AUTOCITS Pilot in Lisbon
Perspectives, Challenges and Approaches

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Abstract: In this paper we describe the Cooperative Intelligent Transport System (C-ITS) framework, the case-studies and the connected autonomous vehicles to be deployed in the AUTOCITS pilot in Portugal. AUTOCITS project - which stands for Regulation Study for Interoperability in the Adoption of Autonomous Driving in European Urban Nodes, has the main goal of contributing to the deployment of C-ITS in Europe, namely in Spain, France and Portugal, by carrying out pilots using connected and autonomous vehicles and by contributing to the regulations/legal framework on autonomous driving. The Lisbon Pilot will be conducted in a motorway (A-9) and in an urban node (in Lisbon city), where autonomous vehicles (AVs) and instrumented vehicles, all equipped with C-ITS instruments, will be evaluated according to three scenarios: dedicated lanes, shared lane and road without restrictions. In the first scenario, traffic control vehicles will also be present during the tests. In this paper we focus on the Lisbon Pilot: the main technical challenges for infrastructure, test cases and scenarios, and the perspectives on the Portuguese legislation.

1 INTRODUCTION

Transportation is one of the essential factors of a country's progress, and the era of connected, cooperative and autonomous vehicles is bringing new elements to the transportation arena (Litman, 2018). Intelligent Transportation Systems (ITS) make use of information and communication technologies to improve the performance of a transportation system to obtain economic, social and energy benefits. Cooperative Intelligent Transport System (C-ITS) (a.k.a. connected vehicle technology in the United States) is the term used to describe technology which allows vehicles to communicate with other vehicles and with the infrastructure (Lu, 2016), and *vice-versa*.

The potential and emerging possibilities, challenges, issues and trends of connected car technology are discussed by (Coppola and Morisio, 2016), (Jimenez, 2017), (Sjoberg et al., 2017), among other studies. Therefore, it is a consensus that C-ITS and Autonomous Vehicles (AVs) will be major components for increasing traffic safety and efficiency of the future ITS. In this regards, one of the key strategies of Europe is to use C-ITS as a catalyst for the implementation of autonomous driving (Parliament and UNION, 2010), (Festag, 2014), (Sjoberg et al., 2017), (Jimenez, 2017).

The AUTOCITS (Castiñeira et al., 2018) project will carry out a comprehensive assessment of cooperative systems and autonomous driving by deploying real-world Pilots, and will study and review regulations related to automated and autonomous driving. AUTOCITS[1], co-financed by the European Union through the Connecting Europe Facility (CEF) Program, aims to facilitate the deployment of autonomous vehicles in European roads, and to use C-ITS services to share information between vehicles and infrastructures to ensure safe coexistence of AVs with

[1] http://www.autocits.eu/

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other (conventional) traffic vehicles.

The AUTOCITS Pilots will be deployed in three major European cities in *'the Atlantic Corridor of the European Network'*[2]: Lisbon (Portugal), Madrid (Spain) and Paris (France). This paper, however, aims to describe the deployment of C-ITS services, the test case scenarios, and the technology of the automated cars to be used in the Lisbon pilot. Moreover, an overview of the Portuguese legal framework related to self-driving cars is also presented.

The paper is organized as follows. Related work is presented in Section 2. The AUTOCITS project and the Lisbon pilot are described in Section 3 and Section 4, respectively. Test case scenarios are explained in Section 5. The legal framework and C-ITS infrastructure are described in Section 6 and Section 7. Section 8 brings discussions and concluding remarks.

2 RELATED WORK

Despite the remarkable progress that has been achieved in recent years to develop AVs capability, making autonomous vehicles a day-to-day reality is still a demanding challenge (Broggi et al., 2008) (Jimenez, 2017). According to *'Connected Automated Driving Europe'*[3], in recent years more than 60 research projects have been actively addressed autonomous driving in Europe to overcome hurdles of all sorts and push forward boundaries. Some of the related projects on connected automated driving are summarized below.

The first European C-ITS project, the Eureka PROMETHEUS, was initiated in the 1980s using inter-vehicle communication. Thereafter, various projects and prototype implementations (*e.g.*, CAR2CAR, DRIVE C2X, SeVeCom, SAFESPOT, COMeSafety, etc) were developed that demonstrated the technical and commercial feasibility of vehicles and infrastructure communication for further development of C-ITS technology. Recently, several major projects (*e.g.*, SCOOP@F, C-Roads, AUTOPILOT, MAVEN, AutoMate, DigiTrans, etc) have been initiated for large-scale field-operational C-ITS deployments across Europe.

In this framework, AUTOCITS aims to contribute to the deployment of C-ITS and autonomous vehicles in urban nodes by developing intelligent transport services based on cooperative systems (C-ITS) that will enable vehicles, users and infrastructures to communicate, exchange, and share information.

3 THE AUTOCITS PROJECT

AUTOCITS involves partners and stakeholders from Spain, France, and Portugal. The Pilots to be deployed in Madrid, Paris and Lisbon, will include the following main characteristics (Castiñeira et al., 2018):

- Include different types of roads in urban environments (such as urban-nodes roads, motorways, connections and interfaces with motorways);
- Provide an open and connected urban environment, where C-ITS services can be tested with automated, autonomous and connected vehicles;
- Involve complementary parties and stakeholders in Spain, France and Portugal, including but not limited to: transport operators, traffic authorities, industry, academia;
- Demonstrate the maturity of C-ITS services in the urban environments based on state-of-the-art C-ITS deployments happening on European motorway networks;
- Evaluate the potential of C-ITS services in urban environments to increase road safety and enhance traffic information and traffic management.

The following general objectives are expected to be achieved by AUTOCITS for the enhancement of regulatory frameworks and also for interoperability among the deployment of connected (CVs) and autonomous vehicles (AVs):

- Demonstrate the potential of C-ITS services provided by Traffic Management Centers that can improve the reliability of AVs in terms of safety and sustainability of transport, as well as to improve the traffic management;
- Develop large-scale implementation of C-ITS at European level as a catalyst for a higher level of automation of road transport, giving recommendations for its deployment and analyzing the different regulations towards its circulation, including the role of C-ITS, and addressing technical and economic issues to demonstrate long term viability and scalability;
- Deploy pilot activities within the TEN-T Atlantic Corridor and evaluate the results in order to validate the studies, draw recommendations and practices, and analyze how legal regulations can be improved at this particular scenario and at similar urban/inter-urban nodes at European level.

[2]http://www.corridor4.eu/
[3]https://connectedautomateddriving.eu/

4 THE LISBON PILOT

The Lisbon pilot will have a direct involvement of all the Portuguese partners: Institute Pedro Nunes (IPN)[4], National Authority for Road Safety (ANSR)[5] and the University of Coimbra (UC)[6]. The other project partners (Indra, INRIA, UPM) and stakeholders (University of Aveiro, A-to-Be, BRISA) will collaborate and participate in this Pilot as well. More specifically, and considering the scope of the Portuguese Pilot, the activities to be carried out will be divided into three main components:

- Technical and engineering aspects related to the deployment of autonomous and connected cars, and C-ITS services;
- Assessment and evaluation of the Pilot;
- Legal/regulatory framework and safety conditions during the Pilot.

Finally, the company BRISA[7] (a motorway concessionary) will join the pilot as the provider of C-ITS infrastructure, and its related technology and services.

4.1 Pilot Location

The Lisbon pilot will take place on two environments, a motorway and an urban-node. Depending on the location and scenario, the vehicles' technology differs: autonomous and instrumented vehicles running at a motorway; and autonomous shuttle running on a dedicated road at an urban node.

In the first environment, the Lisbon pilot will be deployed on the motorway called "A9 - CREL motorway" (Circular Regional Exterior de Lisboa) and will use two segments in both headings (see Fig. 1). The first segment will be located between the service area, near A16 junction, and until Queluz toll plaza; while the second segment will be located between this toll plaza and the beginning of A9, near of National Stadium. Along this pathway, autonomous and connected vehicles will perform several tests in one loop through the test site.

On the other hand, the autonomous Shuttles will circulate on a dedicated road on an urban node in Lisbon, transporting people between parking and main buildings. No other kind of vehicles will have access to the dedicated road of the shuttles.

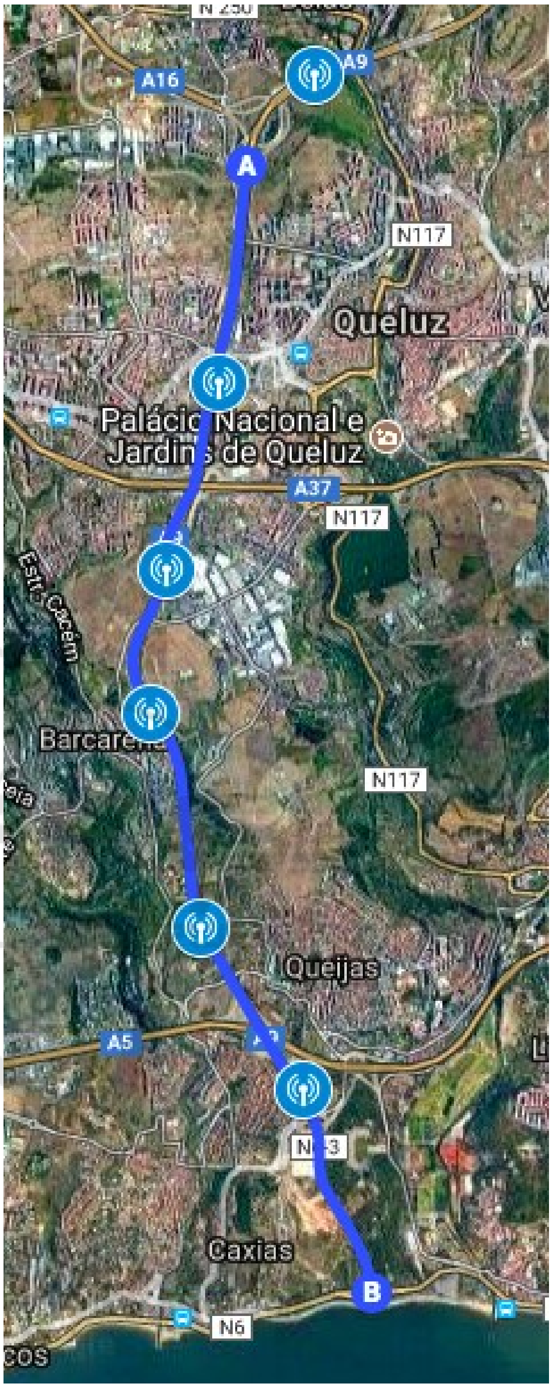

Figure 1: Lisbon pilot location on the A9 motorway. The blue line indicates the motorway scenario for AVs.

4.2 Autonomous and Instrumented Vehicles & Shuttles Specifications

The Lisbon pilot will include vehicles with different types of technology: autonomous, instrumented and autonomous shuttles. All these vehicles should be

[4] https://www.ipn.pt/
[5] http://www.ansr.pt/
[6] http://www.uc.pt/
[7] http://www.brisa.pt/

equipped with OBU units (*i.e.*, onboard communication units). The vehicles to be used on the A9 motorway comprise three technology types: AVs connected to the C-ITS infrastructure; CVs equipped with OBUs compatible with C-ITS infrastructure; traffic control vehicles equipped with OBUs; and some conventional vehicles which will be admitted under specific circumstances. Fig. 2 shows some of the AVs and CVs planned to participate in the Lisbon Pilot.

Figure 2: Autonomous (top) and Connected (bottom) Vehicles.

In the urban-node scenario, two autonomous shuttles developed by IPN, based on ITS technology called MOVE, will be used. The MOVE, shown in Fig. 3, is a driverless electric vehicle, designed for small trips at low speeds, with the aim to be a 'horizontal lift' able to connect buildings of private or semi-private spaces.

Figure 3: Autonomous shuttle MOVE.

4.3 The 'Day 1' C-ITS Services

The C-ITS provides ways to collaboratively share information about potentially dangerous situations on the road. This information comes from road users and traffic managers. Thus, the connected-vehicle (autonomous or not) has the opportunity to take the best actions and adapt to traffic conditions, towards an overall positive impact on road safety, traffic efficiency and comfort of driving.

Under the European strategy on C-ITS, and after a study from the C-ITS platform, a set of priority services ('Day 1' C-ITS services) was defined that must be deployed across the EU for end-users (EU-Commission et al., 2016). The 'Day 1' C-ITS services to be considered in the Lisbon pilot are the following:

- slow or stationary vehicle(s);
- traffic ahead warning;
- weather conditions;
- other hazardous notifications.

4.4 Data Collection

For analysis and efficiency evaluation of the proposed C-ITS for autonomous driving in the Lisbon Pilot, the following data is expected to be recorded during the Pilot: The GNSS path that autonomous and automated cars take from the beginning to the end of each test; the speeds and accelerations that the vehicles undergo; the chronological data for every action of the vehicle or any changes in the present conditions; the detected time and position of obstacles, or possible obstacles, during each test; the distances from other vehicles on the road, and every sent and received ITS message.

5 TEST CASE SCENARIOS

This section describes the test case scenarios for the Lisbon pilot with a focus on autonomous and connected vehicles, followed by scenarios for the autonomous Shuttle site.

5.1 Motorway Test Cases

A series of simulated and realistic tests will be performed. In *Simulated* case, event messages are generated virtually at the Traffic Management Centre (TMC), according to the event triggered, and broadcasted by Road Side Units (RSU); while in *Realistic* case on-site vehicles, positioned at the roadside, will be used to generate event messages accordingly. The experiments will be tested under three conditions (test-cases), where the target autonomous vehicle is expected to be able to reduce its speed and change lane according to the following cases:

1. dedicated lane;
2. shared lane;
3. road without restrictions.

Some common predefined attributes are determined for test case scenarios. The target vehicle receives notification in so called 'Destination area' for taking the appropriate action. The 'Destination area' includes 'Pre-event', 'Event', and 'Post-event' zones which are responsible for slowing down and/or changing lane, maintaining safe conditions, and returning to the normal condition, respectively.

Depending on the type of test conditions on the motorway, it will be used the right-most lane of each carriageway, that is, in both directions. At some predefined road sections, there will be two lanes allowing vehicles to change lane. These lanes will either be excluded from the normal traffic or shared with conventional vehicles.

Regardless of the type of the test, the road will be signalized so that other road users are aware of what is happening. For the real-world events, the vehicles causing the event *i.e.*, a traffic control vehicle (TCV), will stand on the roadside to ensure safe circulation.

5.1.1 Dedicated Lane

In this scenario, a dedicated lane (the right-most one) will be segregated from normal traffic by means of vertical signs, Variable-Message Signs (VMSs) and TCVs, as well as law enforcement agents from local authority. Before each test, the AV will be driven to the beginning of the dedicated lane manually and then switched to automatic.

Three simulated events ('Low road adhesion due to ice on the road', 'Rock falls detected on the road surface' and 'Big objects detected on the road') will be generated virtually and will be send to the target AV. Also, a realistic event 'Stationary vehicle due to break down' will be tested using a connected vehicle stopped as an obstacle on the roadside (see Fig. 4).

5.1.2 Shared Lane

In this case the AV is not isolated from traffic. The current traffic can use the shared lane but the AV must only use the shared lane. This shared lane will be sufficient for reducing speed actions required for the events chosen.

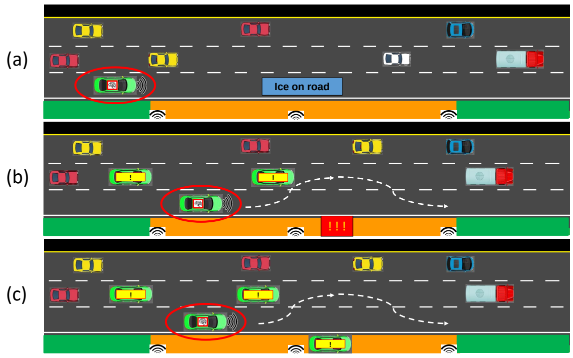

Figure 4: Illustration of the test scenarios for the 'Dedicated Lane' case: (a) 'Low road adhesion due to ice on the road'; (b) 'Rock falls detected on the road surface' and 'Big objects detected on the road'; and (c) 'Stationary vehicle due to break down' scenario. The orange color-coded zone indicates the 'Destination area'.

Three simulated events ('Low visibility due to Heavy Rain', 'Awareness about Strong Winds' and 'Soft Hail') will be generated by TMC and will be send to the target AV. The AV will reduce its speed and after passing the 'Event' zone accelerates again to the normal speed.

5.1.3 No Restrictions

The road without restrictions (no restrictions) scenario means that no physical barriers or other means of constraints exist and therefore AVs are "mixed" with current traffic, changing lane or reducing speed whenever it's necessary (see Fig. 5).

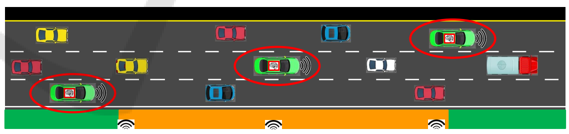

Figure 5: Illustration of the test scenario for the 'No Restrictions' case.

For the 'No Restrictions' scenario one simulated and one realistic tests are proposed, as follows: Traffic jam volume increasing, and slow driving maintenance vehicle.

5.2 Urban-node Test Cases

The following C-ITS services (one realistic and two simulated) will be employed in the autonomous shuttle tests: 'Low road adhesion due to ice on the road'; 'Low visibility due to Heavy Rain'.

The first test case (stationary vehicle due to a stopped public transport) will be a real-world scenario. The autonomous shuttle (as public transport) stops in a bus stop, broadcasts the cause code to alert other approaching shuttles with the same heading for the risk associated to the potential dangerous situation (vehicle as an obstacle on the road). The autonomous shuttle with the same heading of the public transport (the stopped shuttle) must reduce speed and change lane according to its proximity to the place.

The services 'Low road adhesion due to ice on the road', 'Low visibility due to Heavy Rain', simulated by the TMC, are equal in terms of actions proceeded by the autonomous shuttles.

6 REGULATION FRAMEWORK

Governance of Highly Automated Vehicles (HAVs) - being it fully or partially autonomous - has been one of the most problematic and studied legal issues in the last years, whether you approach it from a national point of view, or when looking at it from an international law perspective. Considering the level of regulatory evolution for automated and/or autonomous driving, at this point and disregarding the recent 2014 amendment to 1968s Vienna Convention on Road Traffic article 8th - which can influence the interpretation of national legislation -, there is much to be done in the Portuguese regulatory framework in order to better accommodate this new reality.

Portuguese road legislation closely follows the provisions of the international legal instruments that bind the Portuguese Republic. In fact, like the provisions of Article 8 of the Vienna Convention on Road Traffic of 1968 ("Every moving vehicle or combination of vehicles shall have a driver."), the Portuguese Road Code states:

Article 11
Driving vehicles and animals
1 - Any vehicle or animal that circulates on the public road must have a driver, except for the exceptions provided in this Code.
2 - During driving, drivers shall refrain from performing any acts that are likely to jeopardize the safety of driving.

On the other hand, the driver of a motor vehicle may only do so on the public road if he is legally licensed to do it:

Article 121
Driver's license
1 - A motor vehicle may only be driven on the public road, if its driver is legally licensed for it.

To this is added the liability of the driver concerning all the infringements in which he/se incurs when driving.

Article 135
Liability for misconduct
3 - The liability for the transgressions foreseen in the Road Code and complementary regulations rests on:
a) driver of the vehicle with respect to infringements relating to the driving of the vehicle;

Portugal has been following the different efforts on several international forums where the debate has been taking place, and there has been a recent development in this matter: a work group has been recently created (October of 2017) and mandated with the objective of evaluating, technically, legally and operationally the introduction of autonomous vehicles in Portuguese road traffic as well as to prepare the AUTOCITS test pilot to be conducted in the Lisbon region, where autonomous vehicles will be deployed in a real road environment in order to study its traffic impact and communications with the infrastructure.

The legal modifications necessary for allowing level 4 and 5 autonomous vehicles circulation, where the person behind the wheel, or where the wheel used to be, is no longer the driver, require the previous modification in the international legal instruments to which Portugal is binded. After that modification or if a different interpretation of the terms "driver" and "person" is achieved, then Portugal will be able to make the necessary legal modifications in order to accommodate the circulation of level 4 and 5 automated/autonomous vehicles.

7 C-ITS INFRASTRUCTURE

The capability to exchange information between vehicles and between vehicles and roadside infrastructure in cooperative vehicle systems creates many opportunities for innovation in the way in which the road network is used and managed. This will not only involve the introduction of new technologies, but also changes in the way in which road operators, vehicle manufacturers, service suppliers and other stakeholders work together to provide services for travellers using the road network.

The communication between vehicles and between them and the road infrastructure is crucial to improve road safety, traffic efficiency and comfort to the driver, helping autonomous vehicles (AVs), as well as connected vehicles (CVs), to take the right decisions at the right time. The real-time messages over 802.11p (ITS-G5) will be crucial to provide real time decision making, as well as information to the vehicle at the correct time.

For the deployment of Lisbon Pilot several scenarios will be carried out, as mentioned before. It is expected to test communications between vehicles and the road infrastructure (V2I/ I2V). Two types of components will be used for the Lisbon Pilot C-ITS deployment. The first one is a vehicle based hardware while the second one is a non-vehicle based hardware, that is an equipment located along roadside, on board units (OBUs) and roadside units (RSUs), respectively.

Infrastructure to vehicle (I2V) and vehicle to infrastructure (V2I) communication will be evaluated through wireless communication over IEEE 802.11p (ITS-G5). Those communication systems require components located in vehicles (OBUs) and along roadways (RSUs) to enable complete system operation. Thus, two OBUs equipped with 2 radios, one GPS receiver and a processor unit will be installed on conventional vehicles, as well as on AVs, and connected with an Human Machine Interface (App for tablet).

As non-vehicle based hardwares, six georeferencing RSUs, making use of ITS-G5 communications technology, will be embedded on several roadside cabinets, namely at 7+530, 6+300, 4+410, 3+700, 2+400, 1+600 kilometers. Those RSUs will broadcast messages, needed to support V2I/I2V applications, through the ITS central platform, specified and develop by A-to-Be (a technology company, part of BRISA's Group), making use of hybrid communications, such as ITS-G5 (5.9 GHz) plus 3G cellular networks, either to the vehicles or to traffic management center (TMC).

8 REMARKS

This paper presents the expected scenarios, test-cases and technology involved in one of the pilots to be deployed in the AUTOCITS project: the Lisbon Pilot. Some general and key technical aspects of the Lisbon Pilot have been covered in this paper, with a particular focus on the expected scenarios (motorway and urban-node), vehicles' technology, C-ITS infrastructure, the test-cases that will be carried out, and also the current regulation for the adoption of automated and/or driverless vehicles in Portugal.

The AUTOCITS project is currently under way and its technical and technological aspects are at a very advanced stage. More details and up-to-date information is available at www.autocits.eu.

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