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Executive summary

The current legislation in Europe allows for the certification of ARTS (Automated Road Transport Systems) only through very restrictive conditions such as those of automated trains with severe constraints on the infrastructure such as protected guideway and automatic doors. At the moment, automated diver-less vehicles cannot be certified in Europe because of the Vienna convention that prohibits a vehicle to be driven without a driver inside the vehicle and also that prohibits the operation of the steering by a computer above 10km/h.

This report looks at the current legislation concerning automated vehicles in various countries, at the potential changes in the legislation and at the steps that can be undertaken to allow the demonstrations of ARTS in CityMobil2 selected cities.

The report also considers the few systems currently in operation and how they were certified but also at various demonstrations of automated vehicles for urban transportation and how these demonstrations were performed without certification but with ad-hoc validation procedures.

For instance, local authorities can grant special permissions for operation of ARTS, but they must assume the legal criminal responsibility of any accident. It is therefore the responsibility of CityMobil2 Project and the ARTS suppliers to reduce this risk to the lowest possible level and to convince them of the safety of the system. This can be done through the methodologies already defined in previous projects (in particular the risk reduction methods) and the use of current and future standards concerning automated vehicles and systems.
1. Introduction

Fully automated vehicles have been a research topic for more than 30 years. In 1994, the Prometheus European project ended 8 years of research with demonstration of fully autonomous driving on the A1 highway near Paris. In 1997, the AHS Project in the USA ended with a demonstration of 8 fully automated vehicles driving in a platoon on a dedicated part of highway I-15 in San Diego. In 2005 the DARPA Challenge ended with 4 vehicles running fully autonomously over an off-road course of more than 200km and in 2007, the DARPA Urban Challenge presented several autonomous vehicles operating simultaneously with other manually driven vehicles in an urban environment. More recently and based essentially on the expertise of the best DARPA teams, Google demonstrated several autonomous vehicles that were driven several thousands of miles in California and Nevada, forcing these states (and Florida) to pass legislation concerning the operation of autonomous vehicles on public roads. In 2010, a team from Parma University demonstrated 2 automated vehicles driving in tandem from Italy to China. The OEM and their suppliers such as Valeo and Continental are also actively working, in particular in Europe, on similar autonomous vehicles. These concepts of "autonomous" (meaning without communication with other vehicles or infrastructure) vehicles might soon appear on the market if the legislative barriers concerning the safety can be lifted. However, this approach does not seem to bring much improvement in terms of road capacity as long as the automatic vehicles are « autonomous » and share the road space with non-cooperative vehicles. Furthermore, all these demonstrations involved a driver behind the steering wheel or close-by to take-over the control or abort the automatic operation of the vehicle. Besides, the legality of the operation of such vehicles is still far from obvious as soon as we do not request the driver to be in constant control. The following table was developed in Germany to express the various forms of driving assistance to full automation. As it can be seen from it, the "fully automated" vehicle is still far from being on the road.
Another approach was also developed over the last years with the “connected vehicle” approach. Using various forms of communication vehicles can exchange data to improve safety and in particular, to perform coordinated manoeuvres such as platooning (see SARTRE project) where following vehicles can be fully automated behind a manually driven vehicle (a truck in SARTRE).

However, an alternative approach to fully automatic vehicles has been developed over the years in Europe: the cybercar approach. This approach differs from the previous one as it focuses on urban public vehicles with no driver at all (“fully automated”) but in restricted low driving speed road environments. The cybercars are not “autonomous” but rather cooperative vehicles since their operation is performed based on co-operation with smart road infrastructure and with other road vehicles. The CityMobil2 consortium believes that the cooperation is needed to provide a large improvement in road transport by increasing the capacity of a road network while ensuring high safety and minimizing infrastructure needs (roads and parking places) and energy. Several European projects have allowed the development of the technologies, the emergence of several industrial players and now real life experiments are conducted in several European cities. Furthermore, this approach can provide a realistic deployment of automatic vehicles through the use of dual-mode vehicles that would be fully automated in specific zones dedicated to these vehicles and autonomous under human supervision in mixed traffic.

After looking at various projects involving fully automated vehicles, we will look at the current legislation and we will also look in detail at past projects involving such vehicles. In particular, we will consider several experiments and demonstrations of fully operational cybercars systems, the procedure to allow their implementation and the lessons learned.
2. Relevant previous projects on ARTS

This section presents various projects where ARTS (Automated Road Transport Systems) have been studied and where demonstrations took place. In a latter section, we will examine in details these demonstrations and how the local or national authorities allowed them.

2.1 Cybercars

The CyberCars project was funded by the DG13 (Information Society) of the European Commission between July 2001 and July 2004. Its purpose was to develop the technologies needed for fully automatic vehicles operating at low speed in an urban environment for the implementation of a public transportation system (called CTS for Cybernetic Transportation System) working “on-demand”.

This project came after a number of small companies and public research institutes experimented with such concepts in the 1990’s. In particular, the project was issued from previous work on automated vehicles concepts developed by:

- Frog Navigation Systems in the Netherlands (ParkShuttles),
- Serpentine in Switzerland (the “capsules”),
- Robosoft and Yamaha in cooperation with INRIA (the CyCab and the CyBus),
- University of Bristol in the UK (the ULTra),
- Palle Jensen in Denmark (the RUF).

The CyberCars project developed and demonstrated numerous technologies including vision systems, navigation systems, platooning, obstacle avoidance, fleet management and automatic recharging.

The partners of the project were:

- INRIA (coordinator) (FR)
- Robosoft (FR)
- Frog Navigation Systems (now 2Getthere) (NL)
- University of Bristol (UK)
- Serpentine (CH)
- Auto&Energies (CH)
- Palle Jensen (DK)
- University of Southampton (UK)
- Centro Recerche Fiat
- TNO (NL)
- Yamaha (NL)
- La Sapienza (Univ. Rome, IT)
The demonstrations took place during the sister project CyberMove (see below) but many technical demonstrations also took place during the project without any difficulties but always under human supervision. Most of the vehicles also were insured.

TNO started its work on safety evaluation and certification of automated vehicles during the CyberCars project and issued recommendations. Two deliverables were issued on this topic (publically available on http://www.cybercars.org/indexold.html):

Part 1 - Report on existing guidelines
Part 2 - Recommendations for certification procedures

2.2 CyberMove

The CybeMove project was funded by the DG12 (Research) of the European Commission between December 2001 and December 2004. It is a sister project from CyberCars with almost the same partners. Its purpose was to look into the implementation of a public
transportation system based on cybcars (called CTS for Cybernetic Transportation System) and working “on-demand”.

The project looked in particular at the benefits cities could gain from such implementation and initiated one large scale demonstration that lasted 6 months during the Floriades flower show in 2002 (see further down for details), one large demonstration in Coimbra in 2003 and one final event in Antibes in 2004 with a demonstration of a ParkShuttle in the streets.

The partners of the project were:
- INRIA (coordinator) (FR)
- Robosoft (FR)
- Frog Navigation Systems (now 2Getthere) (NL)
- University of Bristol (UK)
- Serpentine (CH)
- GEA (CH)
- Palle Jensen (DK)
- University of Southampton (UK)
- Centro Recerche Fiat
- TNO (NL)
- Yamaha (NL)
- La Sapienza (Univ. Rome, IT))
- Technion (Israel)
- University of Coimbra (PT)

The large-scale demonstration at the Floriades (see details below) was a great success with 25 vehicles and about 400,000 (paying) persons transported without any incident. However, the operation of the system was made simpler by the fact that it was a private site (no need for meeting the traffic rules) and that the track was protected from intrusions.

The demonstration in Antibes was more difficult to authorize since it was on public streets. The mayor with just 2 restrictions finally gave the authorization: the road was closed to normal traffic (but not to pedestrians and cyclists) and an operator with emergency stop was always present on-board.

TNO developed during this project a risk reduction methodology that is available on the project web site (http://www.cybermove.org/docs/CM-D32-final-deliverable.pdf). This risk reduction methodology was applied for all the demonstrations.
2.3 Cybercars2

The CyberCars2 project was funded by the DG13 (Information Society) of the European Commission between 2005 and 2009 as a successor of the CyberCars project. Its purpose was to develop further the technologies needed for fully automatic vehicles operating at low speed in an urban environment and, in particular, to look at the cooperation between vehicles using communications technologies in order to improve efficiency while maintaining high safety.

The project also developed the concept of “dual-mode” vehicle which means a city vehicle able and certified to drive in an urban environment but also capable of fully automatic driving in dedicated places or in platoon mode.

The partners of the project were similar to the other projects:
- INRIA (coordinator) (FR)
- Robosoft (FR)
- Frog Navigation Systems (now 2Getthere) (NL)
- University of Southampton (UK)
- Centro Recerche Fiat
- TNO (NL)
A large final demonstration took place during one show case of the project CityMobil in the city of La Rochelle in 2008. The city mayor had allowed the use of a protected area on one of the largest city square to implement a figure eight track to demonstrate several automated vehicles working and intersecting simultaneously on the track. Some visitors were allowed in the vehicles but always with a safety operator on the drivers’ seat (although the vehicle was fully automated). The vehicles were insured by their respective owners and ran at low speed (less than 10 km/h).

The deliverables are available on the project website (http://cybercars2.paris-rocquencourt.inria.fr/publications/deliverables/). TNO performed the evaluation of the safety of the cybercars and dual-mode vehicles.
2.4 CyberC3

The CyberC3 project was funded by the DG12 (Research) of the European Commission between 2005 and 2009 as a way to introduce the cybercars technology in China and to establish a strong cooperation between the three partners:

- Jiao Tong University of Shanghai (coordinator)
- INRIA
- Coimbra University

A large final demonstration took place in an amusement park outside of Shanghai in 2006 with 3 cybercars and numerous visitors. The operator of the park who also took the insurance delivered a special permission. No incident was reported.

![CyberC3 demonstration in Shanghai (2005)](image)

2.5 CityMobil

CityMobil was a large project (IP or Integrated Project) of the Sixth Framework Programme co-funded by the European Commission which investigated the potential in urban environments of innovative transport systems based on automation. The project started in
2005 and terminated in 2011. One of the main activities of CityMobil was the implementation of demonstrations of innovative transport systems. The demonstrations served as a laboratory for developing and evaluating solutions and as a source for identifying problems that can be addressed in the project. The demonstrations activities covered within the project were:

- three so-called large-scale city demonstrations and
- a number of so-called small demonstrations and showcases.

In three sites, London Heathrow (United Kingdom), Rome (Italy) and Castellón (Spain), the implementation of the large scale demonstrations was planned. These sites were selected because they had already local consortia formed consisting of public and private organisations. The political support of the relevant authorities and the commitment to invest financially in the demonstrations are seen as key conditions for the successful implementation of advanced and innovative urban transport solutions. These demonstrations have been therefore included into the CityMobil project in order to show the feasibility of the corresponding approaches and to demonstrate and evaluate the advantages of these solutions.

The solutions proposed in the three large-scale demonstrations are as follows.

- Heathrow has implemented a Personal Rapid Transit (PRT) system linking the parking area with the new Terminal 5 of the Heathrow Airport. The PRT is based on small, light and energy efficient vehicles on a dedicated guideway network offering a personal, automated taxi service with point-to-point non-stop travel and no waiting. The vehicles used in the Heathrow demonstration have 4 seats and a maximum speed of 40 km/h (more detailed reported in 3.2.1).
- In the Rome demonstration a Cybernetic Transport System (CTS) in the Rome new exhibition aimed to link the parking area with the two main entrances of the exhibition. The system features fully automated vehicles (cybercars) which should provide an on-demand service on a segregated track. The cybercars were supposed to be provided with obstacle detection systems (more detailed reported in paragraph 3.3.5).
- The demonstration in Castellón was based on a hybrid system of guided bus/tramway. An optical system guides the buses. This eliminates any lateral movement of the vehicle within a traffic lane thus reducing the width of segregated lanes from 3.75-4 m to 3 m. At intersections, the bus/tramway has a higher priority than private traffic.

Additionally, the so-called showcases and small demonstrations were used to raise the awareness of European cities about new forms of urban transportation based on cybercars and advanced city vehicles (see more details about La Rochelle small demo in paragraph 3.3.1). The goal of these activities was to study a number of potential sites in various cities and to bring a number of small demonstrations to the most interested ones.

2.6 CityNetMobil

The CityNetMobil was a three-year EC FP7 support action with the specific objective of helping cities answer the question of whether small, automated, low-polluting vehicles for driverless transport could be integrated with conventional transport networks in the urban structure, and help solving mobility problems in any city. It also aimed at answering how would users react to such systems. The project began on September 1st 2008 and ran until September 1st 2011.
The project invited cities to form a reference group that shared an interest in advanced transport systems (in part coming from the CityMobil project). Five of these cities were selected to organise events, addressed mainly to the general public, featuring a showcase of moving automated vehicles, a conference for the local authorities and the reference group cities, audiovisuals, and a poster display. The events were six to eight months apart and lasted between two days and two weeks each, together with other local scientific or cultural events. The partners of the project were the following:

- University of Rome “La Sapienza”
- GEA
- INRIA
- POLIS

The showcases were carried out in the cities of Clermont-Ferrand (France), Formello (Italy), Ixelles (Belgium), Antibes (France) and Reggio Calabria (Italy). In order to reach the maximum number of visitors, all the demonstrations were carried out in pedestrian areas. INRIA staff plus one of the other project partners were involved in the site preparation and on a simple risk assessment, for which several safety measures (speed limitation, protection of the track, adjustment of automation technologies, signage of the vehicles) were implemented, either by the project or the local authority. The automated vehicle demonstrations were carried out at very low speeds and under a strict control of INRIA staff, with support of staff from the local authorities. Part of the contribution that the cities provided was the request of the legal authorization for the vehicles to circulate, for which INRIA usually provided a technical sheet and an insurance certificate of its vehicles. No incidents occurred.

![Figure 5 Pictures of the showcases of Ixelles (L) and Reggio Calabria (R)](image-url)
Overview of the legal situation and issues of fully automated vehicles

Introduction

From early on, authorities have always regarded (rightly so!) motorized vehicles as dangerous and set regulations to minimize the risks to their passengers and to other road users. In England, one of the first rules was to have a pedestrian waving a flag in front of the vehicles to warn of its approach!

Since motor vehicles were meant to cross borders and to be sold internationally, treaties were discussed from the beginning of the 20th century to set general rules concerning the specifications of the vehicles and the use of public roads to be shared by different users safely. The very first treaty called the Convention with Respect to the International Circulation of Motor Vehicles was signed at Paris in 1909. It formed the basis for later treaties such as the 1926 Motor Traffic Convention, and the famous Geneva Convention on Road Traffic of 1949, signed by 95 states including the USA (who by then had the largest fleet of motor vehicles). The 1949 treaty was drafted under the auspices of the Economic and Social Council of the United Nations to “terminate and replace, in relations between the Contracting States, the International Convention relative to Motor Traffic and the International Convention relative to Road Traffic signed at Paris on 24 April 1926, and the Convention of Inter-American Automotive Traffic opened for signature at Washington on 15 December 1943”.

The Geneva Convention has been essential for future legislation adopted by various states since it forms a universally accepted basis. This convention states in particular the following:

1. Every vehicle or combination of vehicles proceeding as a unit shall have a driver.

2. Draught, pack or saddle animals shall have a driver, and cattle shall be accompanied, except in special areas which shall be marked at the points of entry.

3. Convoys of vehicles and animals shall have the number of drivers prescribed by domestic regulations.

4. Convoys shall, if necessary, be divided into sections of moderate length, and be sufficiently spaced out for the convenience of traffic. This provision does not apply to regions where migration of nomads occurs.

5. Drivers shall at all times be able to control their vehicles or guide their animals. When approaching other road users, they shall take such precautions as may be required for the safety of the latter.

However, there is no definition of what is a driver or if the driver must be in the vehicle! According to this text, some lawyers consider that automated vehicles could be allowed as long as someone, even at a remote location could take over the control at any time (see Brian Walker Smith).
The following Convention, elaborated in Vienna in 1968 and signed by 48 states (out of the 95 who signed the Geneva Convention and not including the USA), was a bit more precise concerning the need for a driver. It stated in its article 8 that:

1. Every moving vehicle or combination of vehicles shall have a driver.

2. It is recommended that domestic legislation should provide that pack, draught or saddle animals, and, except in such special areas as may be marked at the entry, cattle, singly or in herds, or flocks, shall have a driver.

3. Every driver shall possess the necessary physical and mental ability and be in a fit physical and mental condition to drive.

4. Every driver of a power-driven vehicle shall possess the knowledge and skill necessary for driving the vehicle; however, this requirement shall not be a bar to driving practice by learner-drivers in conformity with domestic legislation.

5. Every driver shall at all times be able to control his vehicle or to guide his animals.

A sixth item was added to this list in 2006 (the Convention has been modified several times and can be again modified!):

6. A driver of a vehicle shall at all times minimize any activity other than driving. Domestic legislation should lay down rules on the use of phones by drivers of vehicles. In any case, legislation shall prohibit the use by a driver of a motor vehicle or moped of a hand-held phone while the vehicle is in motion.

In addition, article 13 provides in part that “every driver of a vehicle shall in all circumstances have his vehicle under control so as to be able to exercise due and proper care and to be at all times in a position to perform all manoeuvres required of him.”

Article 1 defines driver as “any person who drives a motor vehicle or other vehicle (including a cycle), or who guides cattle, singly or in herds, or flocks, or draught, pack or saddle animals on a road.” Which is not extremely clear and could apply to human supervision of an automated vehicle or to remote drivers. Even the term “person” could mean a non-physical person: a corporate person could be a driver! Therefore, the Vienna Convention might be amended again to provide clarity regarding driver assistance systems and fully automated vehicles.

In any case, these conventions are merely guidelines that have to be translated into actual traffic laws by the different states. And this is where large differences can occur as we will see below when examining specific laws according to countries.

Furthermore, each state has its own regulation concerning specific vehicles such as taxis, buses, low speed vehicles (or neighbourhood vehicles) and even electric vehicles that share public spaces.

However, some regulations are now accepted at the international level and translated in the state legislation of each country. These international regulations are set by the UNECE World Forum for Harmonization of Vehicle Regulations (WP.29) which is a unique worldwide regulatory forum within the institutional framework of the UNECE Inland Transport Committee.
UN Regulations contain provisions (for vehicles, their systems, parts and equipment) related to safety and environmental aspects. They include performance-oriented test requirements, as well as administrative procedures. Of particular importance to automated vehicles, the regulations contain specifications for “drive-by-wire” systems. These systems are now allowed for acceleration, braking and steering but with important limitations concerning steering described in this paragraph:

2.3.4.1: Automatically commanded steering function means the function within a complex electronic control system where actuation of the steering system can result from automatic evaluation of signals initiated on-board the vehicle, possibly in conjunction with passive infrastructure features, to generate continuous control action in order to assist the driver in following a particular path, in low speed manoeuvring or parking operations.”

However the use of this function is limited to low speeds:

“Automatically commanded steering […] shall be automatically disabled if the vehicle speed exceeds the set limit of 10 km/h by more than 20 % or the signals to be evaluated are no longer being received”.

But discussions are now going on for extending the set limit to allow for more advanced driver assistance.

Different regulations also apply if the automated vehicles operate outside the boundaries of public space. In these cases, the traffic laws do not apply and we have to look for specific regulation concerning guided vehicles such as trains and trams (we can argue that an automated vehicle is electronically guided), or automated people movers (usually mechanically guided), or rides in amusement parks, or even ski lifts (in France the same organization certifies trams and ski lifts as “guided passenger vehicles”).

Often, the regulations make reference to standards that are documents in which requirements for products and processes are given, for instance with maintaining a certain quality or safety level as the objective. Standards are being published by organisations that have a certain interest in maintaining quality of safety standards. These organisations can be authorities, societies of producers or groups of experts in the same discipline.

Here are a few of these standards that can be considered for cybercars (for details, see deliverable D6.1 of the CyberCars Project):

IEC 61508. Functional safety of electrical/electronic/programmable electronic safety related systems. IEC 61508 is a generic standard, aiming at the whole width of application areas. Specific sector-oriented standards can be derived from this standard. The standard particularly addresses systems of which failure can have consequences for persons or the environment; it is less suited for establishing economic damage. IEC 61508 is a European standard and it is mainly used in Europe.

MIL-STD-882C. Safety Systems Program Requirements. Originally an American military standard that also found wide acceptance in the civil world. Comparable to IEC 61508. Both standards are often referenced in the literature.

EN 50126. Railway Applications: The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS). A European standard, espe-
cially developed for the rail world. Defines safety integrity levels just like IEC 61508 and MIL-STD-882C

APM standards. In the US the Automated People Mover Standards (ASCE 21-96; ASCE 21-98 and ASCE 21-00) exist. These standards establish the minimum set of requirements necessary to achieve an acceptable level of safety and performance for an Automated People Mover (APM) system.

CEN EN 1525. This European standard contains safety guidelines for industrial driverless trucks and their systems.

ISO 26262. It is a Functional Safety standard, titled "Road vehicles -- Functional safety". Functional safety features form an integral part of each product development phase, ranging from the specification, to design, implementation, integration, verification, validation, and production release. The standard ISO 26262 is an adaptation of the Functional Safety standard IEC 61508 for Automotive Electric/Electronic Systems. ISO 26262 defines functional safety for automotive equipment applicable throughout the lifecycle of all automotive electronic and electrical safety-related systems.

ISO/DIS2 13482. Robots and robotic devices — Safety requirements for non-industrial robots — Non-medical personal care robots. This is only a draft at this time (March 2013). However, it defines specifically people mover robots (small for only one person or large for 2 or more) and their safety performance levels.

3.1 Overview of emerging legal framework

3.1.1 US – Nevada, Florida, California, etc.

In many states, legal experts consider that it is not illegal to operate a fully automatic vehicle. However, the publicity around the “Google Cars” forced the legislation to consider a more proactive stance in order, first to allow experiments, and in a second stage, to prepare the legislation for the dissemination of these vehicles and their technologies.

In 2011, Nevada became the first state to enact legislation directed at automated vehicles. The primary legislation, passed as Assembly Bill (AB) 511, defines “autonomous vehicle” and directs the state’s Department of Motor Vehicles (DMV) to “adopt regulations authorizing the operation of autonomous vehicles on highways within the State of Nevada.” These regulations are to include, inter alia, “minimum safety standards” and a special “driver’s license endorsement” that “must, in its restrictions or lack thereof, recognize the fact that a person is not required to actively drive an autonomous vehicle.” The DMV’s initial regulation took effect in March 2012. The autonomous vehicle, per Nevada’s definition, does not require human intervention to operate the vehicle.

The regulation also defines the “operator” and “driver” of an autonomous vehicle as “the person [who] causes the autonomous vehicle to engage, regardless of whether the person is physically present in the vehicle while it is engaged.” In understanding the remaining portions of the regulation, it is important to distinguish between (1) the testing of autonomous vehicles for research and development and (2) the sale and consumer operation of these vehicles by state residents. Current regulation
deal only with the first case, since commercially available automated vehicles are not thought to be available for some time.

A person that wishes to test a vehicle must obtain a one-year license by completing the appropriate DMV form (currently available online), affirming that the vehicle meets the relevant safety requirements above, showing insurance coverage, proving that its vehicles “have been driven by the applicant for a combined minimum of not less than 10,000 miles in autonomous mode” and “in various conditions for a number of miles that demonstrates the safety of the … vehicles in those conditions,” demonstrating the technology for approval, proposing geographic locations and establishing the capability of its vehicles in those conditions, providing a surety bond or cash, providing other information required by the DMV, and applying for special license plates. The DMV may deny, suspend, revoke, or not renew a testing license.

With its enactment of Committee Substitute House Bill (CS/HB) 1207 in 2012, Florida became the second US state to expressly regulate autonomous driving. The legislation:
• defines “autonomous vehicle” and “autonomous technology”;
• declares the legislature’s intent to promote autonomous technology;
• “finds that the state does not prohibit or specifically regulate the testing or operation of autonomous technology in motor vehicles on public roads”;
• states that a “person who possesses a valid driver license may operate an autonomous vehicle in autonomous mode”;
• deems the person who “causes the vehicle’s autonomous technology to engage” to be the operator of that vehicle;
• specifies certain requirements for autonomous vehicles registered in the state;
• specifies certain requirements for testing an autonomous vehicle in the state;
• recognizes limitations on the liability of “the original manufacturer” of a vehicle for “alleged defects” related to the conversion of that vehicle “by a third party into an autonomous vehicle”; and
• directs the preparation by February 12, 2014 of a report “recommending [any] additional legislative or regulatory action.”

Similarly, with its enactment of Senate Bill (SB) 1298 in 2012, California became the third US state to expressly regulate autonomous driving. The legislation:
• declares the legislature’s intent to both promote and ensure the safety of autonomous vehicles;
• finds that the state “presently does not prohibit or specifically regulate the operation of autonomous vehicles”;
• directs the state Department of Motor Vehicles to adopt rules by the beginning of 2015;
• maintains the current legal status until these rules are adopted;
• defines “autonomous vehicle” and “autonomous technology”;
• specifies certain requirements for autonomous vehicles registered in the state;
• specifies certain requirements for testing an autonomous vehicle in the state;
• recognizes limitations on the liability of “the original manufacturer” of a vehicle for “alleged defects” related to the conversion of that vehicle “by a third party into an autonomous vehicle”; and
• directs the preparation by February 12, 2014 of a report “recommending [any] additional legislative or regulatory action.”

It is believed by legal experts that the legislation contemplated now in the USA fits with the Geneva Convention. The Legislature hereby finds that automated operation of vehicles under the conditions prescribed herein is consistent with article 8 of the Convention on Road Traffic because (1) such operation has the potential to significantly improve highway
safety, one of the objects of the Convention; (2) each State shall make such operation reasonably knowable to the foreign visitors contemplated by the Convention; (3) the Convention implicitly permits indirect control over vehicles and animals; (4) there shall remain a licensed driver of each vehicle who shall be able to specify or accept the parameters of operation; and (5) these parameters shall be consistent with the traffic laws of this State.

It has to be mentioned also that the Society of Automotive Engineers (SAE) has issued in 2012 a draft for a set of safety guidelines for the experimentation of driverless road vehicles (SAE J3018 Safety guidelines for the on-road testing of prototype models of fully automated vehicles).

In June 2013, the National Highway Traffic Safety Administration issued a preliminary policy statement concerning vehicle automation, including its plans for research on related safety issues and recommendations for states related to the testing, licensing, and regulation of “autonomous” or “self-driving” vehicles. According to this statement, the NHTSA recommends the following:

- Ensure that the driver understands how to operate a self-driving vehicle safely.
- Ensure that on-road testing of self-driving vehicles minimizes risks to other road users.
- Limit testing operations to roadway, traffic and environmental conditions suitable for the capabilities of the tested self-driving vehicles.
- Establish reporting requirements to monitor the performance of self-driving technology during testing.
- Ensure that the process for transitioning from self-driving mode to driver control is safe, simple, and timely.
- Self-driving test vehicles should have the capability of detecting, recording, and informing the driver that the system of automated technologies has malfunctioned.
- Ensure that installation and operation of any self-driving vehicle technologies does not disable any federally required safety features or systems.
- Ensure that self-driving test vehicles record information about the status of the automated control technologies in the event of a crash or loss of vehicle control.

In short, the NHTSA does not yet recommend the deployment of automated vehicles for the general public. Immediately afterwards, Google has opposed this statement and said autonomous vehicles could be available in 3 to 5 years…

### 3.1.2 Europe

Road vehicles of any kind have to be approved for traffic in Europe. This process usually incorporates the assignment of a registration number and requires the vehicle to conform to specific requirements, e.g. for vehicle safety or environmental aspects. The mandate to approve vehicles for traffic belongs to the government of each country, with most countries however accepting those requirements defined by the United Nations Economic Commission for Europe’s World Forum for the Harmonization of Vehicle Regulations (UN ECE WP.29). There are two different types of vehicle regulations: The 1958
agreement system which requires vehicles to be certified by an independent technical service (Europe, Japan, rest of the world) and the 1998 agreement which requires the vehicle manufacturers to certify their vehicles themselves (USA, China, most of the 1958 states).

The 1958 agreement with its' ECE regulations covers most of the world with the exception of the United States and China. It therefore is considered as the most important set of vehicle regulations. ECE regulations provide requirements for functional systems of a vehicle or a vehicle itself.

Of particular importance for automated functions are the regulations concerning acceleration, braking and steering. All of these functions now often involve sensors and microcontrollers. All these complex electronic systems need to be developed according to functional safety requirements, e.g. as laid down in regulation 79 or in the upcoming ISO 26262 normative standard for functional safety. The latter is also relevant with regard to product liability.

If, for acceleration and braking, these electronic systems, which can take over the control of the vehicle, are now well accepted, this is still not the case for steering.

Although regulation ECE R79 applicable to vehicles of category M, N and O does allow the use of steer-by-wire", it does not permit the approval of autonomous steering systems, defined as "a system that incorporates a function within a complex electronic control system that causes the vehicle to follow a defined path or to alter its path in response to signals initiated and transmitted from off-board the vehicle. The driver will not necessarily be in primary control of the vehicle".

Moreover, according to 5.1.6. ECE-R 79 "advanced driver assistance steering systems shall only be approved in accordance with this Regulation where the function does not cause any deterioration in the performance of the basic steering system. In addition they shall be designed such that the driver may, at any time and by deliberate action, override the function".

However, automatic control of the steering is now allowed for low speed operation: automatically commanded steering function means the function within a complex electronic control system where actuation of the steering system can result from automatic evaluation of signals initiated on-board the vehicle, possibly in conjunction with passive infrastructure features, to generate continuous control action in order to assist the driver in following a particular path, in low speed manoeuvring or parking operations." But: "Automatically commanded steering [...] shall be automatically disabled if the vehicle speed exceeds the set limit of 10 km/h by more than 20 % or the signals to be evaluated are no longer being received".

Furthermore, all complex electronic systems need to be developed according to functional safety requirements, e.g. as laid down in regulation 79 or in the upcoming ISO 26262 normative standard for functional safety. The latter is also relevant with regard to product liability.

All of this means clearly that, in Europe, contrary to the USA, road vehicles cannot operate yet in fully automated modes as a standard certified product. Therefore, we have to use other certification procedures addressing for example guided systems (cybercars can
arguably be seen vehicles guided by electronic means) or use special exemption procedures (e.g. local permissions) together with self certification.

In Europe there are just a few experiences about implemented CTS or PRT opened to publics. The one in Heathrow airport has been carried out following the ROGS (Rail and Other Guided Systems) framework but there are some applications, operating in France that are opened to public and operated with a different legal framework.

Two of these systems are operated in France and are provided by Robosoft, a France firm that provided also the CTS for the Rome Demonstration (see further down).

The two CTS have been implemented in two historical and science’s parks:
- The Simserhof Fort, a fort part of Maginot line during the II world war;
- The Vulcania park, a science park on volcanoes.

Both systems are operated thank to the certification provided by the APAVE, an independent certification body. The certification was provided according to the Machinery Directive 98/37/CE implemented in the Franch law in the article R 233-84 of “Code du Travail”. Both systems are operated on “private ground” but it is important to stress that the Machinery Directive should not apply to transport of people (see Art. 1 of Machinery Directive). In France these two applications are possible because of the way the Machinery Directive has been implemented in the France law (allowing the transportation of people).

It may also be possible to do a self-certification of CTS since the vehicles run at less than 40 km/h.

![Figure 6 The Cybercar of Simserhof fort.](image)

3.2 Overview of adaptations to existing legal framework and lessons learned
3.2.1 PRT – Heathrow airport

Description of the system

The first phase of the ULTra network opened in summer 2011. It consists of 21 vehicles, two stations in the N3 Business Car Park and one station at Terminal 5.

Commissioned by Heathrow Airport operator BAA, the system consists of 21 vehicles, a total of 3.8 kilometers of one-way guideway, and three stations – two in the T5 Business Car Park and one at Terminal 5. A single journey in either direction takes about 5-6 minutes. For the majority of the trip to and from Terminal 5, the guideway structure consists of two lanes running in opposite directions separated by a central kerb, as shown on the right. This configuration gives the guideway a very small footprint, allowing ULTra to be installed within the very tight constraints posed by the present airport infrastructure.

Description: Connection with Parking lot
Operational period: Since April 2011
Patronage: ± 700,000 passengers
Peak Capacity: 600 p/h/pd
Service Frequency: 25 seconds
Times of Operation:
Configuration: Line-connection
Operations: On-schedule
Connections: Direct (Non-stop)

Type of vehicle: 2nd generation ULTra
Fleet Size: 21
Passengers seated/standing: 5/0
Drive: Electric

Supervisory Control System: None

Track Length: 3800 meters (one-way)
Number of Stations: 3 off-line
Berths per station: 3-5
Crossings for Traffic/Pedestrians: 0 / 1 (Elevated)

Procedures and organisations involved

UK Procedures

Ultra has ensured that its pod system is safe for public use by consulting with the Office of Rail Regulation on its development and by forming a safety verification team (SVT) under the Railway and Other Guided Transport Systems (ROGS) guidelines.

The Ultra pod system concept received a ‘letter of no objection’ from the HMRI in 2000, as did a safety case for passenger trials in 2003.

Ultra has also produced an application-specific concept safety paper, which considered the safety of the pod system in providing a transport link between T5 Heathrow Airport and the T5 Business Car Park. The SVT reviewed the paper and on the evidence and analysis presented stated:

- The approach adopted was appropriate.

- There are no features of the Ultra pod system design and operating concept that would indicate that its level of safety, once designed in detail for the T5 Heathrow Airport application, would be unacceptable.

In 2008, a series of safety targets were established by Ultra, BAA and the SVT for the operation of the T5 Heathrow Airport pods system and a safety case was developed

US Procedures

Ultra Ltd states that their system is compatible with US federal and state PRT safety standards as well as the national fire escape code. There will be approximately 361 different “safety cases” for any PRT implementation, covering events including earthquake,
truck crashes into column, falling debris, fire, extreme weather, vehicle fails on guideway, slipping on stairs.

Ultra's process for gaining safety approvals for its pods system in the UK is broadly similar to those required in the US.

The relevant legislation in the US is the Code of Federal Regulations (CFR) 659, which provides a series of minimum requirements that are enforced by each state’s regulatory agency. CFR 659 envisions mature transit systems and is therefore less rigorous about "designing safety in" when compared to the UK rail safety regime.

The CFR 659 process follows the same generic steps for any state, with a few customisations within each state implementation:

• A rail transit agency (RTA) is formed to operate an Ultra pods system.

• The RTA informs the state fixed guideway safety regulator of intent to operate a fixed guideway system.

• A competent, independent safety team is formed to certify the system; this team is then approved by the state regulator.

• A safety certification plan is written and reviewed at least 12 months before approval to operate is given.

• The system safety program plan and system security plan are written and follow the American Society of Civil Engineers (ASCE) standards for automated people movers, parts I-IV.

• Once documentation is in order and commissioning is completed, a public hearing is held to grant safety certification and enable the pod system to begin operation.

• Once a system begins operation, the RTA is expected to conduct internal safety audits.

Many of the 361 T5 Heathrow Airport “hazard cases” can be applied directly to meet the requirements of CFR 659. The current T5 Heathrow Airport pods system documentation is closely-matched to the ASCE APM standards; an ASCE compliance matrix was developed for BAA at Heathrow.

BAA and Ultra have had representation on the ASCE APM committee for a number of years and are active in evolving the APM standard to better comprehend PRT systems.

NFPA130 Evacuation


Safety rails are attached to the guideway, primarily for safety of maintenance personnel, but the rails also serve to ensure safety of evacuating passengers.
3.2.2 PRT – Masdar

Description of the system

In the heart of Abu Dhabi work has started on the most ambitious sustainable development in the world today. Masdar City will be the world’s first carbon neutral, zero-waste to landfill, car-free city powered entirely by alternative energy sources. Masdar City will be built on six and a half square kilometres and will grow eventually to house 1,500 businesses, 40,000 residents and 50,000 commuters. There will be no fossil fuel cars within Masdar City. The city will be a pedestrian-friendly environment, with a Personal Rapid Transit system (PRT) available for longer journeys.

The dedicated guide way in the undercroft, an artificial basement created by raising the pedestrian level, will also accommodate the Freight Rapid Transit system (FRT). The FRT system is capable of making 5,000 trips per day carrying the loads and deliveries for residents, stores and hotels. The flatbed vehicles can carry two pallets, with a maximum total payload of 1,600kg.

The PRT & FRT will be entirely powered by renewable energy. The vehicles are equipped with Lithium-Phosphate batteries, allowing a range of approximately 60 kilometers on a 1.5 hour charge. The vehicles will be recharged at the stations, avoiding the necessity of additional parking space (garage). The stations feature angled berths, allowing all vehicles independent entry and exit.

2getthere was selected as the supplier for the first phase of Masdar City, providing the link to the Masdar Institute of Science and Technology (MIST) by means of 8 PRT, 2 VIP (leather interior) and 3 FRT vehicles. In this phase the network will be approximately 1.5 kilometers long and feature 5 stations (2 for passengers, 3 for freight).

The Masdar system was the first PRT to open to the general public on November 28, 2010.
### Application summarized:

<table>
<thead>
<tr>
<th>Description</th>
<th>PRT Network</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational period</td>
<td>Since November 28, 2010</td>
</tr>
<tr>
<td>Patronage</td>
<td>~ 700,000 passengers</td>
</tr>
<tr>
<td>Peak Capacity</td>
<td>500 p/ph/pd currently</td>
</tr>
<tr>
<td>Service Frequency</td>
<td>On-demand</td>
</tr>
<tr>
<td>Times of Operation</td>
<td>18hrs p/d, 7 days p/w</td>
</tr>
<tr>
<td>Configuration</td>
<td>Network</td>
</tr>
<tr>
<td>Connections</td>
<td>Direct (Non-stop)</td>
</tr>
<tr>
<td>Type of vehicle</td>
<td>3rd generation CyberCab</td>
</tr>
<tr>
<td>Fleet Size</td>
<td>10 (+ 3 Freight Rapid Transit vehicles)</td>
</tr>
<tr>
<td>Passengers seated/standing</td>
<td>4 adults + 2 children</td>
</tr>
<tr>
<td>Drive</td>
<td>Electric</td>
</tr>
<tr>
<td>Supervisory Control System</td>
<td>TOMS</td>
</tr>
<tr>
<td>Track Length</td>
<td>1500 meters (one-way)</td>
</tr>
<tr>
<td>Number of Stations</td>
<td>2 off-line (+ 3 freight stations)</td>
</tr>
<tr>
<td>Berths per station</td>
<td>4 or 6</td>
</tr>
<tr>
<td>Crossings for Traffic/Pedestrians</td>
<td>On podium level</td>
</tr>
</tbody>
</table>
Procedures and organisations involved

There are several standards that apply partly to electronically guided systems and/or PRT systems (ASCE APM Standards), or to specific aspects of it (NFPA 130 Standard for Fixed Guideway Transit and Passenger Rail Systems). These standards are taken into account when setting up the Design Safety Case for an application. The Design Safety Case for the application is provided by the system supplier. An Operations Safety Case, set up by the operator of the system, is part of the safety documentation required as well.

At the start of the customization of an application, scenario’s are set up to determine all the possible and likely interactions of the users and operators, which form the top level requirements. The requirements are apportioned to the system level below, and in progressively more engineering detail to sub-system levels. In some cases requirement apportioning is too complex for a straight-forward breakdown resulting in the W-model as used by 2getthere. When all required functionality is determined, validation and verification tests are defined.

The safety of each 2getthere application will be based on the FMECA procedure (qualitative analysis), followed by a more detailed Fault Tree Analysis for the components, complemented by Event Tree Analysis for consequences, leading to a quantitative formulation of the level of safety.

In the FMECA mentioned functionality, mitigations and procedures are verified in tests. Some of these tests are performed at system integration level during vehicle assembly, some during commissioning of the application or even on a separate test location, dependent on the level of functionality. Validation and verification is also done on the needed procedures for operations, maintenance and emergencies.

As there are no specific laws and regulations with regard to these types of systems yet (even ROGS in the UK isn’t specifically aimed at these type of systems), the safety is assessed through safety cases verified by external parties. In the case of Masdar, the Abu Dhabi Department of Transportation hired an Independent Safety Assessor and Independent Health Assessor to evaluate the Design Safety Case and the Operational Safety Case.

2getthere has been granted certification by the Abu Dhabi Department of Transportation for the Masdar PRT System on November 23rd, 2008, based on the Letters of No Objection as issued by the Independent Safety Assessor (Lloyd’s Rail Register) and Independent Health Assessor (Bureau Veritas). The system first opened to the general public on November 28th.

One distinct feature of 2getthere’s systems is the advanced obstacle detection sensors applied on the vehicles. The sensors are capable of scanning up to 200 meters in front of the vehicle -- the actual area taken into account being dependent on the speed of the vehicle. The area is always scanned empty, a fail-safe approach.
3.2.3 GRT – Schiphol airport

Description of the system

In the mid-‘90’s Amsterdam Airport Schiphol decided to improve the quality of its (10,000 spaces) long term parking lot P3. Part of the plan designed was the implementation of the ParkShuttle pilot-project to improve the service to airline-passengers and confirm Schiphol’s image.

In 1997 four ParkShuttles were installed. The track consisted of two (single directions) loops of 1km, each with 3 stations. Each loop had several crossings for automobile traffic (equipped with barriers and traffic lights) and pedestrians (audible alarms). To ensure maximum flexibility in the operations the vehicles are able to access both loops.

During the pilot the ParkShuttles transported passengers from the shuttle stops near their cars to the main stop near the passenger lounge. From here buses provided transportation towards the passenger terminals. The service was available 24/7 and free of charge to users of the parking lot. Surveys proved that the system was well used and greatly appreciated.

At any given time three ParkShuttles were in operation, while one vehicle was being charged. When there were no transportation requests, the vehicles spaced themselves along the track to ensure minimal waiting times at each stop. When necessary the charging vehicle could be made operational by manual override from the supervisory control system to provide additional capacity.

The main purpose of the pilot project was to acquire knowledge about passenger acceptance, ease of use, traffic management, comfort and safety of the ParkShuttle. In a next phase the track could have been extended to the passengers terminals. Although surveys showed great passenger satisfaction over the 7 years of operations of the pilot system, they were ceased in 2004. Installation of the 2nd generation ParkShuttle was seriously
considered, but based on the uncertainty in the airline-industry the decision has been postponed. 2getthere remains in contact with Schiphol Airport with regard to the operations of automated people mover systems.

**Amsterdam Airport Schiphol Application summarized:**

<table>
<thead>
<tr>
<th>Description</th>
<th>Parking lot connection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational period:</td>
<td>1997 – 2004</td>
</tr>
<tr>
<td>Patronage:</td>
<td>&gt; 2.500.000 passengers</td>
</tr>
<tr>
<td>Peak Capacity:</td>
<td>400 p/ph</td>
</tr>
<tr>
<td>Service Frequency:</td>
<td>On-demand</td>
</tr>
<tr>
<td>Times of Operation:</td>
<td>24/7 (365 days per year)</td>
</tr>
<tr>
<td>Configuration:</td>
<td>2 loop network</td>
</tr>
<tr>
<td>Operations:</td>
<td>On-demand</td>
</tr>
<tr>
<td>Connections:</td>
<td>Ride sharing, Multiple Origins to Multiple Destinations</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of vehicle:</th>
<th>1st generation ParkShuttle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Vehicles:</td>
<td>4</td>
</tr>
<tr>
<td>Passengers seated/standing:</td>
<td>8 / 4</td>
</tr>
<tr>
<td>Drive:</td>
<td>Electric</td>
</tr>
<tr>
<td>Supervisory Control System:</td>
<td>Transit Operations Monitoring and Supervision (TOMS)</td>
</tr>
<tr>
<td>Track Length:</td>
<td>2 loops of 1.000 meters</td>
</tr>
<tr>
<td>Number of Stations:</td>
<td>7, on-line</td>
</tr>
<tr>
<td>Berths per station:</td>
<td>6 single berth stations, 1 station with 3 berths</td>
</tr>
<tr>
<td>Crossings for Traffic/Pedestrians:</td>
<td>6 (all at-grade)/ 12 (all at-grade)</td>
</tr>
</tbody>
</table>

**Procedures and organisations involved**

The certification of the first generation at Schiphol did not raise a special issue. As the system is installed on the airport grounds, which are private property, the system 'only' needed to comply with the machine directives. The company that operates the people mover applied for and received a special waiver under the Public Transport Law to have the system function as a public transport system. Since the law was declared applicable to the system, liability was arranged in line with a 'normal' bus system.
3.2.4 GRT – Rivium

Description of the system

The initial decision to implement the ParkShuttle transportation system between subway station Kralingse Zoom and business park Rivium (city of Capelle aan den IJssel) was taken in 1995. The goal of the pilot was to proof that at the same expense, a better service and higher frequency could be achieved – making (public) transportation a more attractive alternative for car drivers.

![Image of ParkShuttle2 at Rivium](image)

**Figure 9 ParkShuttle2 at Rivium**

From February 1999 to November 2001, three ParkShuttle vehicles operated on the 1300-meter single lane trajectory. Bi-directional travel was enabled by means of three passing locations. A highway is intersected by means of a tunnel, while a specially constructed (single lane) bridge crosses a freeway. A journey lasted approximately 4 minutes.

The anticipated required capacity was exceeded because of expansions of the business park. At the same time the capacity was restricted by the number and size of the vehicles in combination with the single infrastructure. The success of the system prompted the decision in December 2001 to upgrade the system from its pilot status.

In phase II, the trajectory has been extended and the number of stations increased to 5. The 1800-meter track has three stops within business park Rivium. A new stop has been created to service business park Brainpark III and the residential suburb Fascinatio. The dedicated infrastructure, installed at grade, is now dual lane (with the exception of the aforementioned tunnel and bridge). Several at grade crossings with pedestrian and car traffic are realized.
The number of vehicles (6) and the capacity of the vehicles (20 passengers) doubled. The quality was also improved by applying state-of-the-art automotive know-how and technology. The vehicles are (even) more reliable, comfortable, silent and faster.

During peak-hours all vehicles are operational, on-schedule, based on a 2.5 minute interval. The scheduled service ensures the capacity is optimally used, while the on-demand operations in off-peak hours ensure the passenger service is maximized.

The business park Rivium case is a good example of the success of Group Rapid Transit applications. The passenger acceptance of the system is great and the experience with the operations of the system have been invaluable, adding to the existing knowledge and being better able to provide insight into the operations to potential customers.

**Business Park Rivium Application summarized:**

<table>
<thead>
<tr>
<th>Description:</th>
<th>Public Transportation to business park</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational period:</td>
<td>Phase I: February 1999 – November 2001</td>
</tr>
<tr>
<td></td>
<td>Phase II: December 2005</td>
</tr>
<tr>
<td>Patronage:</td>
<td>3,500 passengers (daily)</td>
</tr>
<tr>
<td>Peak Capacity:</td>
<td>500 p/ph/pd</td>
</tr>
<tr>
<td>Service Frequency:</td>
<td>2.5 minutes (peak hours)</td>
</tr>
<tr>
<td></td>
<td>On-demand (off-peak hours)</td>
</tr>
<tr>
<td>Times of Operation:</td>
<td>12hrs. p/d, 5 days p/w</td>
</tr>
<tr>
<td>Configuration:</td>
<td>Line-connection</td>
</tr>
<tr>
<td>Operations:</td>
<td>On-schedule / on-demand</td>
</tr>
<tr>
<td>Connections:</td>
<td>Ride sharing, Multiple Origins to Multiple Destinations</td>
</tr>
<tr>
<td>Type of vehicle:</td>
<td>2nd generation ParkShuttle</td>
</tr>
<tr>
<td>Number of Vehicles:</td>
<td>6</td>
</tr>
<tr>
<td>Passengers seated/standing:</td>
<td>12 / 10+</td>
</tr>
<tr>
<td>Drive:</td>
<td>Electric</td>
</tr>
<tr>
<td>Supervisory Control System:</td>
<td>Transit Operations Monitoring and Supervision (TOMS)</td>
</tr>
<tr>
<td>Track Length:</td>
<td>1800 meters</td>
</tr>
<tr>
<td>Number of Stations:</td>
<td>8, on-line</td>
</tr>
<tr>
<td>Berths per station:</td>
<td>4 stations with 2 berths, 4 single berth stations</td>
</tr>
<tr>
<td>Crossings for Traffic/Pedestrians:</td>
<td>6 (3 at grade) / 5 (all at-grade)</td>
</tr>
</tbody>
</table>
Procedures and organisations involved

The certification of the first generation of people movers did not raise a special issue. The new track built for the project was declared 'private road', which meant that the vehicles did not have to meet the rules for vehicles on public roads. The company that operates the people mover applied for and received a special waiver under the Public Transport Law to have the system function as a public transport system. Since the law was declared applicable to the system liability was arranged in line with a 'normal' bus system.

The second generation system was part of the CyberCars/CyberMove programs, with the FMECA method as developed by TNO as part of those programs being applied to the 2nd generation ParkShuttle in the Rivium application. Extensive qualitative analysis, supplemented by concrete external testing by TNO, was conducted to proof the safety of the system and the suitability of the system for public transportation.

3.2.5 Rome

Description of the system

The Rome demonstration had to implement a Cybernetic Transport System (CTS) in the New Rome Exhibition parking place and to open it to public permanently. A CTS is a system where vehicles without drivers (Cybercars) operate an on demand transport service in a mixed environment at least with pedestrians and cyclists. Initially, the system designed for Rome had a track round trip length of about 1.6 km and 11 stops as reported in the figure bellow. It was designed as a single loop without crossings and with on-line stations.

![Figure 10 Map of the system planned at Rome Expo](image)

*Figure 10 Map of the system planned at Rome Expo*
Description: Connection with Parking lot
Operational period: Did not open
Patronage: 500 p/ph/pd
Peak Capacity: 30 seconds
Service Frequency: Opening hours of exhibit center
Times of Operation: Line-connection
Configuration: On-schedule
Operations: Loop
Connections:

Type of vehicle: Robosoft RobuRide
Fleet Size: 4
Passengers seated/standing: 10/20
Drive: Electric

Supervisory Control System: Robosoft
Track Length: 1200 meters (one-way)
The Rome Demonstration certification process started officially with the delivery of the first round of documents to MoT in July 2009 but to arrive to this delivery many work has been done before. The first point discussed with MoT in 2007 was the legal framework to use for CTS certification. After a review of the possible approaches was agreed to use the Standard EN50126 “The specification and demonstration of reliability, availability, maintainability and safety” thus considering the CTS such as a driverless underground. According to the legal framework agreed the CTS could be considered as a driverless train and the trajectories recorded and followed by the Cybercars should be considered as electronic (or virtual) rails. This approach had some restrictions in term of design defined by the MoT:

No intersections between pedestrians, private vehicles and Cybercars – CTS totally segregated. This mean that at least in a first stage there must be fences around the track and doors at the stations.

No intersections between Cybercars – no intersections in the network. This means that at least in a first stage the system should operate in a fixed frequency service and without providing on-demand service.

CTS station doors have to meet the requirements defined for the Torino VAL now under implementation.

These restrictions had a strong impact on the Rome demo that was redesigned to make possible its certification but also to avoid an increase of costs. Indeed in a very early stage Rome demonstration should operate with minor segregations and no fences and stop doors were foreseen but just reserved lanes.

With the MoT was also agreed a step by step certification strategy with a very strict requirement in a first stage and, once the CTS has demonstrated its safety and reliability some of these requirements will be removed.

Defined the certification legal framework, strategy and the main requirements was possible to finalize the CTS design. The Rome demonstration detailed design (D 1.3.2.2 of CityMobil project) was finalized and delivered to CityMobil consortium in early May 2009 and translated in Italian and delivered to MoT in July 2009 thus starting officially the certification procedure.

MoT also accepted to follow, at least partially, CityMobil certification procedure (main output FMECA - Failure Mechanism Effects Criticality Analysis). The FMECA was run on the CTS design with the coordination of TNO. The analysis report was finalized in September 2009, translated in Italian, and provided to MoT in October 2009. After the delivery of
these documents MoT started analysing them deeply and some meetings were held between MoT and ITR personnel to analyse the information provided.

3.3 Research-based project implementations

3.3.1 La Rochelle

Description of the system

At the end of 2008, INRIA proposed, with the support of the mayor of La Rochelle, Mr Bono, that a cybercars demonstration could be done in this city for the CityMobil project. This decision followed closely the final demonstration of the EC project CyberCars-2 where several cybercars were demonstrated in their city. This demonstration took place in September 2008 in the center of the city in parallel with the demonstration of Advanced City Cars for the CityMobil Project. The mayor, who wants to put his city at the forefront of innovation in transport and sustainable development, said he would support the demonstration in real life condition of fully automated vehicles in his city. INRIA decided in June 2010 to work on the preparation of 2 vehicles derived from previous cybercars developed during the CyberCar project with Yamaha.

INRIA therefore refurbished entirely 2 vehicles by redoing the entire electronics, installing doors and new laser scanners (front and back). INRIA also worked on the communication network and the fleet management of the system.

The 2 vehicles (called CyBus) were finalized and tested in Rocquencourt with INRIA engineers and sent to La Rochelle on April 14 for final debugging and installation in cooperation with EIGSI, the local engineering school (in charge in particular of the communication network).

The city of La Rochelle provided the garage for the vehicles (including the charging infrastructure) and the management center and also the ramps for the stops and the call boxes. The communication system was installed by INRIA in cooperation EIGSI.

Initially, in the original planning, the operation of the system was to be provided by Veolia, the transport operator already in charge of the operation of Liselec, the carsharing system in La Rochelle. Due to the change in plans and the short duration of the demonstration, the operation was conducted by students from EIGSI, paid by INRIA and under the supervision of EIGSI staff.
During the demonstration, although the 2 vehicles were operational, only one was operated at a time, the second one being used as a back-up in case of mechanical, electrical or electronic troubles. Also, the management system was not completely operational for operating the 2 vehicles simultaneously.

For the 3 months demonstration, a team of operators was recruited from students of EIGSI. To cover the operation of the vehicles from 3pm until 6pm each day, a team of 3 operators was recruited plus a general manager of the team. The role of the operators was to monitor the vehicles (the “arrêté” from the mayor specified that an operator must be on board of each vehicle during its operation to stop it in case of malfunction). The role of the operators was also to start and finish the operation of the vehicles each day and to collect information from the users. In case of a malfunction, a simple procedure described in the maintenance manual (see Annex 1) was to be used. In case, the problem could not be solved, the vehicle was to be returned manually (or with the help of a tow truck but this never occurred) to the garage.

The operators were therefore trained during the last week in April to operate the vehicles and to run the questionnaires. The operators were also asked to collect data on the operation of the vehicles. At the end of each week, the manager compiled the operating data (hours of operation, incidents, actions and number of passengers).

Description: Pedestrian zone
Operational period: May – September 2011
Patronage: ± 5 000 passengers
Peak Capacity: 60 p/ph/pd
Service Frequency: 25 seconds
**Times of Operation:** 3hrs. p/d, 7 days p/w
**Configuration:** Line-connection
**Operations:** On-schedule
**Connections:** Direct (Non-stop)

**Type of vehicle:** 1st generation CyBus
**Fleet Size:** 2
**Passengers seated/standing:** 0 / 5
**Drive:** Electric

**Supervisory Control System:** Yes

**Track Length:** 700 meters (one-way)
**Number of Stations:** 5 off-line
**Berths per station:** 1
**Crossings for Traffic/Pedestrians:** Yes/Yes

### Procedures and organisations involved

During the preparation of the La Rochelle demonstration, two approaches were taken. The first approach was to define the system and its components and to apply the risk reduction analysis defined by TNO. This led to the detailed analysis of the failure modes, the risk encountered and how to reduce these risks by appropriate measures. One such measure was to reduce the maximum speed to 10km/h. Another measure was to implement stop signs for standard vehicles crossing the path of the cybercars at one location and reducing the speed of the cybercars to 5km/h at the crossing.

The second approach was to look at the regulations. The local “prefecture” who is in charge of allowing road vehicles to circulate was contacted by the city to obtain permission to run such vehicles. Since our vehicles did not fall into any known category, no permission was granted but at the same time, we were not forbidden to run them… The national ministry of transport was contacted with the same results.

Since the mayor was very keen to see this demonstration in his city and having been convinced by the risk reduction analysis, he took upon himself to allow the operation by writing a “décret” allowing the operation and describing under which conditions the vehicles could run. One such condition was to impose for each vehicle in operation an operator under the responsibility of INRIA with an emergency switch.

The 2 vehicles were also insured by MACIF, a national insurance company, as would a regular certified vehicle. These insurances were obtained easily and at no cost from the insurance company.

As generic experience we can say that the cybercars encountered some electric and electronic failures but without any consequences on the safety, due to the low speeds and the presence of the operator. In general, the users felt very safe and some regular users were quite enthusiastic.
One cybercar had a minor accident when a regular vehicle (an SUV) went into reverse and hit it at low speed. The regular vehicle was declared responsible for the event and its insurance covered the reparation of the damaged demonstration vehicle.

3.3.2 Floriade – Cybercars

Description of the system

Every ten years the Netherlands hosts the horticultural show Floriade. Each Floriade lasts 6 months and is organized in cooperation with a different city. The Floriade 2002, near the city of Hoofddorp, featured a 40 meter high observation hill with an impressive work of art at the summit: Big Spotters’ Hill.

During operation from April till October, 25 CyberCabs provided transportation to the top of the observation point. The vehicles used a 700-meter track spiraling up the hill to transport passengers between the two bottom and top stations.

The 1st generation CyberCab vehicles were specifically designed for the application, allowing passengers to enjoy the view of the Park. To ensure the best possible view the speed of the vehicles was limited to 11 km/h and drove outside of the track (left hand side) traveling upwards. The electric CyberCabs were supplied with ‘green’ energy, ensuring environmentally friendly transportation.
A round trip to the summit of Big Spotters’ Hill by the CyberCab was offered for 2.5€. The duration of a single trip was just over 4 minutes. The CyberCab system offered a maximum capacity of 600 passengers per hour (per direction). Quick chargers and the exchange of batteries ensured the maximum amount of vehicles to be operational at any time.

*2getthere* initiated the project to demonstrate the capabilities of automated transportation to the public, test passenger acceptance of the concept and automated transportation in general and gain experience with the operations of these types of systems. The research conducted proved that passenger acceptance of these systems is very good. Both old and young used the system without any reservations. Comments regarding the user friendliness were gathered and have been taken into account in the design of the 2nd generation. The operational experiences are invaluable for *2getthere*, adding to the existing knowledge and being better able to provide insight into the operations to potential customers.

**Floriade 2002 Application summarized:**

- **Description:** Scenic Connection
- **Operational period:** April -- November 2002 (192 days)
- **Patronage:** ± 400,000 passengers
- **Peak Capacity:** 600 p/ph/pd
- **Service Frequency:** 25 seconds
- **Times of Operation:** 12hrs. p/d, 7 days p/w
- **Configuration:** Line-connection
- **Operations:** On-schedule
- **Connections:** Direct (Non-stop)

- **Type of vehicle:** 1st generation CyberCab
- **Fleet Size:** 25
- **Passengers seated/standing:** 0 / 5
- **Drive:** Electric

- **Supervisory Control System:** None

- **Track Length:** 700 meters (one-way)
- **Number of Stations:** 2 on-line
- **Berths per station:** 1
- **Crossings for Traffic/Pedestrians:** 0 / 1 (Elevated)
Procedures and organisations involved

In the system definition phase, the system was defined as the complete CyberCab system, including infrastructure, loading station and stops. As an experiment, the operators were defined as part of the system, while the passengers were not. In total 15 subsystems were defined and analysed. Based on 8 FMECA sessions, the relative simplicity of the system allowed a thorough analysis that provided a lot of information. Ultimately the system was certified according to the rules and regulations for attractions by DNV.

One of the most interesting conclusions was that the people, the operator and the stewards were the major causes of danger.

3.3.3 San Diego demonstration

Description of the system

In the early 1990’s, the federal government of the United States launched an ambitious program called AHS (Automated Highway System) to develop and experiment fully automated vehicles. This program concluded in August 1997 in one of the largest demonstrations to date. Eight passenger cars from automotive manufacturers were fitted with lateral and longitudinal control to operate in platoons on a dedicated part of highway I-15 (HOV lane of 7.6 miles) equipped with magnetic markers and access control.

Demo ’97 satisfies a mandate in the AHS provision of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991. The Act states that “The secretary (of Transportation) shall develop an automated highway and vehicle prototype from which future fully automated intelligent vehicle-highway systems can be developed. Such developments shall include research in human factors to ensure the success of the man-machine relationship. The goal of this program is to have the first fully automated highway system or an automated test track in operation by 1997. This system shall accommodate installation of equipment in new and existing motor vehicles”. The United States Department of Transportation Automated Highway System Program Draft Report to Congress, 1 April 1995 states “The Congressional mandated demonstration is designed to demonstrate the basic technical feasibility of fully automated AHS designs, and key technologies and functions.” The 1997 Proof-of-Technical Feasibility Demonstration conducted by the National Automated Highway System Consortium responded to the congressional mandate and direction as described in ISTEA and the Report to Congress.
Figure 14 Eight automated vehicles on the I-15 in San Diego

Each vehicle entered the infrastructure in manual mode and then could be switched to automatic mode and enter the platooning mode if desired. On demand from the driver, the vehicle could exit the platoon and resume the manual mode.

Six other live demonstrations were also presented but of a much smaller scale (in a parking lot).

San Diego Application summarized:

<table>
<thead>
<tr>
<th>Description</th>
<th>Platooning on a dedicated highway</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational period</td>
<td>August 1997</td>
</tr>
<tr>
<td>Patronage</td>
<td>&gt;2500 passengers (estimated)</td>
</tr>
<tr>
<td>Peak Capacity</td>
<td>400 p/ph</td>
</tr>
<tr>
<td>Service Frequency</td>
<td>On-demand</td>
</tr>
<tr>
<td>Times of Operation</td>
<td>5 days, 6 hours/day</td>
</tr>
<tr>
<td>Configuration</td>
<td>One way dedicated 2 lanes highway</td>
</tr>
<tr>
<td>Operations</td>
<td>On schedule</td>
</tr>
<tr>
<td>Connections</td>
<td>Ride sharing, Multiple Origins to Multiple Destinations</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------</td>
<td>---------</td>
</tr>
<tr>
<td><strong>Type of vehicle:</strong></td>
<td>Buick</td>
</tr>
<tr>
<td><strong>Number of Vehicles:</strong></td>
<td>8</td>
</tr>
<tr>
<td><strong>Passengers seated/standing:</strong></td>
<td>4 plus driver</td>
</tr>
<tr>
<td><strong>Drive:</strong></td>
<td>ICE</td>
</tr>
<tr>
<td><strong>Supervisory Control System:</strong></td>
<td>None (distributed among vehicles)</td>
</tr>
<tr>
<td><strong>Track Length:</strong></td>
<td>10km</td>
</tr>
<tr>
<td><strong>Number of Stations:</strong></td>
<td>one</td>
</tr>
<tr>
<td><strong>Berths per station:</strong></td>
<td>n/a</td>
</tr>
<tr>
<td><strong>Crossings for Traffic/Pedestrians:</strong></td>
<td>None</td>
</tr>
</tbody>
</table>

**Procedures and organisations involved**

Safety of all passengers, participants, and the general public was a top priority. An independent Safety Board and Safety Certification Panel were established by the PMC to oversee and ensure safety. As part of the Panel’s procedures, rigorous pre-certification and certification tests were scheduled for all demonstration scenarios. In addition, extensive demonstration dress rehearsals were conducted three weeks prior to the demonstration. In addition, trial runs were conducted prior to each scheduled to ensure the readiness and safety of all systems, operators and support services. Emergency support services were closely coordinated with local agencies and provided throughout the demonstration including ambulances, fire, police, towing and all other appropriate services. In accordance with Federal and Consortium safety guidelines, a comprehensive Safety Plan was developed and strictly enforced throughout the demonstration planning, development, and execution process. The plan provided safety related requirements, guidance, and direction in the planning and execution of all test and demonstration sessions. All drivers were certified through this safety certification process and all vehicles were certified for both safety and ride comfort.

The methods of validation to be used are: Inspection, Analysis, Demonstration, and Test.

**Inspection** – Certification or validation by visual examination of the item, reviewing descriptive documentation, and comparing the appropriate characteristics with a reference standard to determine conformance to requirements. This includes the mechanical inspection of equipment, validation of accuracy and completeness of documentation.

**Analysis** – Certification or validation by evaluation or simulation using mathematical simulations representation, charts, graphs, circuit diagrams, or data reduction. This includes analysis of algorithms independent of computer implementation, analytical conclusions drawn from test data, and extension of test produced data to untested conditions.

**Demonstration** – Certification or validation by operation, movement, or adjustment of the item under a specific condition to perform the designed function. This includes the content of displays, comparison of vehicle/system products with independently derived test cases, and prompt vehicle/system recovery from induced failure conditions.
Test – Certification or validation through systematic exercising of the applicable item under all appropriate conditions with instrumentation and collection, analysis, and evaluation of quantitative data.

Pass-Fail Criteria

Pass/Fail criteria specify results that must be obtained to determine that a requirement has been satisfied as defined by the applicable test/certification procedure verifying the requirement. Pass/Fail criteria may be binary in nature or employ tolerances and limits. A validation method having a pass/Fail criterion verifies a performance and/or design requirement as specified in the Demonstration Specification with no deviation or exceptions when the results are specified to be within a pre-determined range.

3.4 Main legal issues identified in EU Member States

With the help of CityMobil2 partners, we looked into the legal aspects of implementing ARTS in their own countries and in particular in those countries where demonstrations are considered.

3.4.1 Greece

In Greece whatever concerns the mobility of vehicles and pedestrians is defined in the National Road Traffic Regulation (Κώδικας Οδικής Κυκλοφορίας – Κ.Ο.Κ., N.2696/1999), which can be found in the following official reference on-line, managed by the Ministry http://www.yme.gr/?getwhat=1&oid=249&id=&tid=249. In fact, this Regulation is a super-set of Laws concerning Traffic in various perspectives.

The insertion of a new type of traffic (automated) in the existing provisions of the Road Traffic Regulations (Κ.Ο.Κ.) cannot be implemented at once on the scope of a pilot project as it concerns a limited and not generalized usage that is more or less an experiment.

According to the regulations, the vehicle should pass a standardized process of vehicle registration. At the moment there are no existing criteria/prerequisites for registering automated vehicles.

A Municipal Board decision can define the route of the automated vehicles, which according to Road Traffic Regulation (K.O.K.) should be isolated and guarded. The Callicrates Law (Νόμος Καλλικράτη, Ν. 3852/2010, Article 83, Par. 2e) defines the responsibilities of the Local Authorities concerning traffic in the local level.

The guarded route should be done so both by the Municipal Police and by the Police. As such, the route is defined for specific hours per day.

The vehicle to be used must be insured, in order to carry passengers (according to K.O.K.)

More general information about Road Traffic Security can be found here: http://www.yme.gov.gr/?tid=122&aid=0 (N. 3897).

More general information about Vehicle Specifications can be found here:
3.4.2 Italy

The mobility of road vehicles in Italy is regulated by the Codice della Strada (code de la route, traffic law), hereinafter CDS, which lays down a general legal framework for road mobility. According to Art. 46, CDS is only applicable to "road vehicles of any kind driven by a human being". The textual formulation of this rule leads us to a first consideration that has a major consequence on our project: in fact, it can be inferred that a vehicle must be driven by a human being, otherwise it cannot legally run in a public road. This is further confirmed by the rules applicable to civil liability: according to Art. 2054 of the Italian Civil Code, "a driver of a road vehicle is obliged to compensate for any damage to people or to things he/she may cause while driving". The combined application of these rules leads us to affirm that, according to Italian traffic law, a vehicle must be driven by a human being who's responsible for any damage caused by the vehicle itself. In addition, in Italy road vehicles must, in any case, be covered by an insurance in order to circumvent insolvency of drivers in case of damage. In light of these brief but meaningful considerations, we can safely assume that an automated transport system, such as CM1 and CM2, cannot be considered a road vehicle and be validly certified as such, at least as long as the legislation concerning road mobility remains unchanged.

This is probably the main reason for which the Italian Ministry for Infrastructures and Transport (the authority in charge of the certification of both road and railway transport systems, hereinafter MoT) has considered CM1 a vehicle running on rail tracks. Since it could not be considered a road vehicle, the only solution available was to consider the vehicle's trajectory as a virtual track. In this respect, it worth noting that railway systems of EU Member States have to comply with the technical specifications for interoperability as established by the European Railway Agency (ERA). The latter, in turn, works in close cooperation with the European Standardisation Organisations (ESO), whose main function is to prepare common standards of technical requirements.

More specifically, the standard EN 50126 provides for a specific set of technical requirements of railway systems, its sub-title being "Railway applications – The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS)". As a result, MoT has carried out the validation process of CM1, and will probably do the same with CM2 (see report of the meeting with the MoT, already delivered) applying EN 50126. It is to be noted that the latter was prepared by CENELEC (European Committee for Electrotechnical Standardisation) under a mandate given by the European Commission and the European Free Trade Association. According to Directive 98/34/EC, when a European Standardisation Organisation operates under the mandate given by the Commission, compliance with the standard so produced creates a presumptive conformity with the relevant EU legislation (which is, in case of railway systems, Directive 2008/57/EC).

To put it differently, if a railway system is produced in compliance with EN 50126, that system is presumed to be consistent with Directive 2008/57/EC, and therefore it can be automatically validated by national authorities. The problem of CityMobil is that obviously it is not a railway system proper, and as such it is not produced and implemented following EN 50126. As explained by MoT's engineers in our last meeting, the validation of CM1 had to follow, as a consequence, a step-by-step procedure, since the conformity of CM1 with EN 50126 could not be presumed. In other words, MoT had to verify in practice CM1's observance of the RAMS process set forth by EN 50126.
Subsequently, as far as the Italian legal framework is concerned, it can be safely affirmed that Italian authorities at present do not ground their decision concerning innovative transport systems on a specific legal basis, since such legal basis has not yet come into existence. Technically speaking, this situation can be defined as a normative vacuum. In the present case, this vacuum is filled by means of an analogical application of EN 50126, namely a set of rules which was thought to be applied to a different set of facts (namely, railway transport). In legal parlance, this analogical application to fill in a normative gap at the informal level can be called ‘administrative practice’. The lack of a specific legal basis has a major impact on the certification process, since it imposes on MoT the obligation to conduct a strict case-by-case observance of each single innovative transport system, and even of each single step of their practical implementation. Thus there is a need for a specific and clear legal framework.

3.4.3 Spain

Spain considers that unmanned and driverless vehicles represents a logic possibility for traffic in the future, but Spain has to adapt their legislation to permit their existence. Unmanned (and any level of driver assistance), to be accepted on the traffic, must give to other road users a safety level equivalent to a vehicle with a normal driver.

The safety of an unmanned vehicle is consequence of the technology level (sensors, equipment, software…) designated to replace the driver and fitted on it; then, as consequence, unmanned or driverless vehicles must be authorized to circulate on streets and roads only according to the safety level demonstrated.

Restrictions for circulation of those vehicles by some streets or roads should be specified according to the technology fitted on each vehicle designated to replace the driver; as example, if the vehicle is unable to detect traffic lights, their circulation on roads or streets with this kind of safety equipment should not be permitted.

The use of some streets and/or roads should be permitted only if unmanned or driverless vehicles demonstrate that the technologic equipment designated to replace the driver, are compatible with the traffic conditions by those streets or roads. In such a way, the safety level of those public spaces should not be affected by that kind of vehicles.

Traffic authority may restrict according to the above exposed, the use of unmanned or driverless vehicles by some streets or roads, or may put limits to their circulation, or may designate special streets or roads for the circulation of unmanned or driverless vehicles.

Better safety than manual driving represents the main condition to permit the use of unmanned or driverless vehicles. As much their demonstrated safety approaches the safety level given by a normal driver, bigger will be their possibilities of circulation.

3.4.4 Finland

The legislation related to the use of motorized vehicles in Finland consists of Road Traffic Act, Decree on the use of vehicles on the road and the Vehicles Act. In these regulations and rules, there are no mentions about vehicles without a driver, with automatic or remote
In all actions and decrees the driver is mentioned in different ways: driving the vehicle, driver's responsibilities and obligations and also the different types of vehicle are defined by the numbers of seats in addition to the driver. The Road Traffic act also says that controlling the vehicle must be safe and the control devices shall be constructed and placed so that they are easy and safe to use while driving.

Definition of a vehicle
The Finnish road traffic laws define the requirements for different vehicles. According to definition of a vehicle in Road Traffic Act (Tieliikennelaki 267/1981), vehicle means any device intended to move on the ground but not running on rails. The definition of a vehicle in the Road Traffic Act and the Vehicles Act does not apply to all other vehicles used in rails, air, water or other element than land. Power driven vehicle means any vehicle operated by power; motor vehicles comprise cars, mopeds and motorcycles, vehicles of category L falling outside these categories as well as tractors, public works vehicles and off-road vehicles.

Vehicles on roads
Vehicles Act (1090/2002) applies to the traffic on roads. Road as a general expression is a public or private road, street, square and snowmobile track, as well as other area intended for general traffic or generally used for traffic.

The act does not apply to vehicles which are solely used on building sites restricted from the general traffic or in factory, harbour, storage, racing or equivalent areas. However, some sections of the act e.g. concerning general safety requirements, responsibility for the maintenance, registration and inspection of a vehicle, the imposition of a surveillance inspection, the obligation to repair a vehicle and the penalties apply to such vehicles too.

Type-approval procedures & registration
Type-approval means a procedure in which the approval authority certifies that a vehicle type, a system, a component or a separate technical unit meets the relevant technical requirements. Type approvals comprise EC type-approvals, E type-approvals, national type approvals and small-series type-approvals. Multi-stage type-approval means a procedure in which the approval authority alone or together with the approval authority of another EEA country certifies that an incomplete or complete vehicle type meets the relevant technical requirements, in accordance with the stage of production.

According to the Finnish Vehicles Act, a motor vehicle to be used in traffic must be registered, and notification of any changes pertaining to the vehicle submitted to the register. The registration obligation does not apply to:
- any vehicles that are used solely at a construction site, factory, port, storage area, competition area or a similar area separate from public traffic
- any all-terrain vehicles except for snowmobiles
- any working machinery that is built or equipped for producing crops, harvesting or road maintenance, or any tractors meant to be controlled by a walking person or any similar working machinery
- any trailer meant to be towed by a category L vehicle, tractor, a working machine or an ATV
- any towable equipment
- any sleighs.
Even if the registration of a vehicle is not mandatory, in some cases compulsory motor liability insurance may need to be taken out for the vehicle.

Safety requirements
A vehicle shall be suitable for transport use, and its construction, equipment, maintenance and other characteristics shall be safe and in conformity with the relevant provisions. The construction, equipment and external shape shall not constitute any danger. A vehicle shall be easily controlled in usual driving situations. The control devices shall be constructed and placed so that they are easy and safe to use while driving. The control devices, measuring instruments and signal lamps shall not deviate from the systems of other vehicles of the same category to an extent which would cause discomfort or danger. The Decree on the Vehicle Construction and Equipment also requires that e.g. the speedometer display is clearly legible to the driver.

3.4.5 France

Automated vehicles are already in operation in France but only in private sites. According to French law, these vehicles are operating legally if they are developed according to the machinery directive and are certified as such by an independent certification body such as APAVE.

At the moment, there is no provision to register an automated vehicle to run on public roads. However, an automated public transportation system can be certified according to the décret 2003-425 on the safety of “guided public transports”. This décret is mostly about trains, trams and ski lifts (automated or not) but can be extended to automated road vehicles if they are continuously guided along a finite set of paths. The safety of this guidance has to be demonstrated and certified by an independent certification body. At this time, no such system has yet been certified. However, the certification procedure is clearly detailed in the décret with 4 important steps:

- a preliminary safety definition document
- a preliminary safety document
- a safety and operation document
- the operation and safety rules

Each of these documents is to be transmitted to the administration with its certification by the independent certification body. The entire process may require an entire year.
4. **Conclusions**

Certification is the process that attests that a given product meets given standards applicable within the country it will be used and in particular meets the required safety criteria. The procedure has to be performed by an accredited certification body although, in some instances, self-certification is allowed (such as for the car industry). This certification usually releases the criminal liability of the provider.

The analysis of existing regulations in Europe shows that it is currently not possible to certify fully automated driver-less road vehicles for public roads. The only possibility to certify an ARTS, at the moment in Europe, is to use the framework of automated people movers (ex.: driverless metro train) and to consider cybecars as guided vehicles. However, this framework is very restrictive and does not allow operations on standard roads. The other approach is to use special derogatory procedures allowing the operation locally.

Therefore, the only way to implement an ARTS without going through the constraints of an automated people mover is to validate the system and ask for temporary or permanent authorization from the local authorities. Validation is an assessment of the operational system and all individual parts of it, including operational and emergency procedures. Validation ensures that the various parts contributing to the system meet their requirements, and the system as a whole meets the intended purpose and needs of system’s owner and stakeholders. Validation shall be performed by an independent party against the requirements handed to the manufacturer of the (sub-)system under investigation.

In order to be granted the authorization from the local government, it will be necessary to demonstrate the safety of the system and well identify who is liable for accidents (civil and criminal). The safety should be demonstrated to the local government through the validation process.

For the civil liability, it is just necessary to find an insurance company ready to take the risk. Past experience has shown that this is quite possible at a reasonable cost since the risk of major accidents is very limited. In La Rochelle, for instance, the insurance company MACIF insured the local ARTS for free.

Concerning the criminal liability, which is strictly personal, the person who will endorse the risk (for example the mayor of the city) has to be convinced that the risk for him/her is acceptably low. This has to be done by the providers of the ARTS with the risk analyses.

We recommend the 4-step procedure defined in previous projects such as CityMobil (deliverable D.2.5.3) that could cover safety and certification or validation of automated road transport systems in the various demonstrations planned for CityMobil2:

1- Preliminary risk reduction
2- Determine which safety regulations apply
3- Production and implementation of the system
4- Certification or validation of the system
Preliminary risk reduction

To demonstrate the safety of the system, procedures have already been elaborated such as the risk reduction analyses, Fault Tree Analysis (FTA) and Event Tree Analysis (ETA) to aid in assessing appropriate mitigations during the design phase. For example, the FMECA analyses ensure the design itself does not introduce hazards. We can also rely on the certification of subsystems, which allows incorporating these in the FTA and ETA as a single entry with an approved (low) failure rate.

In the case of short-term demonstrations where a full FMECA analysis would be too costly, a Risk Reduction Method may be applied since the exposure to risk is much lower than for a long term operating system. In this case, the risk reduction method is used to roughly analyse a number of issues that have influence on the safety of the transport system in its environment. The basis of the analysis is a series of checklists that take into account a number of actors present in the environment and estimate their influence on the safety of the system. The analysis has to be carried out by the authorities, the operator and the evaluation organization. The result will be a series of recommendations that can be applied in the first planning phase. By following the recommendations, fewer corrections will need to be made in the later stages. The Risk Reduction Method is a simple method that is also suitable as an instrument to evaluate the safety of showcases and demonstrators, where a comprehensive safety analysis is impractical or too expensive.

Determine which safety regulations apply

In the second step it is established which existing safety regulations the system should meet. In this phase, the cooperation with relevant public authorities is essential. In addition to the safety evaluation and certification procedure, most systems will have to meet particular requirements, related to the environment they are being used in. For instance, requirements concerning the applicability for disabled people or local fire regulations. The second step is carried out by the authorities and the evaluation organization.

Production and implementation of the system

In the third step, for which the manufacturer of the system in combination with the operator is responsible, the system is produced and implemented on site. For the production phase it is highly advisable to follow the Code of Practice for the design and evaluation of ADA systems, as developed in the Response projects. Although the recommendations in the Code of Practice are meant for standard cars with drivers, most of the recommendations are directly applicable to fully automated systems and can greatly improve the safety of a system if applied correctly.

Certification or validation
In case the system cannot be certified, it has to go through an ad-hoc local procedure and through validation. Validation is an assessment of the operational system. It is essential to underline that validation/certification is not limited to the driverless vehicle, but applies to the entire ARTS. Validation ensures the system meets the intended purpose and needs of system’s owner and stakeholders.

This is why, in the CityMobil2 Project, it is important that an independent Validation Panel is appointed at the beginning of the project to ensure that the objectives are met and in particular that safety procedures are well met and implemented during each of the demonstrations. This Panel should be responsible to allow the operation of the system in each case and to give the proper convincing elements to the insurers and to the local officials who will carry the criminal risk.
## 5. Glossary

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>AB</td>
<td>Assembly Bill</td>
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<tr>
<td>ADA</td>
<td>Advanced Driving Assistance</td>
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<tr>
<td>AHS</td>
<td>Automated Highway System</td>
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<tr>
<td>APM</td>
<td>Automated People Mover</td>
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<tr>
<td>ARTS</td>
<td>Automated Road Transport Systems</td>
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<tr>
<td>ASCE</td>
<td>American Society of Civil Engineers</td>
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<tr>
<td>ATV</td>
<td>All Terrain Vehicle</td>
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<tr>
<td>BAA</td>
<td>British Airport Authority</td>
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<tr>
<td>CDS</td>
<td>“Codice della Strada” (Traffic Law, Italian)</td>
</tr>
<tr>
<td>CENELEC</td>
<td>European Committee for Electrotechnical Standardization</td>
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<tr>
<td>CFR</td>
<td>Code of Federal Regulations</td>
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<tr>
<td>CH</td>
<td>Switzerland</td>
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<tr>
<td>CM</td>
<td>City Mobil</td>
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<tr>
<td>CS/HB</td>
<td>Committee Substitute House Bill</td>
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<tr>
<td>CTS</td>
<td>Cybernetic Transport System</td>
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<tr>
<td>DARPA</td>
<td>Defense Advanced Research Projects Agency</td>
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<tr>
<td>DE</td>
<td>Germany</td>
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<tr>
<td>DG</td>
<td>Directorate General</td>
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<tr>
<td>DK</td>
<td>Denmark</td>
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<tr>
<td>DMV</td>
<td>Department of Motor Vehicles</td>
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<tr>
<td>EC (FP7)</td>
<td>European Commission (Seventh Framework Programme)</td>
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<tr>
<td>EEA</td>
<td>European Economic Area</td>
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<tr>
<td>ERA</td>
<td>European Railway Agency</td>
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<tr>
<td>ESO</td>
<td>European Standardization Organizations</td>
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<tr>
<td>ETA</td>
<td>Event Tree Analysis</td>
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<td>EU</td>
<td>European Union</td>
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<tr>
<td>FMECA</td>
<td>Failure Mechanism Effects Criticality Analysis</td>
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<td>FR</td>
<td>France</td>
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<tr>
<td>FRT</td>
<td>Freight Rapid Transit</td>
</tr>
<tr>
<td>FTA</td>
<td>Fault Tree Analysis</td>
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<tr>
<td>GRT</td>
<td>Group Rapid Transit</td>
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<tr>
<td>IEC</td>
<td>International Electrotechnical Commission</td>
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<tr>
<td>IP</td>
<td>Integrated Project</td>
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<tr>
<td>ISO</td>
<td>International Organization for Standardization</td>
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<tr>
<td>ISTEA</td>
<td>Intermodal Surface Transportation Efficiency Act</td>
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<tr>
<td>IT</td>
<td>Italy</td>
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<tr>
<td>MIL-STD</td>
<td>Military Standard</td>
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<tr>
<td>MIST</td>
<td>Masdar Institute of Science and Technology</td>
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<tr>
<td>MoT</td>
<td>Ministry of Transport</td>
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<tr>
<td>NFPA</td>
<td>National Fire Protection Association</td>
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<tr>
<td>NL</td>
<td>The Netherlands</td>
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<tr>
<td>PMC</td>
<td>Project Management Committee</td>
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<tr>
<td>PRT</td>
<td>Personal Rapid Transit</td>
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<tr>
<td>Acronym</td>
<td>Full Form</td>
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<tr>
<td>PT</td>
<td>Portugal</td>
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<tr>
<td>RAMS</td>
<td>Reliability Availability Maintainability and Safety</td>
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<tr>
<td>ROGS</td>
<td>Rail and Other Guided Systems</td>
</tr>
<tr>
<td>RTA</td>
<td>Rail Transit Agency</td>
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<tr>
<td>SAE</td>
<td>Society of Automotive Engineers</td>
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<tr>
<td>SB</td>
<td>Senate Bill</td>
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<td>SP</td>
<td>Spain</td>
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<tr>
<td>SVT</td>
<td>Safety Verification Team</td>
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<tr>
<td>TOMS</td>
<td>Transit Operations Monitoring and Supervision</td>
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<tr>
<td>UK</td>
<td>United Kingdom</td>
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<tr>
<td>UNECE</td>
<td>United Nations Economic Commission for Europe</td>
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<tr>
<td>USA</td>
<td>United States of America</td>
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<tr>
<td>VIP</td>
<td>Very Important Person</td>
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</tbody>
</table>
6. **References**

6.1 **Existing Standards relevant for ARTS certification**

ASCE Automated People Mover (APM) Standards

NFPA 130 Standard for Fixed Guideway Transit and Passenger Rail Systems

2006/42/EC Machinery Directive

ETSI EN 302 665 standard

EN 1525:1997 Safety of industrial trucks - Driverless trucks and their systems

EN 50126/x Railways standards

EN 1525 Safety of machinery

ANSI/ITSDF B56.5-2012 Safety Standard for Driverless, Automatic Guided Industrial Vehicles and Automated Functions of Manned Industrial Vehicles

ISO 13489-1 Safety of machinery -- Safety-related parts of control systems -- Part 1: General principles for design

ISO 26262/x Road vehicles -- Functional safety

ISO 10218 Robots and robotic devices -- Safety requirements for industrial robots

ISO/DIS 13482 Robots and robotic devices - Safety requirements for non-industrial robots - Non-medical personal care robot


ISO 12100: Safety of machinery -- General principles for design -- Risk assessment and risk reduction

SAE J3018 - Safety Guidelines for the On-Road testing of Prototype Models of Fully Automated Vehicles

6.2 **Rules and regulations**

Vienna Convention concerning road vehicles of 1968 (including amendments of 1993 and 2006)

European Directive 70/156/EEC (road vehicles)

European Directive 95/16/EC of 29 June 1995 relating to lifts
European Directive 2008/57/EC Interoperability of Rail Systems


SAE J3018 Safety guidelines for the on-road testing of prototype models of fully automated vehicles (draft initiated in August 2012)


Arrêté CityMobil. Mairie de La Rochelle. March 2011


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