CityMobil2: Challenges and Opportunities of Fully Automated Mobility

Adriano Alessandrini, Alessio Cattivera, Carlos Holguin and Daniele Stam

Abstract The main benefits of road automation will be obtained when cars will drive themselves with or without passengers on-board and on any kind of roads, especially in urban areas. This will allow the creation of new transport services—forms of shared mobility, which will enable seamless mobility from door to door without the need of owning a vehicle. To enable this vision, vehicles will not just need to become "autonomous" when automated; they will need to become part of an Automated Road Transport System (ARTS). The CityMobil2 EC project mission is progressing toward this vision defining and demonstrating the legal and technical frameworks necessary to enable ARTS on the roads. After a thorough revision of the literature which allows us to state that automation will perform its best when it will be full-automation and vehicles will be allowed to circulate in urban environments, the paper identifies where these transport systems perform their best, with medium size vehicle as on-demand transport services feeding conventional mass transits in the suburbs of large cities, on radial corridors as complementary mass transits with large busses and platoons of them and as main public transport for small cities with personal vehicles; then defines the infrastructural requirements to insert safely automated vehicles and transport systems in urban areas. Finally it defines the vehicle technical requirements to do so.

Keywords ARTS · Automated vehicle · Road users · Infrastructure · Safety

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1 Challenges and Opportunities of Fully Automated Mobility

CityMobil2 is a European project which deals with automating mobility. The CityMobil2 vision can somehow clash with others based on the automation of the single vehicle which is supposed to bring all kinds of benefits without requiring neither communication nor the involvement of the infrastructure. The first section of this chapter is dedicated to analysing the claims and quantifies the expected benefits of automation demonstrating that only driverless communicating vehicles which are capable of driving themselves out of the motorway can really provide the promised breakthrough.

Having established that automating mobility is much more than just automating vehicles, not all automation forms are useful whenever and wherever; each environment has a best performing system and sometimes, though sustainable in the long term, the implementation of automated road transport system might require legislative intervention to make possible and sustain the start-up of new transport concepts. Building on the results of its predecessor CityMobil project, CityMobil2 uses a geographical classification to identify the transport tasks better suitable to each transport system based on road vehicle automation. CityMobil2 has 12 cities studying how to best integrate (and where in the city) automated road transport systems. 7 of them will become real life demonstrators.

Where does this vehicle have to run then? How can they be safely (and legally) introduced on urban roads? CityMobil2 defined where these system should run and how to adapt roads to make them as safe as rail transport though as flexible as cars. Section 4 reports on these findings of the project.

Final section of the chapter, before the conclusions, reports on the development of a list of technical requirement for automated vehicles to be part of an automated road transport system.

2 Vehicle Automation Levels and Their Benefits

NHTSA and SAE have recently classified automated road vehicles in levels on the basis of how many and which ones of their functionalities are automated.

NHTSA has defined 5 levels of automation [1], from Level 0 (no automation) to level 4 (full self-driving automation) where *[…] the driver […] is not expected to be available for control at any time during the trip. This includes both occupied and unoccupied vehicles*. SAE is currently defining 6 levels of automation (they will be reported in standard SAE J3016, currently work in progress) [2], from level 0 (non-automated) to level 5 (full automation) where the vehicle automatically manages *[…] all aspects of the dynamic driving task under all roadway and environmental conditions […]*.

The potential benefits of automating road vehicles are: increased road capacity, increased safety, lower environmental impact, opportunity for new business models.

However, different levels of automation bring to different levels of achievable benefits. In this section, the achievable benefits coming from different levels of automation will be discussed and analyzed.

Both SAE and NHTSA fail to include in their definitions of automation levels cooperative systems; V2V (vehicle to vehicle) and V2I (vehicle to infrastructure) communications can be crucial to claim some of the benefits.

2.1 Safety

Piao and McDonald argue in [3] that only cooperative systems allow the safety and efficiency benefits to be gained. For example ACC (Adaptive Cruise Control) allows maintaining a desired time gap from the preceding vehicle but for driving comfort convenience, the braking capacity is limited and the driver has to take over the control when a higher level of braking is needed. Such situations can bring to significant safety issues. Many studies addressed this topic; among them [4–7], agree that Advanced Driver Assistance Systems (ADAS) while increasing safety on one side might decrease it on several others:

- Some drivers might fail to intervene effectively in automation failure scenarios; ADAS seems to make drivers less likely to reclaim control in an emergency-braking; the measured brake time was 3 times higher and the brake reaction time 2 s higher than the corresponding ones in a fully manual scenarios;
- It is conceivable that newly qualified drivers with basic training could immediately use a vehicle equipped with ADAS; this may improve their performance in the short-term, but since novice drivers do not possess the knowledge or experience to react in a critical situation, there will be no experienced reactions to emergency situations and errors may occur.

Level 4 (according to NHTSA) and levels 4 and 5 (according to SAE) on the other hand will need to embed recovery strategies and fail-safe and safe-life protected failure modes because they do not have the possibility to rely on the driver presence in case of automation failure.

2.2 Capacity

Many studies have been carried out to investigate the effects of ADAS on road capacity. In short road, capacity is mainly a matter of time gap between 2 adjacent vehicles. In [8], the effects of both autonomous and cooperative ACC on highway capacity have been evaluated in a simulation of a single-lane highway. They represent the typical results that can be obtained in terms of road capacity using ACC. Setting an average time gap of 1.4 s, they found the greatest impact is from 20 to 60 % of ACC penetration in the flow but, even in this best case, the estimated capacity increase with ACC remain quite modest, at best less than 10 %. This means going from the 2,100 v/h of the reference scenario to the 2,250 v/h of the best scenario. Moreover, increasing ACC penetration to above 60 % leads to modest loss of capacity. The conclusion is that sensor-based (autonomous) ACC can only have little or no impact on highway capacity even under the most favourable conditions.

Time gap between vehicles can be reduced using communication-based (or cooperative) systems. Reducing the time gap under 1.4 s leads both to user acceptance and safety issues if driver intervention is still expected in emergency situations. These issues can be solved not contemplating driver intervention at all through CACC or platooning. According to [8] CACC set with a time gap of 0.5 s can potentially double the capacity of a highway lane at a high market penetration. In this chapter, it is worth to consider that such a result can be reached only with a 100 % market penetration: even a single vehicle not communicating with the other vehicles and/or with the infrastructure would create a non-negligible safety concerns.

Furthermore there is a legal issue to consider in this regard. Road code indicates the brick-wall-stop as the criterion to calculate the safety distance from the preceding vehicle. Setting an average deceleration of 5 m/s^2 and a reaction time of 1 s this criterion returns a maximum lane capacity of 1,500 v/h at 25 km/h that lowers when increasing the speed: 1,300 v/h at 50 km/h, 1,125 v/h at 70 km/h and so on. Basing on this criterion, a lane capacity of 2,100 v/h is already illegal and, in a certain way, the introduction of partial automation tends to force drivers to go against the law reducing even more the time gap between the vehicles. Platooning will only be possible if amendments to the road code are made as explained in appendix 1 to [9].

2.3 Environment

A recent study [10] comparing an automated highway system (AHS) and ADAS in terms of environmental impact, technical feasibility and economic affordability found that AHS are the most promising technology for increasing capacity and reducing CO_2 emissions.

An in-depth overview of many ICT-based solutions and their contribution to CO_2 reduction is reported in [11]. Among the most promising technologies of road automation platooning is the one guaranteeing the greatest CO_2 reduction, approximately between 5 and 7.5 %. At second place, there is ACC, with an addressed CO_2 reduction slightly above 2.5 %. Benefits of platooning in terms of CO_2 reductions are addressed in many other studies. Among those in [12] a 15 % reduction is reported for three trucks driving at 80 km/h with a gap of 4 m. In [13] a fuel reduction between 7 and 15 % is reported for three cars with a gap of 8 m following two heavy trucks at 85 km/h.

A vehicle consumes less energy in a smooth driving at constant speed rather than in stop and go conditions and it consumes less energy at high speed closely following another vehicle because it has less aerodynamic drag. Therefore from the environmental point of view, the major contributors of automation to fuel consumption is keeping the total driving mileage constant, reducing congestion and smoothing driving conditions and platooning to reduce aerodynamic drag at high speed.

As explained in Sect. 2.2 before full automation (and the necessary legal amendments), there is little contribution to be expected in reducing congestion and allowing platooning.

2.4 Lifestyle and Business Model

Automation, the full automation which allows sending empty vehicles to relocate them to where needed most, and therefore allows implementing shared mobility and transit systems. These are much more flexible and comfortable than conventional ones especially in those areas traditionally badly served by public transport.

The eventual increase of public transport (and shared mobility) segment that might result because of automation implies economic changes too, the greatest being represented by the overall business model of the road transportation system. There will be the real chance to substitute the one person-one vehicle business model with other business models. Such a topic deserves an in-depth argumentation that, however, goes beyond the aims of this section. On this regard, part of the work going on in the CityMobil2 project is focused on assessing the socio-economic impact of automated road transport systems. Findings from this work will help to define the economic scenario of the future and to set the proper path to make it real and convenient.

3 Which Automated Transport in Which Part of the City

A new mobility based on automated road vehicles providing door-to-door seamless mobility (on-demand and/or scheduled) with the aim of replacing private cars and, in some contexts, even traditional public transport is the subject of several subsequent research projects funded by the European Commission.

ARTS, Automated Road Transport Systems, as lately defined by the CityMobil2 project, range from large buses to be used on corridors to small individual vehicle to dual mode city cars and have been tested in several European Research Projects and some of them are now operating in different cities and contexts. Such ARTS can be summarized in the following four following categories.

- Personal Rapid Transit (PRT): automatic individual transport systems that use 4-place vehicles running in dedicated lanes.[1] PRTs work like taxis, carrying passengers from origin to destination without intermediate stops [14–17].

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[1] The traditional PRT concept is to keep the entire network dedicated and segregated to the point that most PRT networks are conceived on elevated monorails; however the same concept might apply using road lanes unnecessarily fully segregated and this concept has been exploited here.

- CyberCars (CC): automated road vehicles ranging from 4 to 20 passengers. Such vehicles work in a network as a collective taxi, in which the passengers can have different origins and destinations. The lane used by the network can be segregated or not [15–19].
- High Tech Buses (HTB): vehicles for mass transport using an infrastructure which can be either exclusive for the buses or shared with other road users. They can use various types of automated systems, either for guidance or for driver assistance or for full automation and platooning [15, 16].
- Dual-Mode Vehicles (DMV): city vehicles with zero or ultra-low emission and driver assistance systems, parking assistance, collision avoidance, also supporting full automated driving in certain circumstances (e.g. platooning for relocation, [16, 17].

According to the service required, the four ARTS perform best in different contexts inside and outside the cities.

An approach to evaluate where the ARTS perform best has been developed in the framework of the EU project CityMobil (2006–2011) [20], where the four ARTS were tested in 13 European cities through large scale demonstrators, showcases and city studies. They were evaluated by collecting indicators of social, environmental, economic, legal and technological impacts of the ARTS [20].

A Passenger Application Matrix (PAM), consisting of a two-dimension symmetrical matrix where the results of the evaluations of the ARTS are grouped according to their origins and destinations (respectively rows and columns of the PAM), was developed to consolidate and cross-compare results of different demonstration, study or simulation.

Ten possible origins and ten possible destinations are in the PAM.

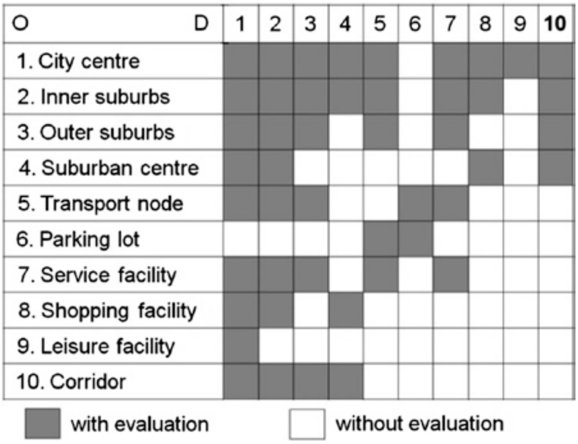
They are:

- City centre,
- Inner suburbs,
- Outer suburbs,
- Suburban centre,
- Major transport nodes (e.g. airport, central station),
- Major parking lots,
- Major educational or service facilities (e.g. university campus, hospital),
- Major shopping facilities,
- Major leisure facilities (e.g. amusement parks),
- Corridor.

The cells of the PAM represent all the possible OD pairs, as reported in Fig. 1, where the final PAM of the CityMobil project is reported, filled with the results of the evaluations made (the grey cells are those with evaluations available, whereas the white cells have no evaluations within CityMobil).

The PAM identifies which automated transport is best suitable to each cell and helps evaluate pros and cons of the implementation of the different technologies in each particular environment.

An example of the evaluations in the cells is reported in Fig. 2, where an extract of the CityMobil PAM, concerning the city centre and inner suburbs rows and columns, is shown.



O D	1	2	3	4	5	6	7	8	9	10
1. City centre	■	■	■	■	■	□	■	■	■	■
2. Inner suburbs	■	■	■	■	■	□	■	■	□	■
3. Outer suburbs	■	■	■	□	■	□	■	□	□	■
4. Suburban centre	■	■	□	□	□	□	□	■	□	■
5. Transport node	■	■	■	□	□	■	■	□	□	□
6. Parking lot	□	□	□	□	■	■	□	□	□	□
7. Service facility	■	■	■	□	■	□	■	□	□	□
8. Shopping facility	■	■	□	■	□	□	□	□	□	□
9. Leisure facility	■	□	□	□	□	□	□	□	□	□
10. Corridor	■	■	■	■	□	□	□	□	□	□

■ with evaluation □ without evaluation

Fig. 1 The passenger application matrix

D O	City centre	Inner suburbs
City centre	CC (Gateshead, Madrid, Trondheim, Wien) PRT (Gateshead, Madrid, Trondheim, Wien, Uppsala) DMV (La Rochelle, Orta San Giulio)	CC (Gateshead, Trondheim) PRT (Gateshead, Trondheim, Uppsala) HTB (Gateshead, Madrid, Trondheim, Wien)
Inner suburbs	CC (Gateshead, Trondheim) PRT (Gateshead, Trondheim, Uppsala) HTB (Gateshead, Madrid, Trondheim, Wien)	CC (Gateshead, Madrid, Trondheim, Wien) PRT (Gateshead, Trondheim, Daventry, Uppsala) HTB (Gateshead, Madrid, Trondheim, Wien)

Fig. 2 An extract of the passenger application matrix

Looking at the city centre to city centre cell, three ARTS were tested in seven European cities: Cybercars in four cities, Personal Rapid Transit in five cities, and Dual-Mode Vehicles in two cities. For each of them, different indicators were measured. The main outcomes on the ARTS after comparing the evaluations, extensively reported in [21, 22], are:

- The dual-mode vehicles are considered by the users as easy to use, useful and safe, in order to substitute the conventional cars.
- People are willing to pay more than conventional public transport to use the innovative service provided through the ARTS and well-disposed to substitute the private car with such new technology.
- PRT resulted to be more convenient than the other ARTSs in terms of performance and emissions reduction, but applicable only in small to medium size cities while conventional mass transits are the best option for the centres of large cities.
- As final result, in the city centre of small/medium cities both Dual-Mode vehicles and PRT can be applied, being well-accepted by the users and providing good improvement to the city mobility.

This is an example on how to use the PAM; the other main results which can be found in [21, 22], are:

- with medium size vehicle as on-demand transport services feeding conventional mass transits in the suburbs of large cities,
- on radial corridors as complementary mass transits with large busses and platoons of them and
- as main public transport for small cities with personal vehicles.

CityMobil2 [23] will contribute to populating the PAM with the results of its 12 ARTSs studies and 5 demonstrators in European cities.

4 How to Integrate Automated Road Transport Systems in Urban Areas

ARTS have the main purpose of providing passenger transportation services in urban areas, but deploying an ARTS in public urban roads must be done, first and foremost, safeguarding both the ARTS' users and the road users in the surrounding environment [24]. Of all road users, special attention must be given to Vulnerable Road Users (VRU). In fact, pedestrians' road fatality in urban areas is above 70 %, both in Europe and in the US [25, 26], with the elderly representing the highest fatality rates [27, 28]. Since elderly-related incidents have greater impact and likelihood of occurrence [29], safety regarding the elderly should define the baseline for the safe integration of ARTS in urban areas. Thus, the focus in the definition of the ARTS' safety requirements in CityMobil2 has been shifted, from a driver-vehicle-centric approach, to a comprehensive, road-safety approach. Other objectives, like the improvement of traffic conditions or users' comfort, were subordinated to safety. Though seemingly conservative, this approach aims might finally help to make road transport as safe as that of rail.

Up to date, the most relevant legal experience of an ARTS using at-grade infrastructure was the CityMobil Rome, Italy. In order to grant the construction and testing clearance[2] to the system, the Ministry of Infrastructure and Transport (MIT) demanded, besides an extensive series of tests of all the safety-related subsystems, that the ARTS' vehicle track be entirely segregated with physical barriers [30]. This approach creates a strong community severance effect in urban areas, CityMobil2's main target. To limit the community severance effect, CityMobil2 defined ARTS safety requirements with a two-fold approach: first, depending on the type of road users potentially present in each class of urban road.[3] Second, in a

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[2] This was among the first clearance valid on public areas in Europe, allowing the system to operate on the final site for test purposes without passengers.

[3] CityMobil2 concentrated on roads classified by TRB Highway capacity manual as (C) arterial road (D) urban street (E) collector street and (F) Walkway.

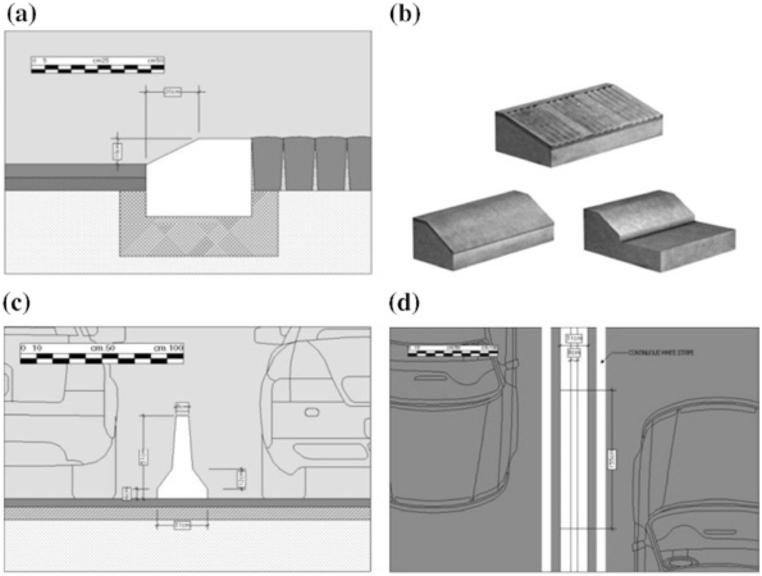

Fig. 3 ARTS infrastructure segregation elements

way that limited the use of physical barriers exclusively when no on-board, off-board or communication-based system could cope with the risks, just like existing, “manual driving” motorways are physically segregated from the surrounding environment.

A series of physical elements that can be used to separate the ARTS infrastructure from the other road users was identified. These elements, providing 13 levels of protection to the ARTS or to the road users, range from horizontal markings on the lowest level (level 1), to carriageway dividers on the strongest level of protection (level 13), plus an additional level on shared roads with no protection (level 0). Figure 3 shows a surmountable curb section view and examples (Fig. 3a, b respectively), corresponding to a level 5 protection, and a “New Jersey” carriageway divider (level 13) section and top view (Fig. 3c, d respectively), corresponding to a protection level 13 [24].

Based on the level of protection they provide and their impact on community severance, the elements were organized in five levels of protection for crossings, and in three levels of segregation for roads, [24]. The following are the three segregation levels defined for roads:

- Segregated: the infrastructure is dedicated solely to the circulation of ARTS vehicles, and it is protected with specific fittings (barriers) that physically prevent other road users from accessing it, even accidentally;
- Dedicated: the infrastructure is dedicated solely to the circulation of ARTS vehicles, and it has all the necessary markings and signals to make the restriction of

use obvious to other road users. The infrastructure may also be equipped with continuous or discontinuous fittings aimed at discouraging, but not physically prevent, other road users from accessing it. It can be accessed by other road users in case of emergency;
- Shared: the ARTS vehicles share the infrastructure space with other road users.

In order to provide recommendations on the segregation level required by ARTS in each road class, the ARTS road segregation matrix displayed in Table 1 was developed. The matrix helps defining the required level of ARTS segregation according to the potential road users present in the environment. Subsequently, a site-specific safety assessment allows selecting from the matrix the infrastructure segregation or crossing protection element (or set of elements), required in each risky location. A similar matrix was also developed for crossings.

As the demonstrations progress, all the involved parties (city and national authorities, transport operators, ARTS manufacturers, research bodies) will gain more experience on the use of the matrix and identify the best practices for the integration of ARTS in urban areas, with the perspective of integrating it into the legal framework.

The time horizon considered for the above delimitation recommendations is that of the demonstrations that will be carried out within the CityMobil2 project (2014–2016). As shown in the matrix in Table 1, no shared use of the infrastructure between the ARTS vehicles and other road users is recommended in the short term, in order to limit the safety risks, and to simplify the authorization process by the national authorities. Shared infrastructure is considered for a longer term horizon, and will be part of the legal framework that will be developed by the project.

These recommendations served as a baseline for the definition of the rest of the CityMobil2 ARTS requirements, and to provide integration examples to the partner cities. Figure 4 shows an example of a Collector street with one lane per direction before (left) and after (right) the integration of an ARTS dedicated lane. The posted speed considered in this example is 50 km/h. Horizontal markings are used to indicate the dedicated status of the lane, while sidewalks are used to separate the lane from the pedestrians and raised lane delimiters are used to separate the ARTS from other motor vehicles.

5 Requirements for ARTS

Section 4 above provides recommendations about the physical integration of Automated Road Transport Systems in urban areas, aiming to guarantee the safety of road users as well as that of the ARTS' users. As formerly mentioned, the use of physical barriers is advised exclusively when no other system, on-board, off-board or communication-based, could cope with the safety risks of a fully automated vehicle. This means that all these systems combined should guarantee a safety level equivalent to that of the physical barriers. The approach taken to reach the

Table 1 ARTS segregation level per type of road and road user

TRB HCM[a]	C				D			E					F	
road class	Arterial road				Urban street			Collector street					Walkway	
Road user	Pedestrians	Cyclists	Motorcyclists	Motor vehicle drivers	Pedestrians	Cyclists	Motorcyclists	Motor vehicle drivers	Pedestrians	Cyclists	Motorcyclists	Motor vehicle drivers	Pedestrians	Cyclists
0 Shared														
1 Dedicated					R	R			R	R	R	R	R	R
2 Segregated	R	R	R	R		R	R	R			R	R		

[a] Transportation Research Board Highway Capacity Manual

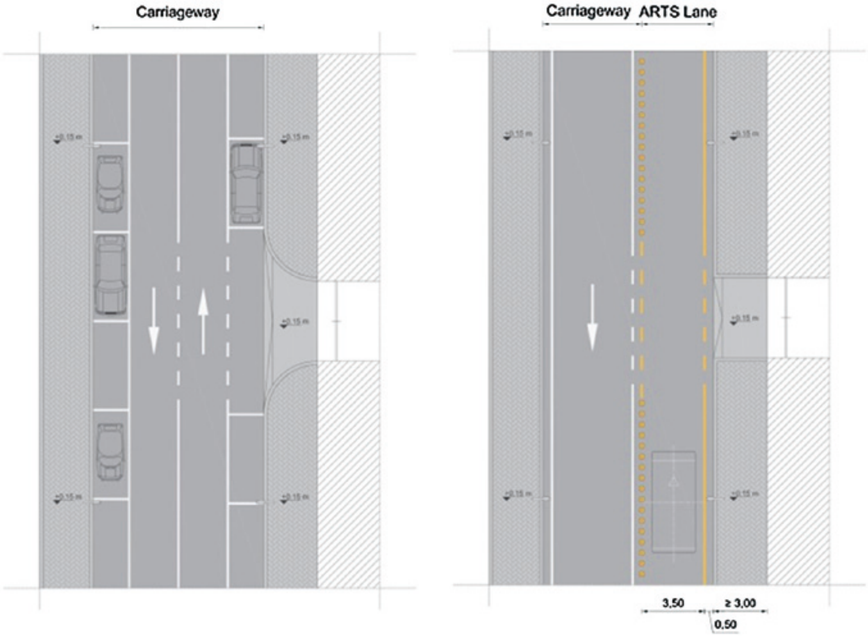

Fig. 4 Integration example of an ARTS dedicated lane in a collector street

mentioned goal was to require that off-board or communication-based sub-systems supplement the weaknesses of the on-board safety systems, which resulted in a set of safety requirements, explicitly independent from all other requirements.

An example of how this approach was applied is based on the limitations of on-board vulnerable road users' detection systems. In the evaluation of a remote (on-board) pedestrian sensor system, [31] determined through the incident analysis of the STRADA accident database[4] that almost half of car-pedestrian accident scenarios occurred in intersections, when a passenger car was going straight in an intersection and the pedestrian was crossing, either after the intersection (31 % of 2,199 accidents) or before the intersection (15.7 % of 2,199 accidents). This analysis determined that a remote (on-board) pedestrian sensor system should have an aperture angle of at least 30° in order to limit the occurrence of the identified scenarios, but if the pedestrian was obstructed to the sensor, this one would "fail to detect the pedestrian in time". When defining the requirements of a system to reduce car-to-vulnerable road users' crashes in urban intersections, [32] identified through the study of microscopic data, that in 48 out of 60 critical events studied, the contributing factor was *observation missed*. The factors contributing to *observation missed* were "reduced visibility" (29 of 48 drivers) due to "*Temporary*

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[4] Swedish Traffic Accident Data Acquisition database.

obstruction to view (8 drivers), *Permanent obstruction to view*[5] (3 drivers), and *Permanent sight obstruction* (1 driver)". Both [33] and [32] conclude that, despite the usefulness of vehicle-mounted VRU detection sensors, their limited visibility from the vehicle should be supplemented with infrastructure based sensors capable of sending to approaching vehicles data about dynamic objects detected in real-time.

This specifically led to three ARTS requirements in the CityMobil2 project. First, to limit the vehicle's speed in areas in which risk is high, the system *shall* have a full a priori knowledge of the physical environment in which the vehicles operate, including not only the road, but also the physical elements that surround it, such as sidewalks, urban furniture, and other elements that might occlude potential obstacles. This information helps in defining the speed profile of the automated vehicles, and can be stored in the vehicle, or sent by the infrastructure using V2I communication. Second, wherever a speed limitation does not guarantee the road users safety by itself, additionally, infrastructure-based obstacle detection sensors *shall* be installed in order to increase the vehicle's field of view. This could be the case in intersections in which other motor vehicles might approach at high speeds. Finally, it was required that the on-board obstacle detection sensors have a horizontal field of view of at least 180° from the front of the vehicle: Lateral obstacle detection was *recommended*,[6] to limit the risks of the ARTS' passengers at the stations.

Previous ARTS experiences have identified the role that other sub-systems play in the overall safety of an Automated Road Transport System. The parties involved in the Rome demonstrator in the CityMobil project defined that the only adapted legal framework under which the system could be certified was the EN 50126 [30] railway certification standard. This framework required that not only the vehicles, but the (fleet) control system, the user information system and the civil works (in particular the station doors) were certified as a whole. Heathrow airport's PRT system,[7] equally consisting on several on-board, infrastructure and communication-based subsystems, was also certified by HM Rail Inspectorate as a railway system [34]. These projects highlighted the need of a supervisory system capable of overseeing the complete fleet and intervene in case of need.

On this basis, the CityMobil2 project defined the ARTS subsystem architecture shown in Fig. 5.

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[5] Such as buildings, vegetation or containers.

[6] This actually means that it was agreed with the ARTS manufacturers not to make this requirement mandatory for the demonstration fleets of CityMobil2 and make it so in the draft legal framework the project is preparing for the EC future approval.

[7] This system runs on a segregated guide-way and therefore is only partially a reference for CityMobil2's on-the-road applications.

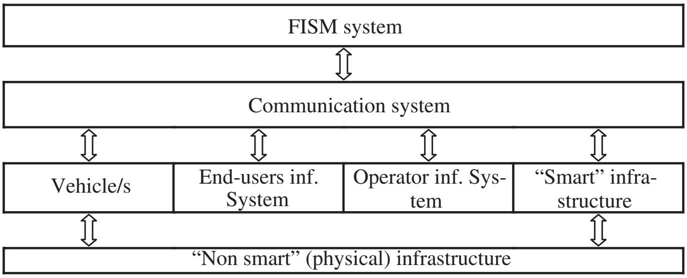

Fig. 5 CityMobil2 ARTS subsystem architecture

The ARTS components description and their role are the following:

- Automated vehicles, whose aim is to transport the passengers in a safe, secure and comfortable way from an origin station to a destination station;
- Fleet and Infrastructure Supervision and Management system (FISM), which automatically monitors all the other subsystems, manages the vehicle traffic and activates emergency procedures in case of malfunction;
- Infrastructure, whose role is to compensate the lack of performance on the on-board safety systems;
- End user information system, which allows end users to interact with the ARTS during normal and emergency operation;
- Operator Information system, which allows a (human) fleet operator to remotely supervise the system operation and to intervene in case of need;
- Communication system, which must allow all the components communicate at all times with, at least, the FISM.

Although standards on vehicle-to-vehicle and vehicle-to-infrastructure are currently under development, and ARTS should definitively comply to these points, CityMobil2 aims at demonstrating off-the-shelf, commercial systems, whose V2X systems are, for the time being, proprietary systems of the participating ARTS manufacturers. The system requirements developed by the project were made with this mid-term approach, but both selected manufacturers were required to cooperate to achieve interoperability between their systems.

6 Conclusions

After examining the quantification of potential benefits of partial automation available in literature, the paper highlighted how most of the promised benefits will be delivered by automation when it will be "full" and on urban roads. The new automated road transport systems, that can become extensively applicable, will make seamless mobility from door to door possible without the need of owning a vehicle and deeply impacting the economy and the society. The paper then reported the main findings of the CityMobil project, which highlighted how Automated Road Transport Systems is suitable for different trips which might range from individual to ridesharing to collective mobility depending on the city area. It finally showed how the infrastructure first and the vehicles and communication system then should be made to make ARTS fully safe, even in non-protected environments.

The main conclusions of this chapter are:

- a legal and public intervention is needed to understand that inserting automated transport on roads is much more than automating a vehicle, but requires revamping the law, the roads, and even the communication infrastructure; much less road and much more rail finally bring road safety to acceptable levels;
- automated vehicles would not need to be autonomous, they would need to be constantly connected and a supervising system (much like the air traffic control) should be established;
- further research and standardisation is needed in the communication field to allow large scale applications of these new transport systems.

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