Use Cases of novel C-ITS solution for the increase of road safety

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ABSTRACT

This paper's scope is to demonstrate the use case scenarios of ODOS 2020 project, pertaining mainly to critical situations on road safety, following the conference's topic on "Improving active safety of vehicles in an increasingly automated environment", focusing on the use of Cooperative intelligent Transportation Systems (C-ITS). ODOS 2020 project's integrated system will also contribute to the optimization of time and procedures related to the identification of road pavement status and the respective time and degree of its predictive maintenance. In addition it will provide personalized information on weather and traffic conditions playing the role of a real time updated individualized VMS system, while also simulating virtual toll station and payment systems. In this paper, the focus is set on the explanation of each one of the discrete scenarios' way of operation with view to the preparation of the official pilot tests which will take place during the December of 2020, having as test bed the Attiki Odos motorway in Athens, Greece. However, at the beginning of the paper, some light is shed on the description of ODOS 2020 project itself, through the provision of data on the project's four discrete applications on active road safety, road pavement status identification and predictive maintenance, personalized VMS and virtual tolls. Finally, at the end of the paper, the future steps towards the completion of the project's activities are also depicted, focusing on the applications' testing, assessment, validation of respective results, project promotion, dissemination activities, business exploitation models and procedures to create patent.

Keywords: active road safety optimization, C-ITS, use case scenarios, ODOS 2020.

1. INTRODUCTION: Background, objectives and method

ODOS 2020 stands for "Intelligent coOperative integrateD system for rOad Safety and road infrastructure maintenance towards 2020". The primary objective is the upgrading of the active road safety level of all types of road infrastructures through the implementation of four (4) Cooperative ITS applications, deploying Internet of Things and embedding Infrastructure to Vehicle communication technologies. The background is associated with the operation of smart systems making the infrastructure more informative, but the currently operating systems have to do with the way the equipped vehicles communicate with the infrastructure. This implies that the establishment of the vehicle equipment is considered as a prerequisite no matter how much the cost is affordable by the majority of owners - drivers. Besides, any information coming from the infrastructure is transmitted with

use of sensors and communication networks which are embedded inside the tarmac, partly destroying the road pavement's cohesion. On the contrary, in the case of ODOS 2020, amongst the innovations the non-destructive methods of encapsulating all the necessary equipment is incorporated, while the largest part of the cost involved to make all kinds of infrastructure smarter, more explanatory, forgiving and responsive is undertaken by the road operators. This fact will be minimizing the precautions and requirements making the system more accessible to all users, no matter their socioeconomic status and technological expertise, literacy and familiarization. This is going to be the real case scenario, because the new system is going to run through a free of charge – easy to use app provided by the road infrastructure provider and / or operator for all kinds of smart phones.

The ambition of ODOS 2020 project consortium is to develop, assess and eventually deliver an integrated system, which will provide personalized information to all road users on critical situations concerning upcoming road events and potential dangers. The integrated system incorporating the set of the four applications is expected to apply for patent in Greece, without excluding the possibility of European or even Universal trademark creation according to the users' - customers' acceptance and the commercial success or market share of the final product. On this direction, the final product will be in position to consist a valuable co-driving supporting tool, transmitting information and alerts on road traffic conditions taking into consideration the driver profile, the environmental conditions and other technical parameters, such as the vehicle status and the geometrical and operational characteristics of the road. ODOS 2020 integrated system is also expected to comply with all the current technologies and provide notification on upcoming tolls, their charging – tariff policies and also their e-pass or ticket collection methods, incorporating even a virtual toll and respective payment collection system. The system will be available free of charge for all road users through an internet based downloadable application and it will fit into both new vehicles equipped with C-ITS and old ones through the use of a smart tab or phone, supporting active road safety and road management.

The method used by the research team (and authors of the paper) for the identification of the critical situations and system needs incorporates both literature review on road safety level statistics in Greece and questionnaire survey addressed to targeted population involved in road safety and pavement maintenance issues, telecommunication circuits and road infrastructure management, including experts and users from public and private domain. The use case scenarios have been finalized and incorporate nine (9) discrete scenarios on road safety. In addition, there are scenarios identified pertaining to the monitoring of pavement health and status in order to better manage the alternative options on predictive road maintenance, also receiving personalised messages on navigation, traffic and environmental conditions or even concerning upcoming virtual tolls.

The method used to end up with the selection of the final set of the use case scenarios incorporated data input from three sources, taking into consideration the parameters depicted below:

i. Research on road traffic accidents types, causes and profile based on data from statistics offices and accident police database.

ii. Identification of experts and users needs and expectations from such an integrated system.

iii. Mapping of all the legislative, regulatory and operational restrictions (e.g. maximum dimensions) pertaining to the establishment of pieces of equipment on road pavement.

The innovation of ODOS final product is that the integrated system to be developed will introduce state of the art technologies, being totally accessible by all road users and traffic management centres, without requiring considerable equipment and eliminating development and operational costs, making all types of road infrastructure smart, forgiving and responsive at urban, rural and highway network level. Therefore, for the first time, the technologies, equipment and respective costs concerning the development of a state of the art system on road safety, management and operation are passed on from the vehicle users or owners to the infrastructure providers and operators, making the cutting edge technology fully accessible to all, promoting equity, integration and effectiveness through the expected massive use of ODOS 2020 system.

2. RESULTS: Description of use cases' way of operation

The scenarios described within this paragraph are grouped per ODOS 2020 project application. The prioritization of the applications according to experts' and users' will, follows the order of the next four paragraphs of the text.

2.1 Active road safety upgrading assisting driver

This application is targeted at the provision of assistance on active road safety issues to drivers and inevitably to all other road users. The application is addressed to both equipped and non equipped vehicles with use of different technologies (e.g. C-ITS to OBU – On Board Unit and use of 3G/ 4G/ LTE, respectively). The scenarios interrelated with the upgrading of active road safety are depicted below:

Scenario 1: "Vehicle ahead moving in the wrong or opposite direction". The system detects those vehicles in order to notify both their drivers and all the other road users moving within the influence area in order to avoid potential collisions. The tracking of illegally and dangerously moving vehicles is considered to constitute a key issue concerning active road safety at critical points of road network (e.g. double entrance in / exit out of motorways) when there is blind spot movement.

Scenario 2: "Upcoming danger or obstacle ahead": The system sends notification to all drivers moving inside the influence area specifying the exact position of danger / obstacle on the road pavement (e.g. lane / lanes engaged). This notification is critical at situations of road works or (permanent) damage / obstacles on road pavement preventing the easy access and seamless movement of vehicles (earthquake rifts or pavement destruction / collapse due to flood etc.).

Scenario 3: "Blind spot entrance on motorway". The system sends notification to drivers moving along the main street or motorway in case there is blind spot entrance of vehicle(s) coming in their circulation lane (potential "meeting" of different trajectories and high possibility for collision occurrence).

Scenario 4: "Modifications or differentiation of geometrical and / or operational road characteristics". All drivers moving within the influence area receive notification and navigation

guidelines concerning upcoming points of road network where several such modifications take place (e.g. change in the number of lanes and / or their characteristics such as width, different tarmac and slipperiness), forcing drivers to differentiation of their driving attitude (e.g. emergency turning, using alternative routes or emergency braking etc.).

Scenario 5: "Inappropriate vehicle speed". Drivers moving with inappropriate speed receive notification and in case of fully equipped vehicles the ISA (Intelligent Speed Adaptation) system is simulated and / or fed with data input. As inappropriate speed the speeding over the indicated speed limits (road signs) is considered, but a number of additional parameters are also taken into consideration, such as traffic (congestion) and weather (rain, snow, ice, wind, fog etc.) conditions, as well as visibility and lightening the presence of which alone or in combination deteriorate the level of active road safety due to vehicle speeding.

Scenario 6: "Pedestrian crossing in low visibility conditions ahead". Each driver of vehicle moving within the area of influence (e.g. zebra crossing) receives a notification concerning pedestrian movement ahead. The time the notification is provided by the system depends on various parameters (algorithm), according to vehicle speed, visibility level, driving profile, weather and traffic conditions.

Scenario 7: "Sharp (e.g. left) turns and vehicle crossings especially at crossroads". The system sends warning message on upcoming crossroads with focus on left turns interrupting the movement of the opposite direction circulation lanes or concerning points of where vehicles enter or exit motorways with or without presence of special acceleration / deceleration lane, taking into consideration the traffic and environmental conditions, visibility, lightening and driving profile.

Scenario 8: "Black spots as identified through the official road accident statistical database". The system provides warning notification to all drivers moving within the area of influence, heading towards black spots (officially identified through road safety studies based on road accident statistics), such as bridges (joints), tunnels, sharp turns (horizontally) and / or big grade slide (vertically), always taking into consideration traffic and environmental conditions, low lightening and visibility.

Scenario 9: "One level rail crossings". The system provides notification of approaching unguarded (without barriers) one level crossing, taking into consideration vehicle speed and programmed train arrival in case this information is available through the railway service operator.

2.2 Individualized Variable Message Signs (VMS)

According to the scenario, this application aims at the provision of real time individualized information on traffic and weather conditions, as well as other guidance and navigation (e.g. POIs – Points of Interest or final destination), according to the needs (or disabilities), expectations and choices predefined by the drivers in their native language. The application acts as a replacement to the current VMS systems, it is much cheaper and it also has the advantage of individualization of the provided information, taking into consideration traffic and environmental conditions, low lightening and visibility, as well as the driving profile for each driver at the exact point where the vehicle moves in real time conditions, ensuring increased effectiveness. In order for this application to be used, the consent of the

user concerning GDPR (General Data Processing Regulation) is required.

2.3 Virtual tolls

This application aims at the multi-level enhancement of traffic conditions through the provision of automatic electronic payment via cell phone use. First of all, there is the issue of the avoidance of time consuming lowering of vehicle speed or even vehicle stop, while the most important parameter is the upgrading of the active road safety level as it has been proven that after the operation of any kind of Open Road Tolling / All Electronic Tolling systems, the number of (potential near) collisions has been considerably decreased by approximately 24% (Yang, Ozbay & Bartin, 2012). In addition, there is the environmental point of view, as the more the vehicles are following a stop and go movement near toll stations (city traffic / congestion conditions) the more the concentration of small particles is increased multiplied by 3 to 6 times more than that of an urban environment (Yu-Hsiang Cheng, 2010).

Moreover, there is the cost issue, considering that a 24/7 toll station needs some 100.000€ at annual basis for operational costs and consumables, plus the considerable design and construction cost at the very beginning. On the other hand, the equipment required for the operation of the virtual tolls is much cheaper, is established mainly on bridges (gantries) over the motorway and the charging is accomplished using simple DSRC - Dedicated Short Range Communication technologies or GNSS - Global Navigation Satellite System, according to EU Directives. This means that no extra transmitter and receiver is necessary to be used other than the user's smart phone which is connected to the afore mentioned equipment. The application is addressed to both equipped and non equipped vehicles.

2.4 Road pavement predictive maintenance (for TMC)

Based on real time data input (e.g. pavement burdening from static and dynamic forces) coming from infrastructure elements and devices, this application aims at the provision of the proper set of tools to TMC and / or the responsible road infrastructure operator, in order to urge them to respond to maintenance programme and respective duties. The equipment (actuators, sensors etc.) is established on road pavement using non destructive methods (encapsulated and embedded on strips) and is aimed at establishing, enforcing and supporting the predictive maintenance routine. According to the scenario, through the application, the monitoring of road pavement health status and its degradation rhythm in real time conditions is enabled, providing alerts to TMC and road infrastructure operators when a lower threshold value is approached, in order to optimize both the predictive maintenance programme and the cost of the respective road works that are necessary in different time horizons. It is highlighted that this application acts as an auxiliary decision support tool supporting the current maintenance procedures.

3. EXPECTED IMPACT

ODOS 2020 project and its applications, activities, use cases, architecture, goals, technological innovations and non destructive establishment methods have been presented in numerous conferences, workshops and the press during the first two years of the project. The future actions involve implementation of pilot tests, system evaluation and optimization, elaboration of dissemination

actions and outreach activities, as well as business model development based on exploitation plan, in order to create patent and try to maximise impact on road safety, pavement predictive maintenance and traffic management. The use cases are expected to constitute the basis and the target for further system development during the project duration, as well as the primary means towards the validation of its necessity and technological excellence. Another given is that the users' acceptance and experts' approval has already been recorded in order for all the populations – targets (users, operators, automobile industry, TMC etc.) to be in position to take advantage of the integrated system's interoperability, advanced quality, added value and increased technology readiness level.

4. CONCLUSION

This paper includes the description of ODOS 2020 project's applications and technological approach, focusing on the identification of the use case scenarios as chosen by experts and users – potential customers according to their needs and expectations from such an integrated system towards the upgrading of active road safety, predictive maintenance and traffic management level of road infrastructures. Following an anthropocentric framework, the initial objective goals of the project have been maturely developed and transformed into a set of discrete set of scenarios grouped in 4 applications namely (in prioritization order): active road safety, VMS, tolls and road pavement maintenance. As per the future research plans, the implementation and transferability of ODOS 2020 experience, expertise and know how to other transportation means infrastructures, integrating a combination of movements, overall monitoring and payment methods towards life, cost, environmental, congestion and time savings.

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