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Position Paper

Innovation in safety of the railway system, protection of the system and the citizens

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I. Introduction

The railway system is going through a continuous and profound process of transformation, dependent on the requirements of an increasingly demanding market in terms of capacity, punctuality, improved service quality and most importantly, safety and security. Innovation in the field of railway safety is essential for the development of this sector in Europe. Building on from the high levels achieved to date, the challenge is still the continuous improvement in areas such as operational safety, protection of people and equipment, threats from cybersecurity, or terrorism and vandalism. Global efficiency and the future of railway transport must be based on an ever-greater knowledge and understanding about the safe behaviour of vehicles, infrastructure and people, in order to mitigate or eliminate risk factors, especially those derived from automation and use of new technologies.

Research and innovation is set to make a significant contribution to the improvement of railway safety, in line with the objectives set out in the European Union White Paper and the ERRAC Rail Vision 2050 document which establishes the research and innovation needs of the sector; in addition to collaboration in the development of a sustainable transport system for international, national and regional routes.

The challenges to be addressed by innovation in railway safety include the ability to manage emerging risks and new threats, especially those associated with cybersecurity, terrorism or the effective integration of human factors in the system.

The Spanish Railways Technological Platform (PTFE) aims to create tools that contribute towards the scientific and technological development of Spanish rail and improved competitiveness, internationalization and sustainability of the sector, in line with Ministry of Economy and Business guidelines, parent body of the PTFE. The PTFE proposed the development of a positioning paper on “Innovation in railway system safety” based on the understanding that safety in all aspects should be a priority in the field of railway sector research and innovation. It is within this context that the current positioning document “Innovation in railway system safety: Protection of the system and the citizens”, aims to explore the innovation applied to operational safety, integration of human factors in the SMS, the challenge of safe infrastructure, risk mitigation in the rail environment, cybersecurity, decision making support systems for emergency situations, Big Data and the use and development of unmanned vehicles.

This document has been produced under the coordination of the area of Research, Development and Innovation at the Institute for Research on Safety and Human Factors (Instituto de Investigación en Seguridad y Factores Humanos) ESM. with contributions from business and universities members of the PTFE. This strategic document has been developed, bringing together a set of conclusions focused on the consolidation of rails´ competitive edge over other modes of transport.

II. SITUATION IN SPAIN

The growing demand for mobility, both passenger and freight, in a context of rapid urbanization, digitalization and market liberalization is setting the future development of infrastructure and rail industry systems and services.

Despite the impact and the scope of technological innovations for rail, in terms of allowing more dynamic, efficient and environmentally sustainable services, one should not lose sight of the significant technical and security challenges faced by the system. For this reason, it is necessary to promote and support a culture of safety in all fields of the rail system, including the development of regulations.

Safety is therefore one of key aspects of the railway system, given that it is essential to guarantee the safe transport of passengers and goods for this mode of transport to be effective and competitive in the current context. That's why, over the last few years, several research projects have been conducted focused on innovating the safety of the system, not only including the impact over passengers but issues such as cybersecurity and the use and development of autonomous vehicles.

This drive for innovation in railway safety, in legal terms, has led to the current European Railway Safety Directive (2016/798/UE 11th May 2016, recast version), or at a national level, the Railway Safety Regulation. (Reglamento sobre seguridad en la circulación en la RFIG (RD 810/2007)). These regulations establish the general framework about safety in the railway sector.

In recent years, at the research level, multiples projects and initiatives have been developed in different fields related with railway safety. With regards to the innovative use of data (Big Data, data mining) and its potential contribution to safety, it is important to mention the work of the Institute of Railway Research (IRR) at the University of Huddersfield (United Kingdom). This institution has published several works on the integration and analysis of data to improve safety in terms of signal overrun and driver assistance systems. Another line of innovative research focuses on the development of algorithms capable of extracting standardised information from accident reports in different languages and written based on different railway regulations and traditions. The railway industry is developing and attempting to implement image processing systems to address different safety related aspects (facial recognition in stations, detection of abandoned objects, identification of vehicles at level crossings…) to focus on and establish regulations and good practice for implementation.

Due to the rapid growth in digital technology and connectivity, cybersecurity has emerged over the last few years as a crucial field of intervention to guarantee a safer railway. In this regard, the newest trends have focused on implementing the most advanced cybersecurity systems and measures developed in other fields and establish a culture of cybersecurity amongst the different sector stakeholders.

Finally, it is worth mentioning the latest developments related to the use of unmanned vehicles, especially drones used for the surveillance of infrastructures and people. Examples of pioneering experiences in the use of drones include railway inspections on the Mediterranean corridor or the use of drones by NetworkRail (United Kingdom) to detect illegal access to infrastructure.

III. POLICY AND REGULATORY FRAMEWORK

There are currently a series of technical rules produced by different bodies, applicable to each specific railway case.

In Europe, it is the European Parliament who defines the applicable regulation, be it through directives or specific regulations. The development of rules for railways comprises the following directives:

- Directive (EU) 2016/797 of the European Parliament and of the Council of 11 May 2016 on the interoperability of the rail system within the European Union (recast)
- Directive (EU) 2016/798 of the European Parliament and of the Council of 11 May 2016 on railway safety (recast)

These Directives take part of the "Fourth Railway Package" being developed and implemented by the European Union Agency for Railways (ERA).

The process has started to make the Royal Decree project on operational safety and rail interoperability public, which aims to develop the Rail Sector Law of 29th September (Ley 38/2015) in relation to operational safety and rail interoperability on the Rail Network of General Interest and the different structural and functional subsystems that make up the rail system. This project transposes the two EU Directives and reviews different regulations in relation to operational safety stipulated in different regulations:

- Royal Decree 810/2007 of 22 June, approving the Regulation on safety in the circulation on the Railway Network of General Interest and the Royal Decree 1434/2010 of 5 November about interoperability of the railway system on the Rail Network of General Interest which will be entirely substituted;

- Royal Decree 2387/2004 of 30 December, adopting the Railway Sector Act which will modify certain articles related to railway safety;

- Order FOM/167/2015 of 6 of February, which regulates the conditions under which different subsystems (structural, railway lines and vehicles) come into service, is now practically revoked;
- Order FOM/2872/2010 of 5 of November, which determines the conditions for obtaining the qualifications allowing railway personnel to exercise the functions related to railway circulation safety as well as the rules governing of recognized training centres and centres providing medical checks to said staff which will be modified or developed in some of the articles;
- Order of 2 of August 2001, which develops article 235 of the Regulation of the Land Transport Law, with regards the elimination and protection of level crossings and Order of 19 of October 2001 which covers the omissions suffered in the Order of 2 of August 2001 (which will be substituted by this new Royal Decree).

Furthermore, it contains provisions which to date have not yet been regulated, such as crossings between platforms, boundary sections, or the development of the system of supervision of the National Safety Authority.

However, since the Project is still in the public information stage and, therefore, both Directives (2016/797 / UE and 2016/798 / UE) have not yet been transposed into the Spanish state, they are currently applicable to the national territory:

- Directive 2008/57/EC on the interoperability of the rail system within the Community (amended by 2009/131/CE, 2011/18/UE, 2013/9/UE, 2014/38/UE and 2014/106/UE).

- Directive 2004/49/EC on safety on the Community's railways (amended by 2008/110/CE, 2009/149/CE and 2014/88/UE), establishing the common conditions and criteria of the European rail systems, in terms of rail safety.

In the Spanish State, the Community documentation and legislation, under the scope of both regulations only apply to the Rail Network of General Interest (RNGI) and not to other railway networks (such as undergrounds, trams or regional railways not included in the RNGI), except in cases where the local or autonomous governments define own legislative frameworks that transpose, in whole or in part, the aforementioned Directives (e.g. Law 7/2018, of 36 March, on Railway Safety of the of the Community of Valencia).

Regarding the interoperability regulations applying, we should mention the technical specifications for interoperability (TSis) which set each sub-system, or part of a sub-system, to the satisfaction of the essential requirements and to ensure the interoperability of the EU conventional rail systems and the high-speed ones.

On the other hand, concerning functional safety, it is worth stressing the Common Safety Method on risk evaluation and assessment (CSMs), set by the European

Railway Agency (ERA), implementing the Directive on railway safety. It is developed by the Commission Implementing Regulation (EU) No 402/2013 of 30 April 2013 on the common safety method for risk evaluation and assessment (repealing Regulation (EC) No 352/2009), amended by the Commission Implementing Regulation (EU) 2015/1136 of 13 July 2015. The CSMs is aimed to harmonize the procedures and methods for carrying out risk evaluation and implementing risk control measures whenever a change of the operating conditions or new material imposes new risks on the infrastructure or on operations.

From a functional safety viewpoint, five regulations, including considerations about concepts and safety levels together with the way to deal with them, must be mentioned. There are:

- EN 50126. Railway Applications - The Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS). It is the most generic and significant for the railway as applied on all the subsystems of the rail system. The latest version in Spanish has been published on 2018 in two parts: the UNE-EN 50126-1:2018 and the UNE-EN 50126-2:2018. These new editions of the standard change and extend some concepts that will play a key role in the development of new products, such as, for instance, the concept of Safety Integrity Level.

- EN 50128. Railway applications - Communication, signalling and processing systems. Software for railway control and protection systems. It should be applied to the development, implementation and maintenance of any software related with safety, aimed to applications of control and protection of the railways. The central concept in this European standard are the five levels of safety integrity of the software (0 being the minimum level and 4 the maximum). The more dangerous consequences of a software failure, the higher level of safety integrity would be required. The current version in Spain is the UNE-EN 50128:2012.

- EN 50129. Railway applications. Communication, signalling and processing systems - Safety related electronic systems for signalling. It is applicable to the phases of specification, design, construction, deployment, acceptance, operating, maintaining and modification/extension of comprehensive signalling systems, and it also applies to subsystems and individual products included in a comprehensive system. Its application is usually considered in the development of the hardware, albeit with the new version of the 2017 standards EN50126, its content has been partially taken up by them. The current version in Spain is the UNE-EN 50129:2005.

These three main standards (EN 50126, EN 50128 and EN 50129) describe the concepts, methods and tools that must be considered when the specification and demonstration of the safety requirements, over the entire life-cycle in both equipment and infrastructure. They apply to new systems and to changes in working systems.

There is a fourth standard that, without being part of the package of CENELEC Safety standards applied to the railway sector, completes the previous ones in the field of communications:

- EN 50159. Railway applications - Communication, signalling and processing systems - Safety-related communication in transmission systems. The implementation of such a rule is a requirement of EN 50129 and EN 50126 when transmissions over not safe communication systems are involved with safety. The current version in Spain is the UNE-EN 50129:2011

In addition, it is important to highlight a fifth standard, published in 2017:

- UNE-EN 50657. Railways Applications. Rolling stock applications. Software on Board Rolling Stock UNE-EN 50657. This regulation adapts the requirements of EN 50128 for its application in the field of rolling stock, and introduces innovative concepts aligned with the new 50126 standards, so they can give an idea of the evolution that 50128 could have. In this regard, it should be noted that this regulation does not specify the requirements for the development, implementation, maintenance and / or operation of security policies, or protection services, that must be established to meet the security requirements associated with a security system. In this regard, since the protection of Information Technology (IT) can affect not only the operation, but also the functional safety of the system, to ensure the protection of Information Technology, specific rules must be applied of IT protection (ISO / IEC standards of the 27000 series, ISO / IEC / TR 19791, as well as the IEC 62443 series).

These standards, exclusively applicable in the railway field, are based on the international standards IEC UNE-EN 61508 Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems.

There is another standard widespread applied, revised in 2018, which specifies the operating conditions, design, construction and testing of electronic equipment shipped in Rolling Stock, as well as the basic hardware and software requirements that are considered necessary for reliable equipment and suitable for operation:

- UNE-EN 50155. Railway applications. Electronic equipment used on rolling stock. Sets requirements related to aspects such as environmental operating conditions, electrical conditions, electromagnetic compatibility, reliability and maintainability, design, components, construction, safety, documentation, tests, etc. This standard can be used as a code of good practice to cover the “technical safety requirements” (concept according to UNE EN 50126-2, which provides specific general guidelines on the application of standard 50126-1 for safety aspects).

IV. Integration of the human factor in the safety management systems

There is a broad work field for research and innovation on the integration of Human Factors in the railway 's Safety Management Systems.

The functional and technical interfaces in the system, subsystems and components have a high concern and influence on the human factors. Understanding the boundaries between the rail system or the system where changes are expected, its environment and interactions with interrelated subsystems is a requirement to understand how system failures or human errors could cause an accident and what are the dangers related to such failures.

Human factors are a central element in the RAMS management process. Progress is necessary in a more accurate determination of the impact on the systems of the characteristics, expectations and human behaviour.

Human influence has both random and systematic aspects. Every human being may be subject to occasional periods of decreasing performance. When these periods take place during the operation and maintenance phases of the system life cycle, they tend to cause random failures. When they occur in the initial phases of the life cycle, they can cause systematic failures in the operation phase. The risk analysis and assessment models, either quantitative or qualitative or a combination of both, must make a progress in clarity and simplicity, built on logics based on multiple factors of influence on behaviour, both in a generic and specific and contextual way.

Incorporating new methodologies and technologies for the identification and evaluation of risks that affect the human element (HMI), through the design of tasks based on principles of cognitive ergonomics that address the impact that people have on the continuing implementation of new technologies and automation, or also innovating the data collection models on safety and human factors (Big Data), allowing real-time decisions to be taken, models of data collection and exploitation (voluntary, independent, confidential and under criteria of Just Culture).

Innovating in the knowledge of the interactions between people and the rail system to avoid the introduction of new risks in automation processes, and with the variability of interfaces, hitherto unknown.

Promoting research on the influence of automation on human behaviour and its ability to react in complex systems or in degraded situations, incorporating the conclusions into the management and monitoring procedures of the SMS.

Adapting to the safety management system the models of analysis of human error in environments with high cognitive requirements, for the implementation of technological barriers able to mitigate this risk, particularly about prevention barriers versus protection barriers.

In increasingly changing environments and increasingly automated systems, it would be positive to investigate the limits and capabilities of traffic managers (control position operators) facing high specific demands or high demands of sustained attention with the consequent impact on their cognitive resources.

It is also necessary to innovate in the processes aimed to create a Positive Safety Culture for European railways, which reflects the interaction between the requirements of the safety management system (SMS), the way in which people interpret them, according to their attitudes and beliefs, and the way they really act.

The application of standard models for the analysis of the human factor in accidents, incidents and risk events should allow us to develop improved methodologies to increase human reliability in frontline workers. The conclusions must be lessons learned and incorporated into freely available international databases, and the recommendations must be used to modify the current norms and regulations

The incorporation of technologies that increase automation, data exchange and connectivity between infrastructure, vehicles and people, poses the challenge of developing user-friendly, friendly, intelligent and secure interfaces, able to mitigate the risk of human error.

Innovative solutions integrating the human factor into the railway safety management system must have a global vision allowing an intermodal transfer with other modes of transport and an inter-regional transfer that considers the different languages and cultures in the European framework

Humans can positively or negatively influence the RAMS of a rail system. This impact concerns the different life phases of the system and it has not yet been experimented with data collected from the positive impact of people in some phases of the life cycle decisive for risk management. The collection and analysis of this data allowing innovative inputs for resource management should be delved into the positive impact (Safety II).

Regarding the identification of some technological challenges we could highlight:

- Development of innovative technologies to limit the amount of damage and the impact of a security incident.
- Tools for security resilience.
- Development of tools capturing behavioural indicators in normal and / or degraded situations.
- Developments and innovations for emerging risk factors that challenge human limits and capabilities.

V. THE CHALLENGE OF SAFE INTERFACES

Over recent decades the Railway System has undergone a deep transformation, motivated by the new needs of a market increasingly demanding in terms of capacity, punctuality, improving quality of transport and, more importantly, in terms of safety.

These demands set by the market have led to the development of increasingly numerous and technologically complex components and subsystems/ components and subsystems that are increasingly numerous and complex from a technological point of view.

This fact testifies to a problem traditionally unnoticed: the interfaces between the different subsystems. We are particularly referring, therefore, to the boundaries between these subsystems and the conditions and requirements that some of them impose on the others, which must be identified and controlled to ensure a reliable and safe Rail System.

At present, the study of Interfaces between subsystems is one of the issues that require a greater analysis effort, as it is one of the main sources of failures and incidents of the current rail system.

One of the reasons that arouses the occurrence of faults related to the interfaces is the difficulty in identifying the relationships between the different subsystems, because, sometimes, these affectation relationships are not direct, requiring complex studies in which, usually, the collaboration between different technologists and companies is needed.

Depending on the types of subsystems involved, interfaces can be classified as follows:

- Interfaces between different equipment of the same subsystem (for example, interface between two railway interlocks each managed by different technologists).
- Interfaces between different subsystems (for example, between the energy subsystem and the communications subsystem, both part of the Rail System).
- Interfaces between different modes of transport (this is the case, for example, of intermodal stations where occasionally certain communications equipment could interfere with each other, evacuation routes being affected by the coexistence of both modes of transport, etc.).
- Interfaces between different modes of transport with other public or private services (for example, airlines or railways that may affect hospital equipment, communication stations, etc.).
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- Interfaces between systems and technological equipment, with people who design, operate, maintain ... and even with the procedures that must be followed by people who interact with the different equipment (this is probably one of the cases harder to analyse, due to the complexity derived from the study of human and organizational factors).

Based on the above, it can be concluded that is necessary to develop specific studies focused on the analysis of the interfaces between the different subsystems at all levels.

A first step could be the development of a generic matrix identifying the different interactions between all the subsystems and systems that could be related in some way with the Rail System. Thus, could be particularized for each of the possible specific cases that could exist in each of the applications of the system.

This matrix should highlight all possible interactions between the different railway subsystems, and between them with external systems, as well as a first classification of their criticality, according to safety and availability criteria.

The Human Factor Interface should be approached in a different way, since its integration as another factor in the matrix is complicated. The analysis of these interfaces is much more complex due to the involvement of many more parameters, (because of the complexity of human behaviour) than the ones you find in technological systems. A methodology for the study of the Human Factor should be developed in an integrated way with the safety study of the corresponding subsystems, which could be used in each specific application of the railway system.

VI. RAILWAY ENVIRONMENTS MINIMISING THE RISK FOR PERSONS

The protection of rail system users and non-users is one vital aspect for the integration of rail systems in urban and interurban environments. The main objective of the regulation should focus on guaranteeing the design of safe railway infrastructure, adapted to the environment and accepted by society. The railway stations, as a point of cohesion of the urban and geographical fabric of the territories and cities, will be the nodes of main action and interaction with society. Railway infrastructures should be conceived as legacies of city and territory that manage to fashion the society with efficient, attractive and safe transport systems

This aspect linked to the changing society and to the new concepts of mobility and the use of technologies opens an up-coming field of action and research that will transform the use of railway systems.

In railway systems, the lines of action and research respond to two problems for minimizing risks for persons:

- Urban transport systems (subway-train-trams, trams, commuter trains) where the railroad is part of the city fabric, and coexistence with other non-rail modes is essential to prevent risks.
- Regional or transregional rail transport systems (medium long distance and high-speed railway) where the action nodes focus on stations and crossings at level with other roads (level crossings).

IoT and Big data, as well as the massive use of mobile devices and the progress in the sensing and research in autonomous vehicles, will be applied to concrete measures that allow the design of safe systems:

- Identification of tools and projects of safe design that include the drafting of a risk matrix at the beginning of the project, which is updated and monitored during the project life cycle.
- For urban Surface transport integrated into the city:
  - 3D visibility analysis tools to improve safety from early stages of design and choice of layout from three points of view (drivers / machinists, pedestrians, private vehicle drivers)
  - Use of sensors and CTVC for information capture and driving assistance for drivers / machinists in coordination with the systems on board in trains.

- For stations:
  - Occupancy detection systems of platforms, trains, online access that allow to give information to emergency management teams, as well as to give information to the user (opportunity)
  - Pictures processing systems to guarantee the people safety (violent behaviour, robbery / theft, identification of suspects or people, identification of abandoned bags or suitcases ...)
  - Online communication and information systems for emergency and information in case of incidents.
  - Monitoring, transmission and image processing systems in level crossings, platform access and access to the tracks and promotion of integrated tools for the control and warning of alarms, coordinated with command posts as well as immediate action (sound, optical warning devices, etc...)

The response to the minimization of risks for persons offers opportunity to develop measures of social acceptance of railway projects and enhance their use. Among these, the following research and development lines should be developed:

- Mobile systems and applications for the transmission of information online to passengers of the services offered by railway (lines, services, stations, frequencies) in an integral way with other systems as well as their status (delays, occupancy, incidents., etc).
- Online sales and cancellation systems (electronic payment, mobile, etc ...) and integrated ticket purchase of several operators.

- Entertainment and leisure systems linked to railway systems, coordinated with telecommunications operators that increase the performance of rail systems on board.

VII. CYBERSECURITY IN THE RAILWAY ENVIRONMENT

Concrete identification of technological challenges: foresight

Technological challenges in the field of cybersecurity in the railway environment derive from the greater use of information systems for management, control and sensor systems.

Specifically, the technological challenges to be addressed are:

- A greater dependence on computer science, technology and information systems, which require a methodical management of the different assets, changes and cybersecurity in these devices, as well as the implementation of security policies, procedures and measures.

- Since the use of computer systems is increasing and the proliferation of devices too, as well as the interrelationships between them, regular audit and management of their security is required, facing their vulnerabilities (firmware update, installation of patches, audits of security, etc.).

- A greater dependence on external software, as well as its integration with the existing software ecosystem. There is a risk that, due to a vulnerability of the externally developed software, the primary system or other software related to it can be accessed. These risks require greater supervision of the code developed by third parties, as well as subjecting it to cybersecurity audits.

- Control access to WIFIs. It is necessary to manage properly their safety, as well as identify the users who access them in order to debug possible responsibilities for crimes that can be committed through them (online fraud, child pornography exchange, illegal downloads, etc.).

IIdentification of projects to develop

To manage the risks in the field of cybersecurity identified in the previous section, it would be necessary to develop the following projects:

- Develop a Security Master Plan that identifies the risks affecting information and systems. The Plan must carry out a risk management, with the aim of remove or reduce the level of risk to an acceptable threshold.

- Implement an information security management system allowing a sustained security management over time. Reactive management is sought facing the changes in assets and threats, both external and internal.

- Carry out audits of the systems and software before they take place in order to avoid vulnerabilities that can be used by third parties to obtain illegitimate access to the systems or the information processed.

- Conveniently secure access to WIFIs, establishing a user identification procedure, usage policies as well as the preservation of the logs needed to trace.

VIII. HELP SYSTEMS FOR DECISION MAKING IN CRITICAL SITUATIONS. SEARCH FOR NEW SYSTEMS

In the railway world the control of all the variables affecting train safety is crucial. Train safety can be focused from probable incidents, differentiating by type of operation (HS, inter-city, metropolitan lines, etc.), from rolling stock or infrastructure, rail track, tunnel, station, etc.

However, the user approach involves the polarization of various other aid decision support systems in critical situations to comprehensively address all the factors that allow to avoid impacts and prevent them, and not only act when the incident has occurred. This leads to digitalize the methods of detection and resolution of incidents on board trains, and on associated infrastructure (tunnels, bridges, stations, etc.) to be able to prevent and solve emergency situations that may arise. It also leads to establish optimum action protocols when the non-probability of an incident occurs implies emergency action. This approach requires the digitalization of the railway operation for this purpose.

On the other hand, and in the face of the risk of terrorist attacks, it is necessary to protect and guarantee the security of large infrastructure such as buildings, railway infrastructure, airports, etc. This is especially important in territories where crisis situations trigger chain destabilizations that can seriously affect many sectors of society.

In the railway industry, with a long tradition of commitment to safety, there is, however, a great gap in the application of technologies in crisis management processes and in the anticipation, detection and prevention of the situation. Thus, having an organized volume of information and using its management systems will be crucial at all stages, allowing the optimization of planning and decision making.

VIII. 1. Information systems inside and outside of emergency evacuation facilitation trains

Concrete identification of technological challenges: foresight

- Digitization allows to extend the degree of security in emergency situations if it can reach each passenger, through an "individualized" and non-collective signalling, coexisting with photoluminescent signalling. It should ensure not only accessibility to mobility but the preservation of security. This is a field in which technology has a long way to go.

VIII. 2. Specialized models for the protection of people against terrorist attacks

The train is a means of transport used daily by the most diverse types of passengers. In an emergency it is important that all passengers can immediately identify emergency and firefighting equipment, as well as evacuation roads. This is where security signalling systems come in. The key feature must be to ensure that in an emergency information and signalling must be able to fulfil their purpose: to preserve the safety of passengers. This security passes, among other measures, through the installation of emergency and firefighting equipment. But for use these devices in an emergency, they must be properly identified. For this purpose, the luminescent signage, adapted to low light conditions, and recognizable for various types of visual impairments, must be designed beyond the applicable regulation, which is detailed and provides extensive guidance to design the implementation.

Below is a list of applicable regulations: Law 31/195, Law 38/201 on the Railway Sector, Royal Decree 443/2001, Royal Decree 485/1997, Resolution of 22 March 2001 from the General Directorate of inland transport, publishing the Resolution adopted by the Council of Ministers on 5 March 2010, adapting the current situation of rail transport to Regulation (EC) No 1371/2007 of the European Parliament and of the Council of 23 October 2007 on rail passengers' rights and obligations. UNE 23032. UNE 23 033, UNE 23 034. Escape routes. UNE EN ISO 7010/2012, ISO 7010:2011, UNE 23 035 UNE 23 035 Part 2, UNE 23 035 Part 3. UNE 23 035 Part 4, Regulation No 107 of the Economic Commission for Europe of the United Nations (UNECE), Regulation (EU) No 181/2011 of the European Parliament and of the Council of 16 February 2011. ISO 3864 Parte1 a 4. ISO 7010. ISO 16069, DIN 67 510, etc.

In the design of action in emergency situations, it is important to develop and implement a concurrent work between the builders and experts in this type of signalling. This is the main internal and external function of safety signalling, and the photoluminescent as the most used: to get passengers, even in a situation of absence of light, an immediate and unequivocal message about the location and use of these equipment. Photoluminescent signage is still of the greatest importance in marking evacuation roads.

State Secretariat for Security Instruction No. 6/2017 provides recommendations on self-protection and action criteria to face terrorist attacks.

The design of a system of alert levels provided to the level of risk detected at any time is fundamental, as well as defining for each of them with enough flexibility, a battery of measures allowing police action to be graded according to the risk. In the railway system it is especially necessary to evaluate measures that not only determine the action when the terrorist attack has already taken place, but also allowing anticipation. In addition, if the attack takes place the system must allow a coordinated action protocol, not only for police forces, but for evacuation and emergency, health and social protocols. In this sense, it is appropriate to design detailed analysis systems that consider the type of terrorist attack risk. It should start from the analysis and detection of anomalous situations and behaviours, allowing a modal analysis to be carried out by environment (rails-units-stations-tunnels, etc.), by severity of a hazard's impact and by criticality of action (from mass evacuation with a wide territorial impact to local). This tool may use as a starting point the AMFE methodology, widely known, but applied to terrorist attacks, reaching a comprehensive risk assessment model analysing and presenting contingency for each phase or stage of the risk. (Revista Científica General José María Córdova, Bogotá, Colombia, January-June, 2017 Tecnociencia - Vol. 15, Nº. 19, pp. 269-289 ISSN 1900-6586).

This process must be subject to permanent review within the framework of existing coordination and operating structures. In some way, technological prevention systems must be combined with those of management and coordination, from operators to security bodies and agents, hospitals and local authorities. The emergency response involves many people: rescue teams, responsible at different levels of government, citizens, etc.

Concrete identification of technological challenges: foresight

- Development of dedicated, harmonized and advanced cybersecurity solutions for smart cities, adopting common approaches with all stakeholders and not only with or from the railway operation. In this way, IoT ecosystems (instead of distributed IoT infrastructures) can be constructed by adopting common approaches in their security management against terrorist attacks, achieving economies of scale (for example, avoiding duplication of efforts in the analysis of IoT data, selection of cybersecurity controls, etc). A simpler level of integration through the development of a security framework against holistic terrorist attacks for smart cities, benefiting their infrastructures and anticipating anomalous attitudes and behaviours.

VIII. 3. Models and tools in real time

Real-time models and tools should be able to mitigate the impacts associated with anthropic risks. They must allow, regarding each emergency, adequate information at any time, excellent coordination between the different relief and rescue groups, the intelligence in the communication of the orders and the information to the different participants, including notices to the population.

We could summarize the general objectives of real-time management systems as: the minimization of risks (to people, the environment and the operation, physical or digital cyber-risk systems), the monitoring and supervision of the state of the safety and risks, the prevention of risk situations and, finally, the governance in emergencies. A Decision Support System must collect, analyse and present information. Critical assets should be known and prioritized. The tracer variables of the various risk and safety situations, their vulnerability, their maintenance, data analysis and the determination of defined action protocols to the control centres of the railway operators must be selected. This system does not make decisions by itself but manages and presents the information in different types of data formats, which help the decision-maker to take the most accurate judgement and action. On the other hand, it must have the capacity of an “expert system” that allows learning from past actions and events and exploring other possibilities for future actions. From the point of view of emergency care, the interoperability of platforms is essential for the correct evolution of all technological developments. The use of web portals as elements to access information in real time allows to provide an interoperable service support environment, providing the integration of new data access services or real-time data processing, in other words, the portal can adapt to the situation while the emergency event takes place.

It is necessary to pay special attention to the fact that the systems must work by accessing, not only through the platform or web, through the Internet or Intranet, but also in offline mode and be fully operational. This is essential in order to continue to have support for decision-making in situations of serious disasters, in which internet or data networks are not available. Updates will be made once a connection mode with the server is retrieved, either through public networks or through the data connection of private radio networks (DMR, TETRA, TETRAPOL) and, of course, through any other private network available as corporate network, Wi-Fi, etc.

Identification of technological challenges: foresight

- The railway operation must be equipped with effective security and detection systems for terrorist activities. The artificial vision and intelligence and the mechanisms of simulation and anticipation of anomalous “states”, with detection phases, risk analysis, proposal of action and specific protocols of coordinated action according to the impacts, will be approached holistically in Detection Systems and Emergency Prevention against Critical Security failures, by failure mode, intrinsic related to infrastructure dysfunction, human failure or terrorist activities. They must have systems for detecting and anticipating anomalous behaviours and suspicious activities, with specialized integral security systems adapted to the operation (for high speed, for medium distance intercity, metropolitan and freight, and associated infrastructure), including the impact of human factor in security

Identification of projects to develop

- Expert systems. Gaming simulation for real-time management of emergencies

IX. DATA MINING AND BIG DATA: APPLICATION TO SAFETY DATA COLLECTION

The current rail systems are composed of complex technologies, where a wide range of human actors, organizations and technical solutions are applied. To control such complexity, a viable solution is to apply intelligent computer systems and make use of technologies such as Big Data, being the optimization of the life cycle of rail assets one of the challenges of the sector.

In this environment, the so-called 'Industry 4.0' refers to the fourth industrial revolution, characterized by intelligent systems and industrial solutions based on the Internet. The transport sector, especially the railways, has largely adopted Industry 4.0. The use of new and emerging technologies is leading to better service quality, new savings, greater use of resources and efficiency. It has also facilitated the development of new services and business models based on the capacity of the industrial internet and the analytical capabilities of Big Data.

The current trend of automation and data exchange leads us towards the adoption and adaptation of new and emerging technologies, in a way that allows us to reach new levels of effectiveness and efficiency. In this sense, technologies such as Big Data allow obtaining information through the data generated on the road, which allow obtaining information on critical elements of the infrastructure, improving decision making or even automating decision making.

The advantages of using Big Data are reflected in:

- Data scaling (Volume)
- Different types of data (Variety)
- Analysis of information in real time (Speed)
- Reduce uncertainty of data quality (Truthfulness)

This large data on the railways come from interconnected stakeholders that provide intelligence to the rail system. The complete Big Data architecture includes cyber systems, Internet of Things (IoT) and Cloud Computing, which would work together to create 'smart railways

A real business case applicable to the sector is predictive maintenance, real-time alarm management, the integration of auxiliary industrial systems (signalling, location, etc.), the diagnosis and location of incidents ..., all areas of application that they are generating considerable enthusiasm by offering better operation and maintenance through self-learning and intelligent systems that predict failures, make diagnoses and activate maintenance actions.

In conclusion, data are currently generated in railway networks of all fields, those related to rollingstock, with infrastructure, with end users ... which, today, are kept in silos and are treated individually, offering a reduced and skewed view of the environment. Despite the existing risks for the field of data management (GDPR, open data philosophies ...) industry 4.0 is moving to increase collaboration, efficiency and improve customer service, through the analysis of this Big Data.

X. USE AND DEVELOPMENT OF UNTRIPULATED VEHICLES (AIR AND GROUND)

The application of platforms based on unmanned vehicles, computer vision and data mining, can respond to the current problems of the Spanish railway system in relation to the protection of the system and citizenship, a fact manifested by the companies developing these technologies.

The railway is indeed what is known as a complex system of systems, in systems engineering, composed of different technologies such as signalling, communications, civil engineering, energy, rolling stock, etc. that interact and have interfaces at all levels. Additionally, and to add more complexity, the different interfaces and levels are managed by multiple companies in a normally public and private mix. In summary: the management of the railway system has a very important technical and administrative complexity. This is possibly the reason why most major railway infrastructure projects worldwide are delivered with delays and cost overruns, according to a study by the McKinsey consultancy in 2016. In addition, the rail system faces security incidents and accidents due this technical-administrative complexity. Broadly speaking, these are the two main challenges that the railroad faces to, on the one hand, make it more attractive for the passengers and, on the other, more attractive, as capital investment for governments and private companies.

The most significant challenges for companies that develop these technologies are:

- Increasing security to make transportation more attractive to the user.
- Reduction of costs and construction times to make transportation more attractive to governments and private investors.

Both challenges can be addressed using new technologies that have matured over recent decades, such as the intensive use of unmanned vehicles, computer vision and data mining.

The proposals of one of these companies to attack the problems identified in the previous section are based on three fundamental pillars:

- Data capture of the state of the railway corridor through non-invasive means.
- Generation of digital models of the railway infrastructure accessible remotely.
- Automated processing of the data taken.

Capture by non-invasive means

Currently, the supervision of the railway corridor, whether under construction or in operation, is mainly based on the visual observation of the operators working on it. This is an obsolete method for performing such work for the following reasons:

- It requires physical access to the railway corridor, something that is not trivial in remote areas and that endangers the operator both in corridors under construction, due to the presence of heavy machinery, and in corridors in operation, due to the presence of traffic and maintenance vehicles.
- It represents repetitive tasks of very little added value. Indeed, visual supervision is a somewhat subjective measure subject to the experience / knowledge of the operator.
- Represents tasks subjected to possible human error

That is why the data capture must be done with non-invasive means, such as unmanned vehicles, both aerial and land; or, even, by taking data on vehicles that make daily circulations in the corridor.

Computer vision

Once the data are obtained by non-intrusive means, the digital models of the infrastructure are generated. Data could be a direct result of the application of technologies such as mobile mapping, LIDAR, image recognition, photogrammetry, etc. The final requirement is to be able to have an exact model of the infrastructure in digital format, accessible remotely by all companies / people working on a railway project. This methodology is in line with BIM technology and tries to create a single source of truthful information, starting point for the construction, operation and maintenance of the infrastructure.

Data mining

The amount of data that can be captured with current technologies is huge and impossible to analyse by human means. Therefore, it is necessary to create an automated data processing technology to be able to extract the required information from the corridor. The application of image and object recognition techniques and machine and deep learning on photogrammetric or 3D models is one of the unequivocal bets of the company that develops this technology. This way you can know the precise state of the railway corridor without having to access it and without an evaluation depending on the subjective measures of an operator.

Applications and references

This proposal would allow the reduction of security problems, costs and commissioning times of a railway corridor by acting, in broad strokes, in the following areas

- Precise planning when knowing the land before tenders.
- More precise and effective bidding process when knowing the exact state of the land and / or ancillary installations.
- Reduced design phase by knowing precisely the characteristics of the land and / or ancillary installations
- Automated and efficient contract management. Indeed, it would be possible to know exactly and impartially the concrete follow-up of a railway infrastructure contract, expediting the fulfilment of the contract and the resolution of disputes. Transparency and traceability would be total and would allow an evolution towards an automated legal framework using blockchain technology.
- Increased security by being able to trace all installation requirements automatically and verifiably.
- Increasing operating safety by knowing the state of the infrastructure prior to the circulation of vehicles.
- Reduction of operating and maintenance expenses by being able to plan resources more efficiently, knowing in detail the state of the infrastructure and ancillary installations.
- Reduction of the installation time of new security and traffic management systems, such as CBTC and ERTMS, knowing exactly the characteristics of the corridor (such as the kilometric point or the gradient). These systems increase traffic safety and make it more efficient and potentially more attractive to the end user with fewer accidents and more traffic frequencies.
- Possibility of automating maintenance contracts.
- Possibility of implementing predictive maintenance by generating real data on the state of the infrastructure.

- Reduction of personnel who need to access the corridor, increasing its safety and reducing occupational accidents in the field of the railway sector

This disruptive technology is a reality that has already been implemented in the following projects:

• High speed between Monforte del Cid and Murcia.
• High Speed Maintenance in sections between Madrid-Toledo and Madrid-Seville.
• Installation of new signalling systems in Barcelona R1 commuter line between Hospitalet and Mataró.
• Installation of new high-speed online signalling systems between Casablanca and Kenitra.

XI. Conclusions

1. The overall effectiveness and future of rail transport involves acquiring more and more knowledge about the safe behaviour of vehicles, infrastructure and people, which allows mitigating or eliminating any source of risk, especially those derived from the automation and introduction of new technologies.
2. Although the introduction of innovative technologies is going to have a great impact and scope, allowing rail services to be more dynamic, efficient and environmentally friendly, we must not lose sight the rail system faces major technical and security challenges. This requires promoting and boost the culture of safety in all areas of the railway system, including regulatory development.
3. The process of public consultation of the Project for Royal Decree on operational safety and railway interoperability, which aims the development of Law 38/2015, of September 29, of the Railway Sector, on safety and interoperability of the Railway Network of General Interest and of the different structural and functional subsystems into which the rail system is divided, has already begun.
4. The study of Interfaces between subsystems is one of the issues that require a greater analysis effort, as it is one of the main sources of failures and incidents of the current rail system.
5. Human factors are a key area in the RAMS management process. It is it is time to achieve further progress in a more precise assessment of the impact of the characteristics, expectations and human behaviour in the systems.
6. Adaptation of the safety management system to the models of human error analysis in environments with high cognitive requirements, for the implementation of technological barriers able to mitigate this risk.
7. In order to manage cybersecurity risks, the development of a Security Master Plan is required. In this Plan, risks related to information and systems should be identified and their management carried out in order to eliminate or reduce their level to an acceptable threshold.

8. For the innovation of aid systems for decision-making in critical situations, it is proposed to develop expert systems and simulation through Gaming for real-time management of emergencies.
9. Nowadays data are generated in the railway networks of all kinds, related to rollingstock, infrastructures, end users… They are kept today in silos and handled individually, offering a reduced and skewed vision of environment. Despite several risks in the field of data management (GDPR, open data philosophies ...), industry 4.0 is moving to increase collaboration, efficiency and improving customer service, through the analysis of Big Data.
10. IoT and Big data, as well as the massive use of mobile devices and the progress in the sensing and research in autonomous vehicles, will be applied to concrete measures that allow the design of safe systems.
11. Innovation in the use of unmanned vehicles (air and land) could contribute decisively to the following objectives:
    a. Increasing security to make transportation more attractive to the user.
    b. Reduction of costs and construction times to make transportation more attractive to governments and private investors.
12. Both challenges can be addressed using new technologies that have matured over recent decades, such as the intensive use of unmanned vehicles, computer vision and data mining.
13. Railway infrastructures should be legacies of city and territory providing society with efficient, attractive and safe transport systems. This aspect linked to a changing society and to the new concepts of mobility and the use of technologies opens an imminent field of action and research that will transform the use of railway systems.

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