TM 2.0

ENABLING VEHICLE INTERACTION WITH TRAFFIC MANAGEMENT

Role of Automation in Traffic Management: Towards a digital infrastructure and classification of infrastructure

November 2017

Table of Contents

1. Introduction

Considering the interest by the research and industrial community on road automation, it is expected that vehicles at higher levels of automation will start entering the real traffic soon. In parallel, the latest developments in the area of mobile and wireless communications will lead to the circulation of numbers of connected vehicles, i.e. vehicles that may communicate in real time with the traffic infrastructure. Thus, in the future the traffic fleet will be a mixture of manually-driven and automated vehicles, at several levels of automation, while a lot of these vehicles will be connected.

The objective of this work by the Task Force "Role of Automation in Traffic Management" of the TM2.0 platform is to discuss the Traffic Management's needs and requirements in terms of digital and physical infrastructure and communication technologies, so as to facilitate the management of mixed fleets of vehicles. Another objective is to propose a scheme to classify traffic infrastructure as regards its suitability to support vehicles of different levels of automation.

The work has been based on analysing the Traffic Management's requirements for specific traffic scenarios, which have been identified as being most relevant for traffic management. The scenarios were: Intersection regulated by Traffic light, Intersection regulated by Police officer, Road works ahead, Priority request by emergency vehicles or by public transport (buses), Dynamic lane assignment to specific vehicles, Intelligent Speed Adaptation, Parking space availability (e.g. detected roadside parking), Extended Probe Vehicle Data collection and analysis, Unsignalised intersections support by Traffic Management and Shockwave damping. The work was based on collecting the requirements expressed by traffic managers as regards the efficient management of the traffic flow and the safeguarding of road safety. Additionally, some considerations on how the infrastructure may support automated vehicles have been highlighted.

2. Digital infrastructure requirements

Previous discussions among the members of this Task Force have resulted in the vision of an intelligent local Traffic Management Controller (iTMC), which can be implemented at a roadside ITS station or at traffic light controller or in the cloud.

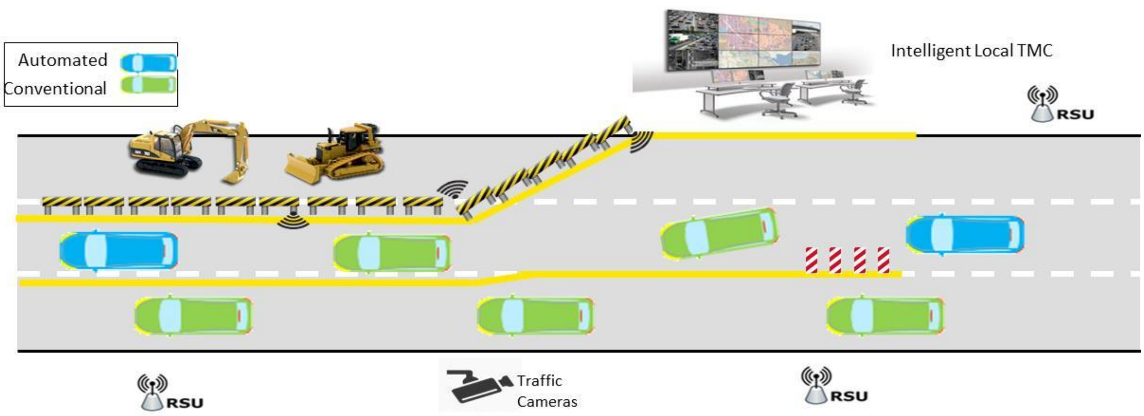

Figure 2 Intelligent local Traffic Management Controller

The iTMC will maintain a dynamic registry of all connected vehicles in its control area. This registry can be possibly integrated within a local dynamic map or within the Common Operational Picture[1] of Traffic Management and should include the status of automation of each vehicle.

The iTMC will be responsible to communicate with the vehicles in its area of control or with the service providers and any other relevant Control Centre. It will be also responsible to receive an acknowledgement from automated vehicles, that the communicated information has been received. Such an acknowledgement should be standardised and included in the ETSI protocols[2], and should be automated to avoid causing additional processing burden.

The iTMC should be inter-connected and exchange information with all other stakeholders, for example with public transport control centres, with operators or vehicle manufacturers back-ends. In general, all cloud systems and back office operations of vehicle manufacturers, service providers, road operators and traffic managers should be interoperable. Work should be devoted on defining one common framework for the exchange of all relevant information between all stakeholders.

3. Physical infrastructure requirements

It is expected that, at least for mixed fleets of vehicles, spatial or temporal restrictions may be enforced on the circulation of automated vehicles. All traffic signs and road delineation relevant to such restrictions should be harmonised among countries, to allow interoperability of automated functions, as they may be based on the recognition of such markings and signs. Additionally, inter-connection of the automated vehicles Control Centre with the Traffic Management Centre should be ensured.

Automated vehicles will benefit from the transmission of traffic signal phase and timing information. Traffic lights should be equipped with appropriate systems.

Good lane markings condition can support the accurate positioning of automated vehicles. Stricter criteria and maintenance processes as regards the condition of lane markings should be studied.

Systems informing about other the presence of other traffic participants, including vehicles and pedestrians, would be beneficial at locations with reduced visibility, for example at urban intersections. Such systems may be decentralised, but should be possibly connected to the iTMC for better information and warning of all involved.

As regards intersections regulated by a police officer, a system to digitalise and transmit the officer's commands should be deployed and should be connected to the iTMC.

4.

[1] A Common Operational Picture (COP) is a term widely used within the military
domain to support situational awareness for command and control in netcentric operations and has been proposed for Traffic incident management in: http://degree.ubvu.vu.nl/RePEc/vua/wpaper/pdf/20110033.pdf. Information from all sources, like roadside stations and service providers, is combined, to create a complete picture of the network.

[2] ETSI EN 302 637-2, ETSI EN 302 637-3

Organisational requirements

Expecting that there will be a digital infrastructure, containing the information to be digitally transmitted to automated vehicles, a significant organisational challenge will be to ensure that the two worlds, the digital and the physical infrastructure, exactly match. This implies that the digital infrastructure should be updated in real time with all the changes and updates done in the physical one, for example changes in speed limits or existence of roadworks.

This becomes even more complicated when one considers that there are multiple Authorities responsible for different parts of the network. A possible approach is the creation of a National Data Warehouse, that will collect data from different public and private sources and authorities, and will check them and maintain a global view of the real-time situation.

Liability issues in case of inconsistencies between the digital and physical infrastructure should be studied.

6. Supporting localisation of automated vehicles

The safe and efficient execution of several automated driving functionalities requires precise road and lane localisation of the vehicles. For highway driving, the positioning error should be less than 30 cm, but this may be limited to up to 3 cm for manoeuvres like lane changes.

Pure GPS may offer an accuracy up to 5 m. The Galileo is expected to offer an accuracy of 4 m and EGNOS to improve GPS by providing an accuracy of 3 m. Laser scanners are often present in automated vehicles and they offer a range accuracy between 0.02 m and 0.5 m, but their performance is limited by environmental conditions and their cost is still high[3]. Equipment manufacturers reported lately that new applications require a range accuracy of 0.2 m.[4]

Enhanced localisation precision may be achieved by matching information from different sources, namely from on-board sensors, from other vehicles and from roadside units. Additionally, the vehicle's localisation can be based on reference points, which may be the lane markings and specific points or landmarks. In urban environment, such points may include bus stops, fire cranes, traffic signs or certain buildings. In highways and open rural areas, traffic signs may be used. The roadside units and reference points should be accurately localised too.

The above derive the requirement for the maintenance of a high definition digital map of the reference points. The map should accurately reflect the current situation in the physical infrastructure. The appropriate reference points per traffic environment, highway, urban, rural, should be standardised across road operators and countries. The reference points should be annotated on the digital map and should be regularly verified and updated. The accurate positioning of the reference points should be available on the digital map.

7. Connectivity needs

Continuous connectivity with automated vehicles should be ensured. On 30 November 2016 the European Commission presented the "European Strategy on Cooperative Intelligent Transport Systems" which among others requires complementary communication technologies so that drivers

[3] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5335929/
[4] Presentation from AutoBild at the IAA 2017 in Frankfurt

receive all information seamlessly across Europe. Road authorities, service providers, vehicle manufacturers and industry are expected to adopt a strategy towards this hybrid communication approach. Connectivity, with vehicles and reference points, may be difficult at specific locations, for example in urban canyons or tunnels. The installation of fixed land stations for such locations should be motivated. Services should not encounter problems when passing from one communication technology to another. The messages exchanged and interfaces should be independent of the communication technology used.

8. Example use cases

To derive concrete Traffic Managers' requirements in order to manage mixed fleets of automated and manually-driven vehicles, two example applications have been studied. The first application was Intelligent Speed Adaptation (ISA), which is typically categorised as SAE Level 3 of Driving Automation[5]. The second application selected was the operation of fully automated urban shuttles, which is categorised as SAE Level 5. The following two tables collect the members opinions and expectations as regards: i) the Traffic Management' requirements to enable the efficient and safe management of the flow and ii) the ways that the infrastructure and Traffic Management can support the vehicles.

ISA

The following assumptions were used to analyse the ISA example:

1. A dynamic ISA system is available on a highway, covering the highway and the exit and entrance ramps. The TM can dynamically adjust speed limits to optimise the traffic flow.
2. A dynamic ISA system is available in urban environment. The TM can dynamically adjust speed limits, depending on the circumstances, for instance at school or rush hours and in case of road works.
3. The speed limit per segment is communicated to the vehicle via the iTMC.

Function	**Necessity**	**Justification**
Automated flow data collection	must	A system can only be dynamic when data is collected, processed and the results transferred automatically
Automated data processing	must	idem
Automated decision making about the speed limit	must	Idem; although manual input must always be possible
Automated update of digital infrastructure	nice	Changes in the speed limit should be reflected in the digital infrastructure
Continuous connectivity along the segment	must	Necessary to collect speed data and send speed limit to all vehicles
Availability of highly accurate maps	nice	Accurate localisation is not so important for ISA
Good lane markings condition	n.a.	If speeds are communicated to the vehicle by iTMC's, no lane markings are needed
Dense location referencing points	nice	Accurate localisation is not so important for ISA
Presence of segregated	n.a.	

[5] https://www.sae.org/misc/pdfs/automated_driving.pdf

or dedicated lanes		
Presence of physical and digital signs and messages	n.a.	If speeds are communicated to the vehicle by iTMC's, no physical and digital signs and messages are needed

Fully automated urban shuttles

This example studies fully automated (autonomous) shuttles operating in urban environment. It is assumed that they will be allowed to circulate on dedicated lanes.

Function	**Necessity**	**Justification**
Automated flow data collection	must	A fully automated shuttle needs additional sensors from the infrastructure to get a complete image of the traffic state. That information should be delivered by the iTMC
Automated data processing	must	A task of the iTMC
Automated decision making	must	although manual input must always be possible
Automated update of digital infrastructure	must	Update to be released from iTMC
Continuous connectivity along the segment	must	
Availability of highly accurate maps	must	
Good lane markings condition	must	
Dense location referencing points	must	
Presence of segregated or dedicated lanes	must	
Presence of physical and digital signs and messages	must	

9. Conclusions – Towards a scheme for infrastructure classification

The aim of the work presented in this document was to collect the Traffic Management's requirements as regards the efficient management of mixed fleets of automated and manually-driven vehicles.

The discussions among the members of the Task Force have resulted in the vision of an intelligent local Traffic Management Controller (iTMC), which will maintain a dynamic registry of all connected vehicles in its control area and will be responsible to communicate with them and acknowledge reception of the information sent. Any physical traffic signs or road signage relevant to automated vehicles should be standardised, for automated functionalities to be interoperable among countries. A reliable dynamic digital image of the physical infrastructure will be beneficial, so that automated vehicles systems may be informed. Localisation reference points should be standardised and should be annotated on a high accuracy digital map. Procedures should be established to ensure the agreement of the digital with the physical infrastructure. Connectivity should be ensured and appropriate technologies should be available along the network. Services should seamlessly pass from one technology to another.

Finally, it will be beneficial if an infrastructure classification scheme is agreed, to signify whether a specific infrastructure satisfies the Traffic Management' requirements as regards the efficient and safe management of the flow and whether the infrastructure can support the safe and efficient flow of mixed vehicles fleets. Based on the example cases, the following indicators can be used in the form of a checklist. The values used in the table "must", "nice" and "n.a." are based on the discussions in the framework of the present work, the values signifying the matching of each indicator with the automation level should be further discussed among experts in the field.

Function	**L3 requirements**	**L4/L5 requirements**
Automated flow data collection	must	must
Automated data processing	must	must
Automated decision making about the speed limit	must	must
Automated update of digital infrastructure	nice	must
Continuous connectivity along the segment	must	must
Availability of highly accurate maps	nice	must
Good lane markings condition	n.a.	must
Dense location referencing points	nice	must
Presence of segregated or dedicated lanes	n.a.	must
Presence of physical and digital signs and messages	n.a.	must

It must be noted that the vehicle performance and how the vehicle subsystems process the information provided is not considered in the proposed classification scheme, only the infrastructure side is being considered.

It must be also noted that the classification of a specific road segment may change due to dynamic circumstances, which may have implications for automated vehicles and may result in temporary changes in the authorisation of automated vehicles on the segment, as it may be highly advised to downgrade their level of automation for this specific segment or even suggest a take-over from the driver. This may occur for example in case of an emergency on the road, when the road is occupied by VRUs, in extreme weather conditions and so on. It should be studied who will be responsible for a decision on the allowance or not of automated vehicles, in the vehicle or at the Traffic Management side or in a collaborative way.

Agreements between all stakeholders, namely road operators, service providers, vehicle manufacturers and others, on roles, standards for access to vehicle data and framework for cooperation, will be necessary in order to realize an efficient traffic management, supporting connected and automated vehicles.