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USE CASE SCENARIO BUILDING CONCERNING INTEGRATED I2V COMMUNICATION FOR SMART INFRASTRUCTURES

TABLE OF CONTENTS

INTRODUCTION

The cars as wheeled motor vehicles carrying passengers and / or goods were officially invented and rapidly came into global use during the 20th century, providing advantages such as on-demand transportation, mobility, independence, and convenience. The year 1885 is regarded as the birth year of the modern car when German inventor Karl Benz patented his Benz Patent-Motorwagen, the first vehicle designed to be propelled by an internal combustion engine (DPMA, 2014). One of the first cars accessible to the masses was the 1908 Model T, an American car manufactured by the Ford Motor Company, selling some 15 millions of models from 1908 to 1927, named car of the century and ranked within the top 10 most sold cars of all times (James, 1999; Steele, 2008; US: Forid, 2013). Cars were rapidly adopted in the US, where they replaced animal-drawn carriages and carts, but took much longer to be accepted in Western Europe and other parts of the world. Once cars became affordable and entered the mass production chain, the first car accidents entered the everyday routine.

So, road safety issue has been a life and death importance issue for over a century, puzzling all involved stakeholders from road users to infrastructure and equipment developers and operators and from technology and service providers to the automotive / automobile and fuel industry. Despite the technologiucal progress, according to the World Health Organization (WHO), more than 1 million of people are killed and over 50 millions of people are injured in road accidents at annual basis all over the world and especially in the developing countries. Statistically, road accidents represent the first cause of death among children 10–19 years of age and it is ranked in top-5 in other age groups. However, the number of casualties could be halved if simple prevention measures such as the compulsory use of seatbelt, or the obligatory speed limitation were taken (WHO, 2010 and 2014).

Analyzing the profile, type, conditions, causes and impacts of car accidents, the research community has ended up discriminating the triptych of human, vehicle and environment as the main factors contributing and interrelating towards the increase of car accident occurrence potential and probability (Lenard et al, 2004). The most important component is the human factor as, according to bibliographic review and statistics analysis, the 90-93% of car accidents are linked to human error during critical situation management in driving (Haghi et al, 2014). Pertaining to the enhancement of driving techniques, experience has proven that both education and training in safe driving techniques constitutes a multiple life long, complex, individualized learning process as traffic safety has been studied, developed and reviewed as a science for more than 80 years (Evans, 2014).

Concerning the upgrading of vehicle technical and electromechanical specifications and automations, as well as road environment features and attributes, an entire industry has been developed during the past 3-4 decades working on innovative technology systems used either for the prevention of road accidents (active safety) or for the alleviation of the accidents' impact (passive safety). Especisally focusing on the assistance provided from vehicles to drivers and riders, an exhausting list of Adaptive Driver's / Rider's Assistance Systems (ADAS / ARAS) have been developed, tested, pattented and in many cases been incorporated within the standard equipment of new vehicles (Kuschefski et al, 2010).

In the world of smart systems integration, information and communication technology development, electromobility and autonomous driving, a possible alternative solution creating a recent trend is to have both smart vehicles and smart infrastructure communicating with each other with use of internet based Cooperative Intelligent Transportation Systems (C-ITS), acting as driver assisting tool in the management of critical situations. Within the frame of the project ODOS 2020: "Intelligent cooperative integrated system for road safety and road infrastructure maintenance towards 2020", a disruptive technological solution (ODOS integrated road safety system) will be developed in order to achieve the implementation of Cooperative Intelligent Transportation Systems (C-ITS) applications, deploying Internet of Things (IoT) and Infrastructure to Vehicle (I2V) technologies. The innovative solution is expected to be designed in such a way that it will not be requiring for costly interventions in the infrastructure or purchasing costs on vehicle equipment. The focus will be set on the increase of road safety and traffic efficiency, while it will also be contributing to the in-time detection of road infrastructure critical deficiencies leading to predictive maintenance of the infrastructure.

In this paper, a preliminary use case scenario building is presented, with view to identify both the proposed locations of motorway where the solution should be applied and the target groups of people where it is addressed. In addition, the authors investigate the potential for interoperability, adaptability and transferability of the proposed solution into a different environment or with alternative users or to another mode of transport. The research work is based on the authors' personal state of the art review, as well as on the results of a questionnaire survey elaborated for this reason in the frame of the project, addressed to representatives from the domain of road transport network operators, equipment / infrastructure / maintenance service providers, also incorporating the end users using the proposed smart solution and assessing its effectiveness and operation at daily basis.

The research aims and results of this paper are listed below:

1. Presentation of the integrated road safety system, its architecture and attributes, together with all its added value innovative services and respective applications developed in the frame of ODOS 2020 project (section 1 of the paper).
2. Highlighting the road safety issue, focusing on the main reasons causing the occurrence of accidents with fatalities / injuries, in order to validate the development of such an integrated system upgrading road safety (section 2 of the paper).

3. Identification of user needs and expectations concerning ODOS 2020 integrated system (questionnaire survey results in section 3 of the paper).
4. Determination of the most critical use cases that have to be developed based on the respective scenario building even in a preliminary phase, produced as a result of the system architecture, available technology and user needs (section 4 of the paper).

The goal is to end up with the identification, presentation and analysis of the final use case scenaria based on which the integrated C-ITS system will be tested and evaluated, in order to promote road safety, enhance traffic efficiency and support or upgrade the road transport infrastructure maintenance. The end product of the survey is expected to be characterised by technological innovation as well as equal accessibility by all interested audience and potential customers, including the end users - drivers.

This paper is structured in 5 chapters. The introductory one is where the general idea, aims and goals of the research are developed. The second chapter includes all the necessary information on the innovative system architecture and operation. The third chapter is dedicated on the brief description of the current situation in EU and Greece as per the road safety. Within the third chapter, the stakeholder needs that justify the development and deployment of ODOS integrated road safety system are identified. The use cases produced based on accident analysis and stakeholders' needs are presented in the 4th chapter. Any conclusions and further research steps are depicted in the last chapter.

1. ODOS 2020 ROAD SAFETY SYSTEM

ODOS 2020 road safety system is coming to play a complementary role, alleviating modern cars from extra (standard) equipment, weight burdening and respective costs acquiring, purchasing and establishing new safety systems, making infrastructure smarter and more communicative. Following the current trends, the general idea is to introduce I2V and V2I[1] communication to a new era, entering infrastructure to a more active role, aggregating all information exchange equipment and providing data to road users. Apart from road safety assistance, the system will also incorporate another two human addressed applications 1) the individual variable message signs (VMS) providing personalised information, guidance and navigation necessary especially while handling critical situations with great potential for accident occurrence and 2) the virtual toll collection system for electronic payment, avoiding delays and extra costs, also guarrnteeing for equal charging according to distance travelled and road pavement burdening based on the respective vehicle type specifications. Last, but not least, the integrated system wil also incorporate an application addressed mostly to traffic management centers (TMC), informing, indicating and alerting the responsible stakeholders on road pavement state, damages, malfunctions and maintenance needs across a number of critical points on the transportation network as set by the users according to needs.

The aim is not to completely replace ADAS / ARAS or 'traditional' successful road maintenance techniques and services, but to develop, deploy, test, assess and finally optimise an integrated assistance system with complemtary functionality. The system is designed to be operational to all types of vehicles, minimising the purchasing and operational cost and also be equal and precise as per its use in all situations and conditions, guaranteeing accessibility by all types of users (through pads such as smartphones) and its applicability and compatibility to all types of infrastructure transforming it to a fits all solution.

The innovative solution will incorporate the establishment of strips markers on the road embodying micro nano sensors witch will be interconnected with a road side bridge (communication gateway). There will be sensors measuring and estimating several parameters from vehicle speed and trajectory, to the driving profile of each user and the environmental conditions in the atmosphere and on the road pavement (e.g. temperature, humidity etc). According to the integrated system's architecture (Figure 1), there will be seamless, continuous and real time communication and data exchange amongst the road users' devices, the traffic management center and the road infrastructure. The purpose of the functional architecture of the system is to provide useful insight about the way, in which the major structural modules and components interact with each other. The architecture consists of a sensor interface device, which is installed on the road and incorporates a microcontroller

[1] Infrastructure to Vehicle and Vehicle to Infrasrtructure

unit. This unit has all necessary interfaces for connecting all sensors that receive data measurements from the road. Furthermore, a wireless network communication module is included. This interface (transmitter device) sends the received data through Bluetooth network.

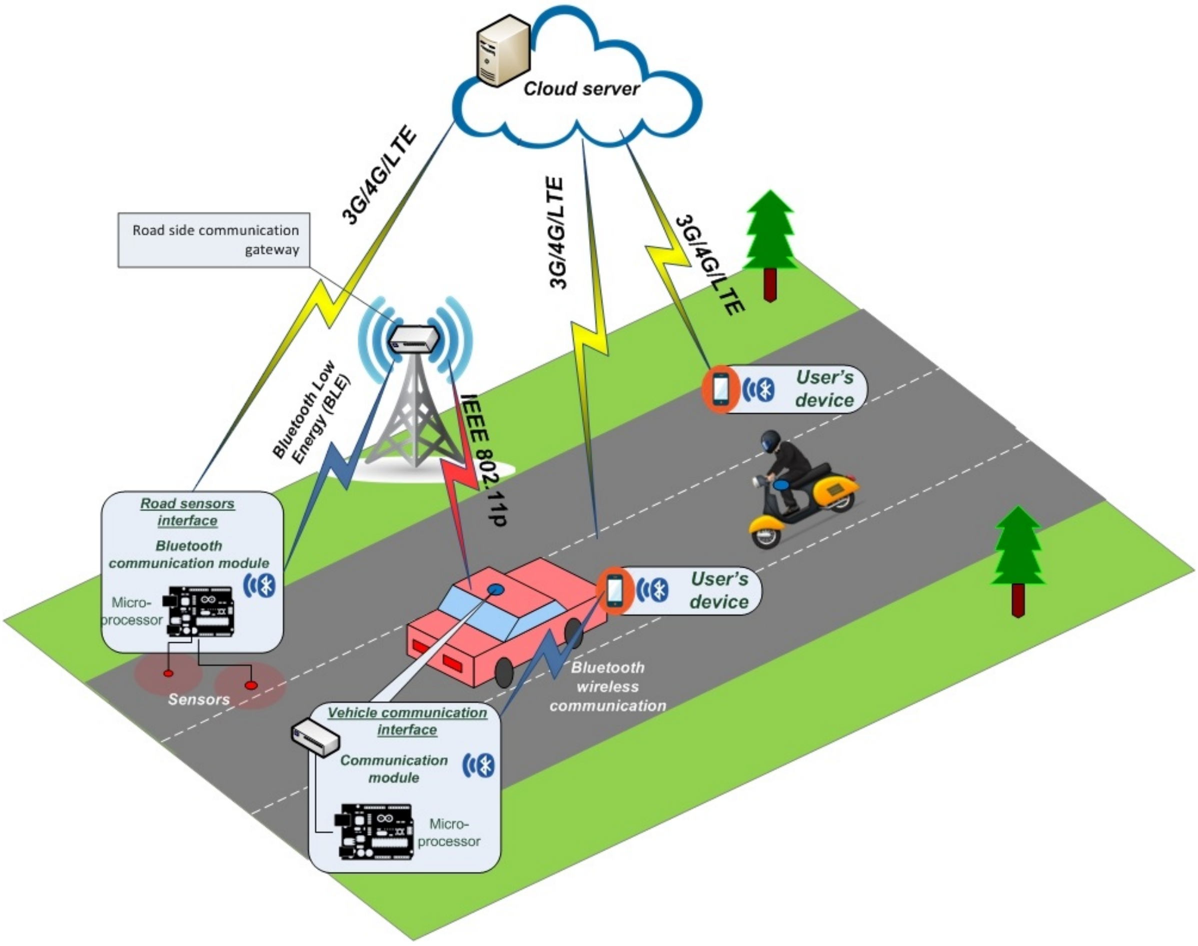

Figure 1: ODOS 2020 integrated road safety system architecture (Gogas et al, 2019)

Another communication gateway device, which is located at the edge of the road, consists of a microcontroller module and a network communication module. The latter is compatible with the IEEE 802.11p wireless communication protocol, designed to support intelligent transport systems applications, through its ability to transmit data to vehicles moving in high speed (>120km/h) and in the range of 300-1000m. The role of this communication device is to receive data from the aforementioned transmitterdevice through a low energy Bluetooth network and to further transmit the processed data according to the IEEE 802.11p communication protocol. Also, it supports wireless broadband communication 3G/4G/LTE for transmitting data to a properly configured cloud server.

A vehicle communication module, which supports the IEEE 802.11p protocol, is installed inside the vehicle. This module receives the transmitted data, and also transmits data from and to the mediation device, respectively. Information processing is undertaken by a dedicated embedded microcontroller which supports the IEEE 802.11p protocol. Bluetooth wireless communication is supported, as well.

The integrated technological solution will address all types of vehicles and will require zero to minimum vehicle equipment and respective cost, incorporating applications for road safety and wear monitoring and predictive maintenance (support to driver and traffic management centers through the provision of personalized notifications / information / warnings and recommendations on traffic, environmental and maintenance issues in real time), as well as virtual toll collection.

In the end, the goal is for the system to provide clear personalised information to the involved stakeholders / users without burdening or brainstorming or even distract them with too much information.

2. ROAD SAFETY IN EU AND GREECE

2.1. ROAD SAFETY IN EUROPE

In Europe, the EU's millennium top priority strategic planning on sustainable mobility incorporated a set of policies and measures towards the reduction of road transport fatalities towards "vision zero" with time horizon the year 2050, achieving to rapidly reduce the deaths (from almost 55000 in 2000 to 25000 of today) and to create the world's safer roads (49 fatalities / mio inh vs a global average of 174). This is why the EU has adopted the Vision Zero and Safe System approach (OECD, 2012). The introduction of smart systems integration, the upgrading of road transport network and the enhancement of driving skills through education and training has led to a considerable diminishing of the total number of fatalities in road accidents especially during the last decade. However, progress in reducing EU-wide road fatalities has stagnated in recent years (from 2013 until today), and the EU objective of halving road fatalities between 2010 and 2020 has been turned into an extreme challenge. So, the problem remains and the goals set have not been achieved yet (Figure 2).

So, even though road safety in the EU has improved greatly in recent decades and EU roads are the safest in the world (EU, 2018), the number of deaths and injuries is still far too high. In particular, there are over 25000 road accident fatalities at annual basis (equivalent to the population of a small town) or 70 deaths per day (equivalent to a large coach), which is 20% less than in 2010, but with no significant improvement since 2013, having another 135000 injuries, entailing in a total estimated socio-economic cost (health care and insurance compensation) of 120 bio € per year. The current situation calls for the intensification of efforts from all actors to make European roads safer, i.e. to eliminate deaths and serious injuries. This needs emergency but targeted action in the three road safety pillars based on road accident analysis, taking into consideration facts such as the ones listed below with special focus set on the protection of vulnerable and the young road users (Figures 2 and 3).

According to the EU's Strategic Action Plan on Road Safety (EU, 2018), throughout the framework period, the Commission (steered by a cross-DG coordination group) will engage with Member States and stakeholders to monitor and accelerate progress, for example by organising biannual results conferences and by promoting voluntary commitments, in particular in the context of an enhanced European Road SafetyCharter[2] (EU, 2018).

[2] The European Road Safety Charter is a civil society platform for road safety, created by the European Commission, with more than 3500 members today

Figure 2: Current situation and EU actions on road safety (EU, 2017 and 2018)

Based on the state of the art review (Worldbank, 2003; BBC, 2010; UN, 2010; WHO, 2010 and 2014; OECD, 2011 and 2015) and EUROSTAT[3] data base (2018 data):

- ➢ The human factor is responsible for the majority (90-93%) of road accidents.
- ➢ 10-30% of accidents are caused by distraction.

[3] EU statistics service

➢ 25% of road fatalities in EU are alcohol related.
➢ Speed constitutes the main factor for almost the one third of fatal road accidents.
➢ The greatest share of accidents occurs in rural roads (54%) and built up areas (38%) and only 8% of them happen in motorways.
➢ Pedestrians make up 11% of fatalities in non-urban areas.
➢ Half of those dying on the world's roads are "vulnerable road users": pedestrians, cyclists and motorcyclists and also road traffic injuries are the leading cause of death among people aged 15–29 years.

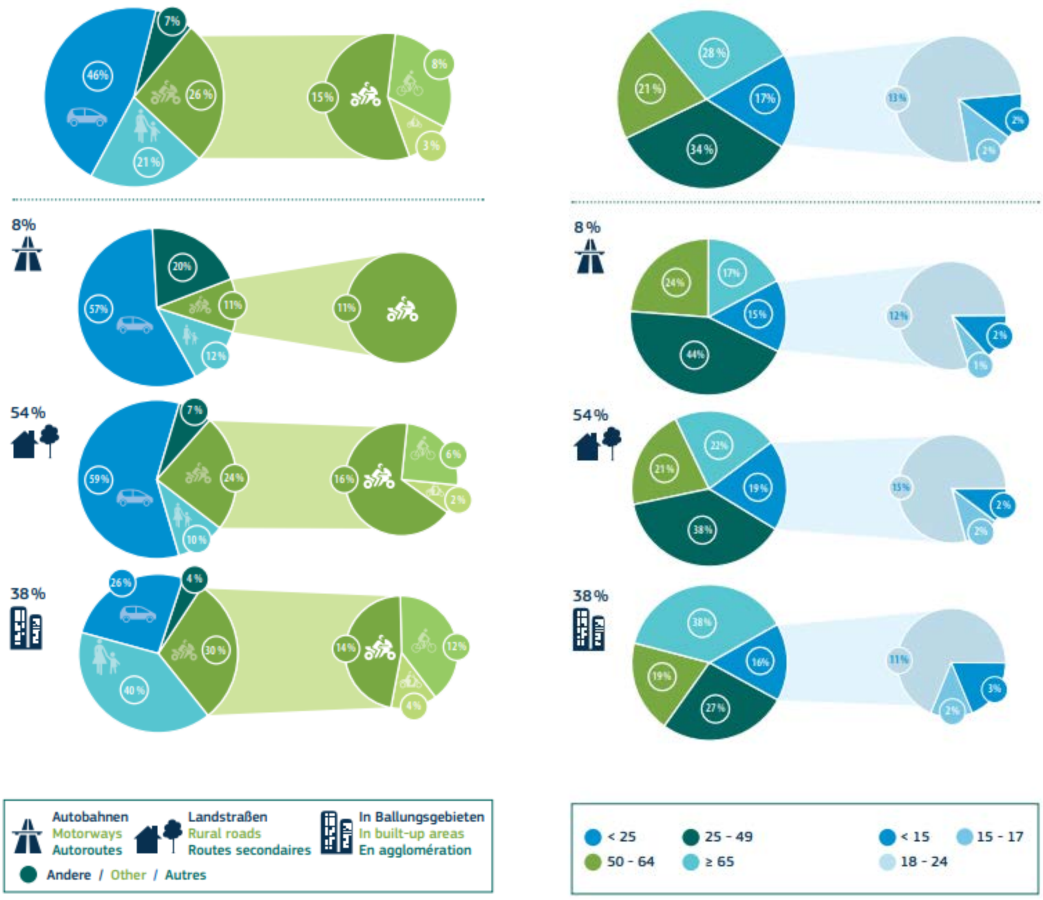

Figure 3: Current situation and EU actions on road safety (EU, 2017 and 2018)

It is estimated that motor vehicle collisions caused the death of around 60 million people during the 20th century, around the same number of World War II casualties. 91% of the world's fatalities on the roads occur in low-income and middle-income countries, even though these countries have approximately half of the world's vehicles. Only 28 countries, representing 416 million people (7% of the world's population), have adequate laws that address all top-five risk factors (speed, drink-driving, helmets, seat-belts and child restraints) (Worldbank, 2003; UN, 2010; WHO, 2010 and 2014; OECD, 2011 and 2015, EU, 2017 and 2018).

It is pinpointed that without action, road traffic crashes are predicted to result in the deaths of around 1.9 million people annually by 2020. On this direction, the EU's policy framework "vision zero" for 2050 includes an interim target of halving the road accident fatalities between 2020 and 2030, setting in action a set of legislative initiatives on vehicle and pedestrian safety and on infrastructure safety management, an integrated EU Strategic Action Plan on Road Safety identifying additional measures as well as communication on connected and automated mobility systems, also enabling Connecting Europe Facility programme to support projects in the Member States contributing to road safety, digitisation and multimodality.

According to the "safe system" approach (EU, 2018) adopted by the EU, people make mistakes but the aim is to ensure that this does not lead to fatalities or serious injuries. All the involved stakeholders should guarantee the improvement of the road safety level of all parts of the system, i.e. roads and roadsides, speeds, vehicles, road use – so that if one element fails, another will compensate. Today's proposals by the Commission focus on both vehicle and infrastructure safety, building on the positive experience of existing mandatory safety measures and on the emergence of new technologies and infrastructure (Figure 4).

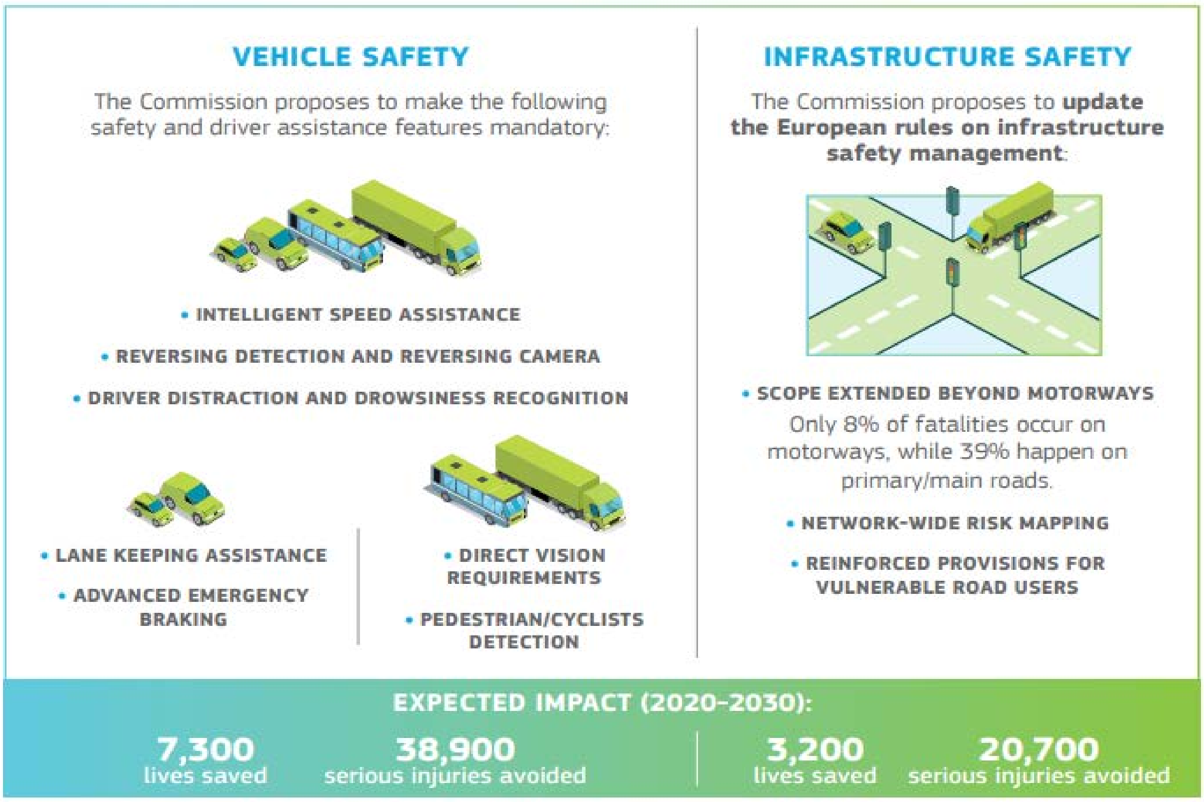

Figure 4: Road safety systems to become mandatory for vehicles and infrastructure in EU

The expected impact refers to more than 10500 lives saved and almost 60000 thousand serious injuries avoided (Worldbank, 2003; UN, 2010; WHO, 2010 and 2014; OECD, 2011 and 2015, EU, 2017 and 2018).

2.2. ROAD SAFETY IN GREECE

Based on ELSTAT[4], in 2017 (2018 data still in processing), in Greece a total of 10,848 road accidents resulting to death or injury occurred, recording a decrease of 4.2% in comparison with 2016, when the corresponding number of road accidents amounted to 11,318 (Table 1). The total number of road accidents casualties in 2017 recorded a decrease of 4.4% in comparison with 2016 (14,002 casualties in 2017, 14,649 in 2016). More specifically, the casualties of the injury-causing accidents that occurred in 2017 were as follows: 731 deaths, 706 serious injuries and 12,565 slight injuries in comparison with 824 deaths, 879 serious injuries and 12,946 slight injuries in 2016, thus recording decrease of 11.3% as regards deaths, of 19.7% as and of 2.9% as regards serious and slight injuries, respectively (Table 1).

Table 1: Road traffic accidents and casualties 2016-2017 in Greece (source: ELSTAT)

Table 1: Number of road traffic accidents and casualties, 2016 and 2017

	2016	2017	Annual change 2017/2016 (%)
Accidents	11,318	10,848	-4.2
Thereof fatal	772	679	-12.0
%	6.8	6.3	
Total of casualties	14,649	14,002	-4.4
Fatalities	824	731	-11.3
Total of injuries	13,825	13,271	-4.0
Serious injuries	879	706	-19.7
Slight injuries	12,946	12,565	-2.9

Out of the total number of 731 fatalities, drivers account for 69.4%, passengers for 14.5% and pedestrians for 16.1%. As regards the breakdown of data by gender, 84.1% of the fatally injured persons were males and 15.9% were females (Table 2). In addition, the assignment of road accidents fatalities by age group, category of the person fatally injured and by mode of transport is presented within Tables 3 and 4.

In Figure 5, an infographic of road traffic accidents in Greece is presented according to ELSTAT data base. Based on these data, it seems that most of the accidents involve male stakeholders (especially drivers) at the age group of 25-49.

As per the accident index, the region of Attiki is the most "dangerous" one with 1469 accidents / mio inh.

[4] Greek statistics service

Table 2: Road traffic accidents per gender and road user category (source: ELSTAT)

Table 2: Road accidents fatalities by gender and category of person fatally injured, 2017						
Category of person fatally injured	Total of fatalities	%	Males	%	Females	%
Total	**731**	**100.0**	**615**	**100.0**	**116**	**100.0**
% row	**100.0**		**84.1**		**15.9**	
Drivers	507	69.4	481	78.2	26	22.4
Passengers	106	14.5	58	9.4	48	41.4
Pedestrians	118	16.1	76	12.4	42	36.2

Table 3: Road traffic accident fatalities per age group and road user category (source: ELSTAT)

Table 3: Road accidents fatalities by age group and category of person fatally injured, 2017								
Age group	Fatalities	%	Category of person fatally injured					
			Drivers	%	Passengers	%	Pedestrians	%
Total	**731**	**100.0**	**507**	**100.0**	**106**	**100.0**	**118**	**100.0**
% row	**100.0**		**69.4**		**14.5**		**16.1**	
0-24	122	16.7	82	16.2	28	26.4	12	10.2
25-49	263	36.0	209	41.2	38	35.8	16	13.6
50-64	151	20.7	116	22.9	17	16.0	18	15.3
65+	192	26.3	99	19.5	23	21.7	70	59.3
Not specified	3	0.4	1	0.2	0	0.0	2	1.7

Table 4: Road traffic accident fatalities by mode of transport and type of area (source: ELSTAT)

Table 4: Road accident fatalities by mode of transport and type of area, 2017								
Mode of transport	Number of fatalities	%	Motorway	%	Residential area	%	Non-residential area	%
Grand total	**731**	**100.0**	**54**	**100.0**	**340**	**100.0**	**337**	**100.0**
% row	**100.0**		**7.4**		**46.5**		**46.1**	
Passenger car	285	39.0	34	63.0	78	22.9	173	51.3
Two-wheel vehicle	250	34.2	9	16.7	162	47.6	79	23.4
Pedestrian	118	16.1	4	7.4	83	24.4	31	9.2
Other type of vehicle	78	10.7	7	13.0	17	5.0	54	16.0

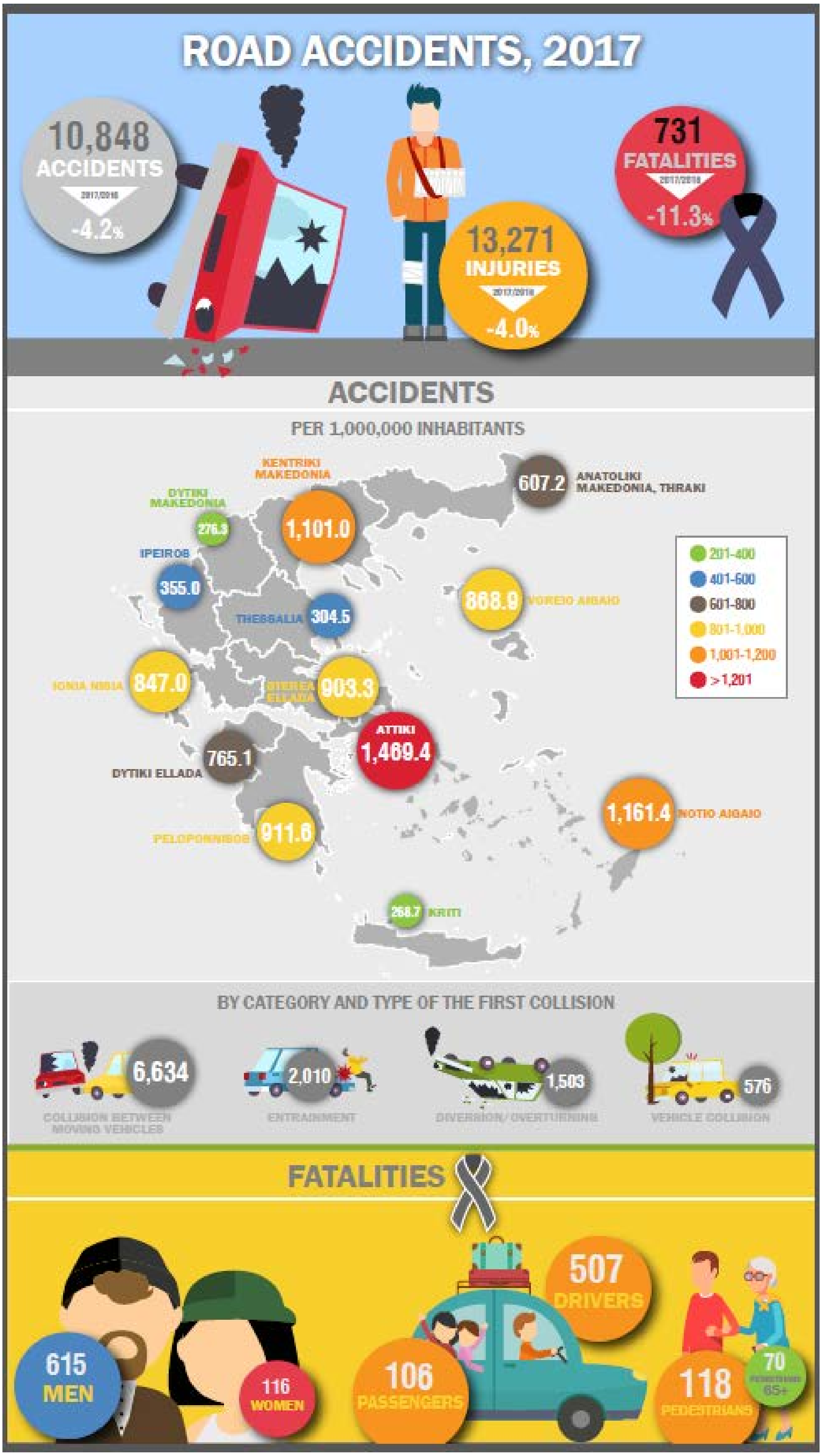

Figure 5: Road traffic accidents and impact (fatalities & injuries) in Greece (2017)

3. IDENTIFICATION OF NEEDS

The identification of the involved stakeholders’ needs has been accomplished through the elaboration of a questionnaire survey, both using electronic forms and personal interviews, based on three different questionnaires addressed to population target groups:

1. The quantiatative analysis questionnaire, addressed to drivers, transport / traffic controllers, legislation authorities, academia, infrastructure and equipment providers and operators.
2. The qualitative analysis questionnaire, addressed to drivers, transport / traffic controllers, legislation authorities, academia, infrastructure and equipment providers and operators.
3. The special questionnaire, addressed to experts on road safety.

A total of 41 representatives from all population target groups have corresponded. In an attempt to decode their contribution and replies, the following aggregated lists of statements is indicative (Gogas et al, 2019).

Concerning the technoeconomical characteristics of the system and its implementation:

- From the total four applications of the system, full priority is given to road safety, while the others (wear monitoring and predictive maintenance, as well as individualized VMS and vitual toll collection) are supposed to play a secondary role.
- The system should apply to all types of vehicles (private cars, buses, trucks etc.), new, modern and old type ones, requiring a budget of no more than 1000 - 2000€ per vehicle and 3000 - 6000€ per critical point.
- As far as the time horizon for implementation, the road safety and the wear monitoring and predictive maintenance are expected in due time (short-term), while the individualized VMS and the virtual toll collection system are due later (mid-term or long-term).

As per the most important concerns from the part of the stakeholders, they are focused on the:

- System’s degree of maintenance (time frequency, type of works, responsible stakeholders), in order for the system to provide reliability, seamless operation and provision of high level services.
- Energy autonomy.
- Time sustainability and viability of the system (funding for maintenance and / or upgrading, use of alternative renewable energy sources etc.).
- Collaboration framework with public organizations and bodies (legislative / regulatory framework and cooperation conditions).
- Privacy rules and requirements during information exchange (GDPR).
- Involved costs for equipment purchase and replacement.

- Achievement of high rate of virtual toll payment (responsible stakeholder needed for controlling and management).
- Degree of responsibility of each involved stakeholder especially in case of inadequate fidelity, correctness and updating of the individualized messages sent to road users, including delays in processing, entailing the occurrence of a respective road traffic accident.

In particular, drivers are concerned mostly about road safety issues, such as the stability of riders passing over the strips, driver / rider distraction using pads and smartphones while driving, as well as GDPR[5]. The legislation authorities express the need for the innovative technological solution to be compatible with current operation and technological standards and regulations (dimensions, colours, degree of reflexibility, friction etc.). The infrastructure and equipment providers and operators are mostly worried about potential failures due to material wear coming from hard everyday use, environmental conditions, natural disasters and cyber attacks, involving the respective costs for the maintenance, repairment and replacement of the system components. The academia is more focused on the technical and interoperability precautions and conditions, respectively, concerning the interrelation and adaptability of the new solution with the already set technological and communication standards, protocols, methodologies, services and methods. The traffic controllers are interested in the provision and maintenance of a reliable, updated and real time I2V and V2I communication system, promoting collaboration, complementarity and avoiding any kind of competitiveness. All the involved stakeholders are in favor of having a seamlessly operative system, eliminating failures, delays and interruptions, even during the replacement of the obsolete equipment with new one which entails the pausing of provided services and the engagement of road lanes for the installation / uninstallation of the strips and the associated equipment components (Gogas et al, 2019).

Finally, the most critical transportation scenaria for which the users asked for support and guidance through individualized information according to emerging needs are (Gogas et al, 2019):

- The involvement in / occurrence of a road traffic accident.
- The existence of traffic jam ahead due to traffic congestion.
- The adjustment (limitation) of speed due to obstacles (e.g. accident) ahead.
- The provision of guidance and navigation on alternative routes in case of emergency (e.g. road works for maintenance).
- The provision of real time information concerning environmental conditions (e.g. intense rain, heavy snow and / or ice and pavement failures, reduced friction etc.).
- The provision of information on upcoming tolls and alternative routes including cost, time and distance information.
- The provision of real time information on railway crossings, availability of parking lots and potential to accomplish automatic toll payment based on the vehicle

[5] General Data Protection Regulation, approved by the EU Parliament on April 14, 2016 and was enforced on May 25, 2018 in all EU countries (including Greece).

position and speed according to distance travelled, establishing interoperability with current toll collection systems.

4. USE CASE SCENARIO BUILDING

Within this section, the author makes a preliminary attempt towards the identification of use cases of the integrated I2V communication system, based on ODOS 2020 project facts and figures so far (1st semester), also taking into consideration:

- The current situation on road safety in EU and Greece (Section 1).
- The identification of involved stakeholders' needs and priorities (Section 2).
- The regulations, standards and constraints pertaining to the dimensions, colours, reflexibility, friction and other technical and operational characteristics concerning horizontal signs and road marking attributes (e.g. max height of 1 cm in motorways).

According to the questionnaire survey, the emerging needs of road users and especially focusing on the experts' opinion, the critical points, situations and conditions interrelated with road safety, road pavement maintenance, individualized VMS and virtual tolls were identified. So, discriminating scenaria for each one of the four applications of the system:

1. Pertaining to "road safety supporting driver" app, the critical points incorporate:
   i. Crossroads and meeting points, as well as points where there is change in the transportation network geometrical and / or operational attributes (e.g. motorway entrance / exit).
   ii. Black spots.
   iii. Areas where road works for maintenance take place.
   iv. Situations when the lane change is necessary or performed accidentally.
   v. Cases where there is considerable road wear or snow, ice, rain water etc near the strip entailing to low friction.
2. As per the "wear monitoring and predictive maintenance" app, the critical points include:
   i. Points with considerable road wear or damage and the Traffic Management Center (TMC) must be informed in order to engage and correspond.
   ii. Cases with infrastructure (and equipment) failure (e.g. bridge joints with road, tunnels etc.), to inform the TMC to engage and correspond.
   iii. Points with pavement height and surface differentiation.
   iv. Cases when the horizontal signs and road markings are not clearly visible by the road network users due to wear and the TMC needs to be engaged and correspond.
3. Concerning "individualized VMS", the critical situations are: the ones when the road user is in need for individualized real time information on road safety and guidance on traffic / transport management.
4. As far as the "virtual toll collection system", the critical circumstances are: the ones when the toll payment has to be made automatically, taking into consideration the type and dimensions of vehicle (pavement burdening), the travelled distance, the load factor, the time delays etc.

Based on the above mentioned, the preliminary use cases are briefly depicted within Table 5, below according to the respective scenario building (Gogas et al, 2019).

Table 5: Preliminary use case scenario building

Application	Priority	Use case	Details / Scenaria
Road safety supporting driver	Top	Crossroads and points where there is sharp differentiation in geometrical and / or operational characteristics of road (surface) transportation network.	Crossroads signed or not, with or without traffic lights and points where the stopping or change of trajectory of moving vehicles is necessary. Motorway entrance / exit. Warning for upcoming obstacle avoidance (e.g. parked vehicle on road side, accident, pedestrian etc. in combination with bad weather conditions and slippery pavement / reduced friction).
	Top	Black spots	Sharp turns with slippery pavement and / or reduced visibility. Sharp levelling (uphills and downhills). Statistically dangerous points (with high risk accident indices recorded).
	Top	Road construction ahead warning	Almost permanent construction zones engaging considerable pavement width and length with deviations and information provision on alternative routes, speed adaptation, delays etc. (applicable for bridge joints, different level junctions, tunnels etc. indicating max vehicle dimensions permitted and warning on differentiation of geometrical and operational characterictics of transportation network).
	Top	Road works for maintenance ahead warning	Semi-permanent construction work zone with or without deviation or alternative route engaging part of or all the pavement (available road lanes), also involving respective speed adaptation and provision of information on time and cost of alternative paths and on time of completion of works.
	Top	Lane departure warning	Indication of DOs and DONTs and guidance / navigation according to destination, upcoming danger or accident or critical situation warning (without need for GPS use and roadmarkings in really bad condition due to wear). Special care on autonomous driving support.

Application	Priority	Use case	Details / Scenaria
	Top	Low friction warning	Especially on turns with slippery pavement, reduced visibility conditions (in combination with information provision from agencies and political service concerning hard environmental conditions, upcoming obstacles ahead etc.).
Wear monitoring and predictive maintenance (for TMC)	Secondary	Pavement surface failures	Reduced friction, hollows, springles, cracks, different levelling etc due to environmental conditions, accident, normal wear from everyday use etc.
	Secondary	Failures on joints	Wear, failures, damage, gaps on ramps, joints with bridges, tunnels or differentiated level due to construction failure etc.
	Secondary	Differentiated (reduced) pavement height	Normal expected wear due to inadequate maintenance or neglection of replacement or environmental conditions or accident etc.
	Secondary	Horizontal (and vertical) signs and road markings	Normal expected wear due to inadequate maintenance or neglection of replacement or environmental conditions or accident etc.
Individualized VMS	Complementary	Full individualization	Provision of individualized guidance / navigation and warnings / alerts on upcoming danger and risks, based on vehicle's final destination.
Virtual tolls	Complementary	Full individualization	Upcoming toll station warning with provision of information on tarrifs and guidance / navigation to appropriate lane according to vehicle type. Depending on the transportation network operator's tariff policy. Interconnection, compatibility and interoperability with current payment and charging systems, methods and techniques.

5. CONCLUSIONS AND NEXT RESEARCH STEPS

Within this paper, an innovative integrated low budget solution is introduced in order to enhance road safety level setting the focus mostly in the smart infrastructure and its individualized real time communication with the users with use of IoT and C-ITS. Through it, the author supports the latest trend according to which the focus is transferred from vehicle to infrastructure in order to "lighten" vehicles as well as upgrade all infrastructures, making it more equal for all to have access to C-ITS system applications, as the cost will be undertaken mainly from infrastructure provider (social benefit and internalization of costs) rather than the driver (individualization). The innovation stands both on the technological equipment used for the development of the I2V and V2I communication system, but also on the fact that for the first time such an integrated and innovative masterpiece sets new rules pertaining to its socioeconomicaly equal accessibility by all types of users and its applicability and compatibility to all types of infrastructure transforming it to a fits all solution. The future planning incorporates the testing and application of the system to other means of surface transportation as well such as trains, in order to establish an interconnection amongst them towards the enhancement of safety level.

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