The success and value of such services is among others also related to the Quality of the content, namely to its reliability, availability and timing. The quality of Traffic Management Plans should satisfy these requirements and such requirements will be even higher when aiming to provide services towards automated vehicles. Road operators and traffic management authorities should work towards the automation of their own processes with regards to Traffic Management Plans, in order to increase the level of detail, i.e. roadworks, since such information is typically dynamic.

A stakeholder category, not depicted in the general ITS ecosystem of Figure 1, but very much related to road automation are the Public Authorities. Ministries, Police authorities and standardisation bodies are some of the actors that issue regulatory and legal requirements with regard to road automation. With regard to the integration of road automation in the road network, Public Authorities will require the issuing of standards and the establishment of certification procedures for automated vehicles and related systems and services. They will also require new legislation to regulate the circulation of this kind of vehicles in standard roads. Another issue to be tackled will be the reliability of information and who may be liable in case of an accident involving an automated vehicle at level 3 and above. Special care should be given to the analysis of the possible liability and the clarification of possible implications for road authorities and road operators as regards their data, systems, services and operations. Another issue to be tackled is the standardization of communication security, considering the increased vulnerability of automated vehicles in case of cyber-attacks. The division of responsibilities among the various stakeholders should also be clarified so as to establish the necessary arrangements that will facilitate road automation.

Conclusions and challenges

According to the work within the TM 2.0 TF on "*TM 2.0 and Road Automation"* road automation will be a reality very soon. This will entail automated vehicles at level 3 and higher in real traffic environment, interacting with other vehicles and other traffic participants, and with all stakeholders involved in Traffic Management services provision. It will also entail automation in the provision of Traffic Management services themselves, as for example services between roadside systems and vehicles, but also services within the Traffic Management Centre itself. The introduction of automation in all systems and processes along the whole Traffic Management services value chain is expected to make them faster, with shorter latencies and more effective. Specifically, the automation of the TMC operators' tasks will reduce human errors and may enable the quicker reaction to incidents and even the prediction and prevention of incidents, thus enabling proactive Traffic Management. The provision of better Traffic Management services will result in much higher level of road safety and transport efficiency as well as better environmental protection.

Additionally, the feedback provided by automated vehicles on road and traffic conditions will be beneficial to the Traffic Management service providers. The sensors of automated vehicles will generate larger amounts of high quality data, thus making the Traffic Management services more efficient. For example, the quality of traffic light control plans may improve with a higher traffic throughput. Moreover, the increased interaction between vehicles, roadside and infrastructure will enable a more effective and efficient Traffic Management, resulting in a more reliable and effective transportation system. Ultimately, if in the future all vehicles are automated, an entire new transport system may be formed, offering a more intelligent and comfortable mobility. For example, in a transport on demand scenario, parking and charging of electric vehicles may take place outside the city boundaries, resulting in reduced private ownership of vehicles.

More to that, road authorities will operate along an automated chain of effects towards automated vehicles and therefore in traffic in general, enabling thus a more efficient use of the capacity of the network along with better road safety. Indeed, automated vehicles are expected to be able to tackle all aspects of the driving task by themselves, i.e. without human intervention, therefore since the Traffic Management Centre will be able to directly reach the vehicles by being able to send out instructions to traffic information Service Providers partnering in the automated vehicles, it will be able to influence and support the behaviour and driving decisions of the automated vehicles. This will be an enabler for safe automation. Still, this cannot be guaranteed, especially in the transition phase and in view of many other road users in urban environments.

For all this to happen, the members of the TM 2.0 TF on "*TM 2.0 and Road Automation*" have identified several challenges that need to be overcome. Initially, the automated vehicles service providers have to adapt to the current situation and make their systems so reliable that they are trustworthy in the current transportation system. The systems performance should result in a humanised behaviour of the automated vehicles, including their potential to interact with Other Traffic Participants.

More to that, high quality and detailed data with regards to the current status of the road network and also the whole transport system should be always available. Traffic information services should be of high quality and timely. Data and services should be available at all times, in a standardised format across operators and providers in all countries. Moreover, the existing big diversity in road design and traffic environments should be harmonised across the several European regions.

Fully (or highly) automated vehicles will involve high levels of connectivity. Data generated and acquired by the vehicles will be used to sense the environment for the automated driving tasks (to detect other vehicles, the infrastructure, other users such as pedestrians, VRU, etc.), to fuel in-car services but also for the provision of many other services currently provided by third-party service providers, like eCall, bCall, remote diagnostics, UBI, etc. International standards for data privacy and data quality should be established. Also more attention should be paid to cybersecurity of data, services and systems, as increased automation will also increase the security risks.

Another aspect with regards to the integration of road integration involves the means of communication of information from the Traffic Management Services Providers to the automated vehicles. The visual and audio means for interacting with the human drivers will be replaced with digital communication addressed to the automated vehicles. Automated vehicles should “know” what to do, i.e. what is allowed and/or recommended at all times, for example which dedicated lanes they can drive in, which is the allowed speed limit, etc. In other words, automated vehicles have to receive Traffic Management Plans and information in a digital format, not via the signalling means currently used for human drivers. This means that different techniques for communicating with the automated vehicles should be designed and standardised. This may also require changes in the physical infrastructure. As an example, traffic lights should be able to directly communicate with the automated vehicles. It can also be expected that intelligent speed adaptation services will become more prominent, thus reducing the need for infrastructural measures, e.g. the 30 km/h zones. In the transition period, there might be the need to upgrade some parts of the infrastructure, for instance if dedicated lanes are reserved for automated vehicles, these should be signalled accordingly, for example painted in a different colour. In the longer run, one may expect that there may be less need for traffic signs and ultimately for traffic lights. In any case, all the necessary infrastructure elements, i.e. communication means, traffic management signalling, etc., and the communication itself should be conceptualised, designed, standardised and established in real conditions.

A scheme for classifying the infrastructure and the road networks will be required to support Traffic Management and Road Automation in the future. Automated vehicles will need to “know” specific characteristics of a specific road segment, for example there are roadworks ongoing, there is delineation and digital signing and there are V2X capabilities. In this respect, there is a clear need for an international consensus on a protocol to rate and classify roads towards automated driving, and this classification should be included in the data layers of future maps for navigation. A good starting point could be the iRAP’s Road Protection Score methodology [9].

Finally, the increasing levels of automation will have obvious implications in the way drivers interact with their cars, e.g. as regards the transition between manual and automated driving, the activation of partial automation, etc. This will generate the need to adapt and update the drivers’ training curricula. Similarly, the operators of the Traffic Management Centres should be adequately trained. Raising awareness of the implications of road automation will be also necessary. This should include advocating for safe application of automation features and promoting its widespread introduction when there is solid evidence that such features will indeed reduce accidents and emissions and will make travelling more comfortable.

All these have to be supported by regulatory and legislatory measures, in order to regulate the possible liability of Traffic Management stakeholders in case of incidents. Road infrastructure is owned by authorities, automated vehicles will typically be owned by users or operators, therefore a close cooperation between all stakeholders will be required for a well-supported, optimal automated traffic system. TM 2.0 is a concept that promotes interactive Traffic Management. Applicable for non-automated vehicles, which receive traffic information (enriched with the data from Traffic Management Plans) via traffic service providers operating within the car and directly accessing the driver, TM 2.0 is a step before road automation. According to TM 2.0, all stakeholder groups work under win-win business models for the benefit of the driver and the optimisation of the road network. The gradual introduction of road automation can –and must - take advantage of the change in Traffic Management introduced and supported by the TM 2.0 platform. A central objective of the TM 2.0 is the alignment and satisfaction of the individual objectives of the driver (safe, fast and efficient use of the road-network) and those of the public authorities and road operators (network optimisation, traffic and environmental targets) which is also the basis upon which road automation is build. Road automation is expected to satisfy the needs of all transport stakeholders and as such, it is very relevant to TM 2.0 and to the work the Platform is conducting in this respect. It is the TM 2.0 belief that TM 2.0 should identify the contributions which interactive Traffic Management can make to road automation, so that it 'feeds' into the discussion and preparation of the gradual integration of road automation in the road networks in Europe.

References

1. www.tm20.org
2. http://venturebeat.com/2015/06/03/googles-self-driving-cars-have-driven-over-1-million-miles/
3. Feddes, G. (2015), Dutch legislation for automated driving, In Proceedings *22nd ITS World Congress*, Bordeaux.
4. http://www.citymobil2.eu/en/
5. B. Konstantin Sauer, B., Molin, H., Op De Beek, F., Reusswig, A., Smetthurst, G. (2015). Deployment of cooperative ITS in the C-ITS Corridor – mastering in the challenges, project dissemination session PR04. In Proceedings *22nd ITS World Congress*, Bordeaux.
6. van Dijke Jan Jaap and Marcel Westerman (2015). Action Plan Data – Data Top 8, Programme "Optimising use" from Dutch Ministry of Infrastructure and Environment.
7. https://www.rijkswaterstaat.nl/english/about-us/doing-business-with-rijkswaterstaat/charm-pcp/index.aspx
8. http://2r1c5r3mxgzc49mg1ey897em.wpengine.netdna-cdn.com/wp-content/uploads/sites/8/2015/10/TM20_TF1_Preliminary-Report-1.0-17022015.pdf
9. http://www.irap.org/en/about-irap-3/methodology