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INTERNET OF VEHICLE INFRASTRUCTURES AS AN INNOVATIVE APPROACH IN ROAD SAFETY KEY PERFORMANCE INDICATORS DATA SHARING

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Abstract: Road safety key performance indicators (KPI) are the indicators reflecting those operational conditions of the road traffic system that are influencing the system's safety performance. The automated process of KPIs data collection, accompanied by advanced smart solutions in urban areas, smart in-car solutions, etc. is expected in the near future. The European Commission developed a set of common methodological guidelines for the data collection and estimation of the KPIs in the European Union countries. Internet of Vehicles is an emerging technology approach that can be expected to become a promising solution to overcome serious traffic issues. The objective of this paper is to explore the process of road safety KPIs data collection and sharing using Internet of Vehicles networking. In that context, a star rating of driver's behavior could be done, and such data could be shared aiming to better improve drivers' safety behavior.

Keywords: road safety, internet of vehicles, key performance indicators.

1. Introduction

At the beginning of the Second Decade of Action for Road Safety (proclaimed in the United Nation (UN) resolution *Improving global road safety*, A/RES/74/299, September 2020), the fact is that the world has not reached the target set in the previous road safety decade of action. According to the European Commission (EC) (2020), the number of road fatalities reached 1.35 million in 2016. As for the European Union (EU), 22,660 people lost their lives on EU roads and around five times more suffered serious injuries with life-changing consequences, in 2019 (Adminaite-Fodor et al., 2021). This is an unacceptable and unnecessary human and social price to pay for mobility. Moreover, the progress in reducing road fatality rates EU-wide has stagnated over recent years. In order to better understand road safety problems in its member-states, the EC has adopted the EU Road Safety Policy Framework 2021-2030, in which special emphasis has been placed on monitoring the road safety progress, at both the individual Member States and EU level. To that end, a set of eight road safety key performance indicators has been suggested to be collected under a common methodology to better grasp different road safety issues

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and define the earlier goal-oriented actions for improving the road safety (European Commission, 2020a).

Over the last years, digital technologies have been transforming the economy and society, affecting all sectors of activity, especially those of transport and mobility. With an aspiration to become a global "digital data hub" the EC adopted the European strategy for data in 2020 (European Commission, 2020b). Building on the ongoing experience of the research community with regard to the European Open Science Cloud (EOSC) the EC will support the establishment of nine common European data spaces, including also a common European mobility data space. Based on the growing need to facilitate data-sharing/reuse, the EC has initiated the development of the EOSC since 2016 (Anagnostopoulou et al., 2020). The aim was to link the existing infrastructures from research sectors and Member States (MS) in order to ensure sharing of research data (European Commission, 2018a). The EOSC is the basis for a science, research and innovation data space that will bring together data resulting from research and deployment programs and will be connected and fully articulated with the different sectoral data spaces (Franklin et al. 2020; European Commission, 2020a). Within this context, the need for establishing a Transport Research Cloud (TRC) as a subset of the EOSC platform has already been declared (European Commission, 2020c; 2018a).

Recent progress in the development of Artificial Intelligence (AI) tools, supported by the development of cloud computing technologies and 5G mobile communication networks is a strong driving factor for upgrading traditional Vehicular Ad-hoc Networks (VANETs) into flexible heterogeneous Internet of Vehicles (IoV) global communication architectures which are expected to satisfy strict communication requirements related to the networking of a wide range of entities (vehicles, pedestrians, infrastructure equipment, personal devices, sensors, etc.) for the needs of future IoV applications. Therefore, IoV could be seen as an extension of the dedicated VANETs by upgrading and integrating them with the forthcoming Internet of Things (IoT) technology. The central issue for this concept to be practically feasible is to design the proper and reliable telecommunication infrastructure to fulfill the Quality of Service (QoS) requirements of future IoV applications. Such level of coordination will be necessary for the provision of the pace and the critical mass of road safety data required for comprehensive and in-depth analysis of the road safety situation in a territory, detection of emergency problems at an earlier stage, evaluation of road safety measures, exchange of best knowledge, etc.

This paper is an extended version of our preliminary work (Miladić-Tešić et al., 2022). The objective of the paper is to explore the development of a road safety KPIs data ecosystem that could be integrated into the TRC as a subset of the EOSC platform. The Section 2 reviews the basis and road safety KPI in the EU and Serbia. The Section 3 presents IoV models of connectivity and integration of some software and cloud technologies into a single platform. The open data platform for road safety KPIs and a proper governance plan are explored in Section 4. Finally, conclusions are drawn in Section 5.

2. Road Safety Key Performance Indicators

2.1. The Basis of Road Safety KPI

The development of the scientific thinking on road safety performance indicators has been running very quickly over the last decade. Further on, with the development and comprehension of road safety issues, methods for comparing road safety situations in specific areas have been also developed. Efforts are being made today to improve the traditional monitoring method of road safety situation based on the monitoring of road accidents and their consequences. The development of the modern, more human method of road safety management is under way worldwide, based on the monitoring of a variety of safety (key) performance indicators. Monitoring of safety performance indicators (in addition to monitoring road user's attitudes) is one of the modern approaches having the highest potential for road safety improvement. Until now, in a not-so-insignificant number of countries, road safety management has been based only on road accidents and their consequences. From European Transport Safety Council, 2021 via the most important projects dealing with the research of safety performance indicators in a territory, up until the third Mobility Package Europe on the move – Sustainable Mobility for Europe: safe, connected, and clean (European Commission, 2018b), many individual studies and research have been carried out globally. All of these studies dealt with road safety performance indicators, while placing the emphasis on exchanging the lessons they have learned from the existing best practices. KPIs can give a more complete picture of the level of road safety and can detect the emergence of problems at an earlier stage (European Transport Safety Council, 2018). Phase 1 includes the authors who made the calculations of a road safety level on the basis of indicators for only one layer, while Phase 2 gathers together the authors who calculated a road safety level on the basis of indicators of various layers. The compromise between the need (for as many indicators as possible) and the real situation (availability of only a limited number of indicators for specific territories) eventually means identifying the most significant indicators (a comprehensive set of performance indicators).

2.2. Road Safety KPI in the EU and the Republic of Serbia

The Staff Working Document titled EU Road Safety Policy Framework 2021-2030 – Next steps towards "Vision Zero" recommended the establishment of a range of road safety KPIs that are directly related to the prevention of road deaths and serious injuries. The EC has defined a general methodological consideration applicable to all indicators. Also, the EC-funded project Baseline has further developed a set of common methodological guidelines for the data collection and estimation of the KPIs in the EU countries, including minimum data requirements, measurement procedure and data analysis requirements. With these methodological considerations, the various restraints can be overcome and the standardization of the suggested key indicators for international comparisons can be achieved. Nevertheless, the Republic of Serbia has been monitoring and measuring safety performance indicators following the best practices since 2013. The Road

Traffic Safety Agency is the main road safety stakeholder responsible for monitoring road users' behavior.

Progress towards collecting KPIs in the European countries is presented in Fig. 1, based on information gathered from 32 MS countries (Adminaite-Fodor *et al.,* 2021) and *IRTAD Road Safety Annual Report 2020* (OECD/ITF, 2020). An overview of the availability shows that there is still a way to go in terms of developing and collecting some of these KPIs. Most countries collect and analyse data related to safety belts (93.8%), speed (87.5%), alcohol (87.5%), protective equipment (84.4%), distraction (84.4%) and vehicle safety (56.3%). Only a few countries follow the KPIs related to infrastructure (34.4%) and post- crash response (37.5%). From the practical point of view, it is important to note that countries apply different methodologies in collecting KPI data. The level of detail of each KPI and the frequency on how often KPI data are collected differ between countries. With the methodological consideration adopted by the EC, the restraints that emerged with regard to a data collection method, diversity in definitions of KPIs, etc., have been overcome and the standardization of indicators, as well as selection of a key list of indicators for international comparisons or the benchmarking process, have been provided. The standardization of indicators will contribute to the comparison, monitoring and measuring of efficiency of the simple and good quality measures undertaken for the improvement of the current road safety situation.

Although a road safety assessment level obtained on the basis of a narrower comprehensive set of KPIs can offer an adequate and efficient way of road safety monitoring (Tešić *et al.,* 2018), the road safety assessment performed based on a broader set of KPIs will provide a more accurate identification of good and poor road safety performances, which is in line with the recommendations by European Transport Safety Council (2018).

Current mobile telecommunication networks in Serbia (UMTS or LTE) are widely deployed in urban areas, but they are not able to fit the rigid Quality of Service (QoS) specifications for IoV services (such as the time-critical safety applications). In addition, the dedicated Road-Side Equipment units (RSU) to provide dissemination of traffic information between the vehicles and road infrastructure are not hugely deployed, mostly due to relatively high RSUs equipment costs and considerable networking issues. Moreover, the existing cloud computing-based solutions are not suitable for vehicular applications and should be improved to fog networking platforms. In order to reach the minimum QoS specifications of future IoV services, telecommunication networks have to be carefully up-graded and deployed.

Following the trends worldwide, it is expected dynamic growth of IoV market in Serbia, with its primary area of application in urban environments characterized by the large number of vehicles and passengers, pedestrians, cycles, buildings and crossroads.

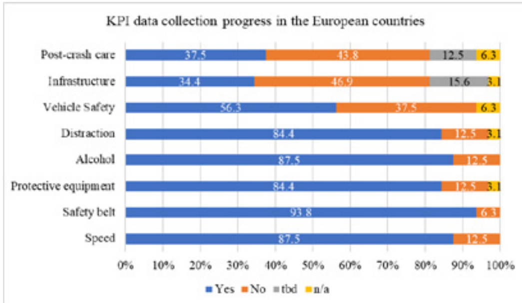

Fig. 1.
Progress Towards Collecting KPIs in the European Countries

3. Internet of Vehicles Networking in Urban Environments

Internet of Vehicles is a new concept raised from the rapid growth of information and communication technologies and their integration with the traffic and transport systems. IoV systems are highly complex to design and require a number of challenging problems to be researched and solved. To achieve the functionality of such system, the requirements on low latency, reliability, security and the need to bring processing power closer to vehicles are becoming more stringent and the subject of scientific research.

3.1. IoV Models of Connectivity

The IoV concept presents a complex heterogeneous system of hierarchically organized communication networks and includes different modes of connectivity (V2X, Vehicle-to-Everything), such as communications between vehicles, V2V (Vehicle-to-Vehicle), vehicle communications with traffic infrastructure, V2I (Vehicle-to-Infrastructure), connecting vehicles to the Internet and other communication networks, V2N (Vehicle-to-Network), vehicle communications with pedestrians/personal devices in the environment, V2P (Vehicle-to-Personal Device) and gathering information from various sensors, V2S (Vehicle-to-Sensor). IoV focuses on the intelligent integration of people, vehicles, things and environments with the aim to provide different services. It implies an open and integrated traffic management network system and consists of multiple users, multiple vehicles, multiple things and multiple networks. Intelligent interfaces are used to integrate heterogeneous networks. IoV services offer road users numerous benefits (level of service, safety, etc.) and also have a significant impact on the reduction of energy consumption and minimization of costs and travel time.

Wireless technologies and protocols used in IoV networking can be divided into three general categories: mobile cellular networks (Wi-Max, 4G/LTE, 5G/NR); dedicated networks for vehicles (DSRC/WAVE) and short-range networks (Wi-Fi, Bluetooth, ZigBee, NFC, and others). Table 1 shows some WAT (Wireless Access Technology) technologies that can be used for the networking needs of various entities in IoV systems. Selection of appropriate WAT technology for specific IoV application and QoS requirements is done according to priority, data transfer rates, communication range, mobility support, delay, security level, network compatibility, etc. As one of the promising solutions for future IoV systems, the upcoming 5G mobile cellular network certainly stands out, thanks to a range of advanced technologies, such as mm-waves, ultra-dense networks, massive MIMO (Multiple Input Multiple Output) antenna concept, beamforming, and full-duplex technology. The mentioned technologies provide numerous advantages in terms of the ability to meet the requirements of future IoV applications, providing increased bandwidth, high data transfer rates, high reliability of communications, low delays, etc.

The abbreviations in the table imply: Wi-Max (Worldwide Interoperability for Microwave Access), LTE (Long Term Evolution), NR (New Radio), DSRC (Dedicated Short Range Communication), WAVE (Wireless Access in Vehicular Environments), 3GPP (The 3rd Generation Partnership Program), Wi-Fi (Wireless Fidelity), NFC (Near Field Communications), IEEE (Institute of Electrical and Electronics Engineers), ISO/IEC (International Organization for Standardization/International Electrotechnical Commission).

Effective planning and allocation of IoV network resources is a challenging task. Considering that urban environments include a large number of intersections and frequent changes in topology, it is necessary to bear in mind that the density of the distribution of vehicles is uneven, that is, the density of a network is variable, which can affect the functionality of the communication network. The model of a heterogeneous IoV architecture in an urban area consists of vehicles equipped with appropriate wireless communication equipment, network gateways at intersections, cellular base stations, RSU units and other infrastructure equipment (Cheng, et al. 2018; 2015). If a vehicle speed is known, the range of wireless devices for vehicle networking and the density of vehicles on a certain road section, it is possible, according to the analysis presented in Cheng, et al. (2018), to model the connectivity of network nodes in a dynamic IoV environment.

Table 1

Characteristics of Different Wireless Technologies for IoV Applications

Type of Network	Name of Technology	Standard	Frequency Range	Maximum Range
Mobile cellular networks	Wi-Max	IEEE 802.16 d/e	2-11 GHz	50 km
	4G/LTE	3GPP	700 MHz - 2.7GHz	10 m - 100 km
	5G/NR		700 MHz - 6 GHz > 24GHz (mm)	~ 4G/LTE < 500m
Dedicated networks for vehicles	DSRC/WAVE	IEEE 802.11 p	5.9 GHz	1000 m
Wireless networks for short ranges	Wi-Fi	IEEE 802.11 a/b/g/n	2.4 - 5 GHz	100 m
	Bluetooth	IEEE 802.15.1	2.4 GHz	10 - 100 m
	ZigBee	IEEE 802.15.4	868-915 MHz, 2.4 GHz	10 - 100 m
	NFC	ISO/IEC 18092	13.56 MHz	< 10 cm

Source: (Benalia et al., 2020)

3.2. Integration of Software and Cloud Technologies into a Single IoV Platform

The concept of IoV requires new perspectives on the development of platforms, algorithms and techniques for controlling vehicles and traffic generated by users through a combination of cloud, network and virtualization techniques. This includes Software-Defined Networking (SDN), Network Function Virtualization (NFV), fog/edge computing and the use of containers (Da Silva Barbosa *et al.,* 2020). SDN is based on the separation of the control plane and the user plane. NFV, standardized by European Telecommunications Standards Institute (ETSI), involves the creation of a dynamic network in a virtual environment, enabling any network configuration required for testing. Edge/fog computing enables data processing and storage to be brought closer to end users. It is implemented in the form of an intermediary between the cloud and IoT infrastructure (Mitrović *et al.,* 2018). Containers enable virtualization at the application level, by running services across different platforms.

The SDN vehicle network architecture includes SDN-based components, such as RSUs, base stations or even individual vehicles, which achieve a higher level of control and automation of VANET networks and enable the realization of SDVN (Software Defined Vehicular Networking) networking. The control plane enables the establishment, maintenance and management of connections through regulated paths. In this way, the efficient transfer of user data from the initial node to the end node through different domains is enabled. The exchange of signalling messages takes place through a special protocol between software components that we call signalling controllers. Signalling controllers (switches/routers) collect data on traffic (e.g., speed and density of vehicles) and application characteristics and make a decision on the routing method. By integrating SDN and SDN-enabled equipment (RSU, base stations or vehicles), the network manager is allowed to allocate resources, avoid interference, integrate multiple types of technologies (Wi-Fi, Wi-Max, LTE, NR), control traffic congestion and serve traffic demands evenly (Chahal *et al.,* 2017).

Network virtualization aims to minimize hardware by using a generic infrastructure based on servers and virtual machines (VMs) that adapt to the physical infrastructure. In this way, any configuration or addition of resources is enabled according to the requirements. NFV is highly dependent on cloud computing, and hypervisors that are responsible for separating processing and memory resources from hardware. This makes it possible to develop software independently of hardware and vice versa.

Applying the concept of cloud computing to support big-data-based IoV services leads to numerous disadvantages, such as increased delay, insufficient efficiency and poor scalability of the system. The key cause of these problems stems from the centralized concept of cloud service data processing and storage. To overcome these problems, advanced solutions based on distributed fog/edge computing are proposed, which achieve the localization of cloud services (cloudification of the network).

Fog Computing (FC) represents an extension of the cloud environment, which is realized as an intermediary step between the cloud and the IoV infrastructure with the aim of bringing computer resources and fast data transfer closer to the end users (data sources). It significantly reduces the delay compared to the centralized cloud architecture. Any device that has the ability to process, store and transmit information is called a fog node, regardless of whether it is an industrial controller, switch, router, embedded server, advanced surveillance camera, etc. (Mitrović *et al.,* 2018). Although FC does not have the processing and memory capabilities of cloud resources, it's most important feature is to ensure sufficiently low latency within the operation of the corresponding IoV applications.

Edge computing (EC) or computing at the edge of the network is also a distributed concept of computing, where all computing operations are performed directly on end devices (e.g., sensors/actuators, vehicles) or on their interfaces. EC has similar functionalities to FC, and the basic difference between these two concepts stems from the different positions where data processing is performed. Unlike FC, which involves the transfer of data from end devices/interfaces to fog nodes within the local computer network (LAN) for their processing, with EC all computer operations are performed on end devices, without the need for data exchange via the LAN network.

Software containers are a way to run applications in their own isolated process. As their name suggests, containers are used to "pack" only what is needed to run the application. The integration of containers into a single IoV platform refers to the application of virtualization, that is, the virtual creation of services or applications. An application that runs using a container means that the libraries are installed in the containers, not in the operating system. Containers are executed as separate (isolated) processes that share the resources of the operating system on which they are launched, and their launch takes significantly less time. Because they require fewer resources (they don't need an entire operating system), they are easier to ship and provide the ability to run multiple services using the same hardware. The container contains only the application, the necessary libraries, components on which the application depends and configuration files, which makes the application independent of the infrastructure on which it runs (Brogi *et al.,* 2017).

4. Open Data Platform for Road Safety KPIs

4.1. Concept

Over recent years, the need for open data in the transport research area has been more relevant than ever, due to the great number of different types of data collected by researchers, transport stakeholders, private companies and public authorities associated with the increasing real-time data collection from vehicles, infrastructure, and various applications. One of the biggest initiatives to promote Open Science in transport research is the H2020 project BE OPEN, funded by the EC. Within this context, the importance of collecting performance indicators has been also emphasized in Yannis *et al.* (2020) and Tešić *et. al.* (2022) including them in the structure of road safety management, as part of the platform for global road safety data analysis. The synthesis of the results of the European Commission (2018a) led to the formulation of ten recommendations grouped into five thematic areas, which are considered essential for the development of a sustainable TRC, as a subset of the EOSC platform. Following the EC's efforts to ensure the collecting and monitoring of KPIs at the EU level, as useful tools for monitoring road safety progress, the need to define an open data platform for road safety KPIs (OPEN RSPIs) has been widely recognized. Further on, the platform is compatible with the EOSC principles, such as: multi-stakeholders, openness, FAIR principles, the federation of infrastructures, and machine actionable.

Establishing the OPEN RSPIs as part of the TRC meets three strategic objectives relating to people, knowledge, and infrastructures, as defined in the Strategic Research and Innovation Agenda (SRIA) of the EOSC (EOSC Executive Board, 2020). Despite the fact that the platform provides a "new normal" related to the open science practices and data stewardship, the greatest contribution is expected in developing a web of FAIR data and related services that are underpinning the in-depth research addressing major road safety challenges. Further on, the platform is compatible with the EOSC principles (EOSC Executive Board, 2020), as it includes a wide range of stakeholders, such as: research and science stakeholders, research- funding organisations, governmental road safety stakeholders and private sector (Principle (P).1. Multi- stakeholderism). They are interested in the OPEN RSPIs data and are able to generate the value by using this platform. By defining the EU Road Safety Policy Framework 2021-2030, the EC stressed the importance of sharing KPIs data (P.2. Openness), in order to ensure transparency and inclusiveness of the joint work and to benefit from the widest possible input in its decision-making. Research, science, and governmental road safety stakeholders need to embrace the new approach, where knowledge is shared at all stages of the research lifecycle of KPIs (esp. raw/ study data), as opposed to the old way, where results are shared primarily through publications made available when the work has achieved a sufficient maturity level. Challenges related to the openness and P.3. FAIR principles have been overcome by the standardized methodology for collecting and monitoring KPIs, which improves the trust in and culture of sharing data. Based on that and with due respect to all the components of the FAIR ecosystem, the interconnectedness of people, services and content can be at a high level, and the emphasis placed on the data management plan. From the practical point of view, a federation of the existing and planned research data infrastructures (P.4. Federation of infrastructures), is quite sufficient for the functioning of the entire KPIs monitoring system. The challenge is to define the national road safety KPIs hub/ leading road safety stakeholder that will conduct the research and enter the (meta) data through the national e-infrastructure. By monitoring the KPIs data at the EU level, activities have grown in volume and complexity in many ways (reading, analysis, comparison, reporting, etc.) and (meta) data must be catalogues based on machine-readable metadata (P.5. machine-actionable).

The EOSC system consists of three layers: 1) the federating core (or the EOSC-Core), 2) the federation of existing and planned research data infrastructures, and 3) the EOSC-Exchange that builds on the EOSC-Core to ensure a rich set of services (common and thematic). In accordance with the EOSC structure, an open data platform for road safety KPIs engagement of the wider public/ government sector and private sectors have been proposed. As shown in Fig. 2, the platform proposed can be exploited by both the EC/DG Move and the MS to monitor road safety progress, identify and exchange best practices through cross-country comparisons, as well as to identify major road safety problems. The governance plan implies a proxy at the national level (Route 1) between the EOSC-TRC and the leading government road safety stakeholder, which is responsible for KPIs measurement, collecting and monitoring at national level, as well as for national research and science stakeholders or private sector. In addition, the leading government road safety stakeholder and research stakeholders may engage in the EOSC via one or more umbrella organizations (Route 2), (i.e., ECTRI, FEHRL, etc.), addressing different layers of the EOSC, primarily the providers of the EOSC-Core and those enabling the EOSC-Exchange. Initially, both routes are acceptable since umbrella organizations are expected to bring their members closer to the EOSC and align their needs with EOSC principles. But in the long-term and within the context of established open science culture, Route 1 is indeed the most appropriate.

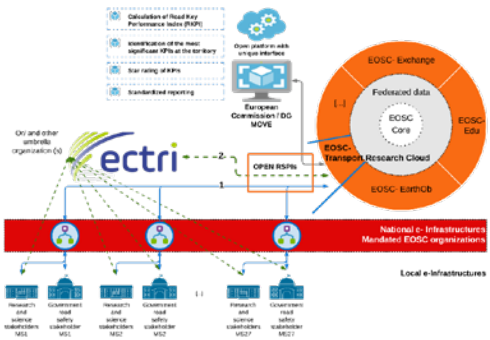

Fig. 2.
Concept of the Open Data Platform for Road Safety KPIs (OPEN RSPIs)
Source: (Manola et al., 2020)

No matter which route is used for communication with the EOSC, all Member States need to define a comprehensive methodology for collecting and monitoring KPIs at the national level, which is completely in line with the EC minimum methodological requirements. Nevertheless, this methodology should define a leading road safety stakeholder for collecting KPIs (e.g., ministry of transport or leading traffic safety agency), the list of KPIs (in line with EC recommendations) and a list of additional safety performance indicators (e.g., related to vulnerable road users), a sustainable funding source for periodic, long-term monitoring of indicators, as well as mechanisms for reporting to the parliament, citizens, etc. Being able to recognize the importance and generate the proposed platform value, as part of the EOSC- TRC, the governance plan implies direct involvement of the EC/DG Move, as a focal point for KPIs management at the EU level.

The results indicate that a culture and practices of data sharing still need to be developed in the area of transport research (European Commission, 2018a). The establishment of an open data platform for road safety KPIs will contribute to building a research road safety environment that will promote the Open Science and increase the trust and reproducibility of research outcomes.

The MS should ensure: 1) data management planning and 2) research data resulting from publicly funded research being findable, accessible, interoperable and reusable (‘FAIR principles’) within a secure and trusted environment, through digital infrastructures. All potential types of road safety KPI data (original research data obtained by observations; operational data and data from published research in transport) should follow the FAIR principles, being ‘as open as possible, as closed as necessary’.

In the context of an open KPI data ecosystem, data policies could be issued by the EC/DG Move, leading road safety stakeholders at the EU MS level, as well as by research and other related stakeholders. Additionally, data management plans, which will articulate all relevant information concerning the generation or collection of publicly funded research data.

4.2. Data Sharing

In accordance with the recommendations from European Commission (2018c), Member States should ensure: 1) data management planning should become a standard scientific practice early in the research process, when data are generated or collected, including the requirement of data management plans, and 2) research data resulting from publicly funded research should become and remain findable, accessible, interoperable and reusable (‘FAIR principles’) within a secure and trusted environment, through digital infrastructures. Further on, Bardi *et al.* (2021) summarized 14 recommendations for FAIR Open transport research data. These recommendations suggest actions, not only to single researchers, but also to the transport research community as a whole. Within this context, all following categories of road safety KPIs data: 1) original research data obtained by observations, as the most common category of KPIs data, 2) operational data directly related to research (data from public authorities), and 3) data from published research in transport (journals, deliverables, etc.), should be ‘as open as possible, as closed as necessary’ enabling the FAIRness of data. This principle provides the monitoring of road safety progress, identifies best practices through cross- country comparison at EU level, etc., making the FAIR ecosystem of KPIs data.

The implementation of the FAIR principles relies on the following essential components: policies, data management plans, identifiers, standards, and repositories (European Commission, 2018d). In a KPIs data ecosystem, data policies can be issued by the EC/DG Move, by leading road safety stakeholders at the EU Member States level, as well as by research, scientific and other stakeholders. A Data Management Plan (DMP) articulates all relevant information relating to a research project that is generating or collecting publicly funded research data (European Commission, 2018d). The DMP should address data management as a core element necessary for the delivery of its scientific objectives and should also hold valuable information on the data and related outputs, which should be structured in a machine actionable way to enhance their reuse. From the KPIs data point of view, it is necessary to define the structure of a DMP so that it includes at least the following data:

- title, description, and language (define title, briefly describe the context and purpose of a DMP, language);
- visibility (KPIs data are public data and should be fully visible);
- researchers and organization (list all researchers and organizations);
- funding organizations, grants, projects (Phase 1- KPIs data collection can most often be funded by the EC through certain projects at the EU level; Phase 2- research funded by a government, when the conditions for sustainable monitoring of KPIs are provided; projects funded from multiple sources);
- license (selecting the most appropriate license from the Creative Commons licenses; permit the widest reuse);
- dataset info (data types; file formats; data production methods (observers, smart cameras, and solutions, etc.); expected size of the data; metadata; persistent identifiers for raw data, institutions, researchers, funders, etc.; search keywords; data openly available; briefly describe the KPIs collection methodology; vocabularies of meta (data); re-using a policy and the "embargo" period; and other specifications which can be useful for data reusing).

Disciplinary interoperability frameworks are essential to the implementation of the FAIR and are organized in four layers: technical, semantic, organizational, and legal interoperability (European Commission, 2021). Interoperability frameworks that define community practices for data sharing, metadata standards, tools and infrastructure, play a fundamental role (Franklin, et al. 2020). With the development of the proposed OPEN RSPIs platform, having a unique interface and enabling a triangle knowledge exchange such as: 1) the EOSC/TRC and the EC/DG MOVE; 2) the EOSC/TRC and leading road safety stakeholders at EU Member State level, and 3) the EOSC/TRC and academic stakeholders, it will be possible to ensure the interconnectedness of people, services, and the content. The challenges can occur in the semantic layer, when it comes to differences in the definitions of certain indicators i.e. (different legal requirements concerning helmet use by cyclists, applicable legal provisions relating to the maximum permitted BAC, definition of KPIs related to the vehicle and infrastructure). In that case, it is necessary to explain in detail the differences and specifics of certain indicators in the metadata, in order to ensure a high level of road safety management at the EU level.

In open science, data must be shared in such a way that both humans and machines are able to access, understand, and reuse them (Yannis and Folla, 2019). A key issue of the reusability of KPIs dataset is the availability of high-quality metadata, which will provide precise information on data collection procedure and methodology, data process, data owners, access to data, etc. To provide a higher level of interoperability and reuse, the OPEN RSPIs platform should enable exporting or generating standardized reports which will be published by the EC/DG Move or the leading road safety stakeholders of the EU.

4.3. Opportunities and Barriers to Road Safety KPIs Data Collecting and Sharing

The use of to- date scientific and technological achievements in the field of information and communication technologies, cloud computing, AI and IoT significantly improves road safety across Europe for all road users. This requires mass involvement of public decision-makers, research and scientific community, vehicle manufacturers and suppliers, traffic information service providers, etc. Such a level of coordination and participation will be necessary for the provision of the pace and the critical mass of road safety data required for a comprehensive and in-depth analysis of road safety situation in a territory, detection of emergence problems at an earlier stage, evaluation of road safety measures, exchange of best knowledge, etc. Under this assumption, it is possible to generate large amounts of KPIs data, obtained from various projects, naturalistic driving studies, field operational tests, smart cameras, advanced smart solutions in urban area, smart in-car solutions, etc.

Moreover, the AI technology is expected to contribute to the improvement of the safety level of vehicles, drivers, and roads. Automated process of KPIs data collection by using the AI, communication between the vehicle, infrastructure, and driver (i.e., V2X) and the IoT system, will enable the management of the road safety performance generally, management of driver's behavior and identification of the most common risky behavior, which can lead to a reduction of harmful impacts of traffic in the said transition period. Under this assumption, it is possible to generate large amounts of KPIs data, obtained from various projects, naturalistic driving studies, field operational tests, smart cameras, advanced smart solutions in urban areas, smart in-car solutions, etc. Organization of periodical, multi- day training courses (or a series of workshops/ webinars) for road safety stakeholders at the EU Member States level, in cooperation with the representatives of the EC/DG Move, the representatives of the EOSC, academia sector and traffic information service providers, has a great potential for improvement of the culture of data sharing and interoperability, with a high level of trust and security. Developing the next generation of FAIR professionals and professionals for the management of KPIs data should be a priority at all levels of road safety management, which is in line with the recommendations in Manola *et al.* (2021).

However, the numerous challenges that can hinder the reuse of KPI data are listed in European Commission (2018a), among which the following ones stand out: data storage, fragmentation of data ownership, a lack of interoperability between datasets and platforms, etc. Shortly, the automated process of KPIs data collection, accompanied by advanced smart solutions in urban areas, smart in-car solutions, etc. can significantly improve data quality, by taking into account that data providers may be unwilling to use cloud services for fear of data breaches or unauthorized access. All potential restrictions should be listed in the data management process until a clear legal framework supporting data security, data protection and privacy has been developed.

5. Conclusion

In order to have a better understanding of the road safety problem and define the earlier goal-oriented actions for improving road safety, the EC has set an initial set of eight road safety KPIs to be measured across the EU Member States, which will be further enriched in the forthcoming years. The IoV concept enables an automated process of such measurements and data collection. Simultaneously, the development of a TRC as a subset of an EOSC platform provides the conditions for comprehensive management of the KPIs data. Through the paper, guidelines are given for the development of an open data platform for road safety KPIs that could be integrated into the European TRC. The development of the OPEN RSPIs platform enables comprehensive and periodic monitoring and management of the KPIs at the EU level, sets ambitious national KPI targets, more accurate identification of good and poor road safety points, as well as strengthening proactive road safety management. In order to make the transition period as safe and efficient as possible, the development of the star rating for assessing the road safety performance of a territory should be a possible game-changer for the systematic management of road user behavior, especially in case of automated process of KPIs data collection and sharing by using the IoV concept.

From the open data point of view, the OPEN RSPIs platform ensures high level of openness, integrity, fairness, interconnectedness of people, services, and the content, as well as the reproducibility and reuse of KPIs data. By using to-date scientific achievements in road safety management, as well as technological achievements in the field of information and communication technologies, the development of the OPEN RSPIs platform does not require large resources (architecture, infrastructure, services, and other requirements) and could be a very useful tool in the hands of the EC/DG Move and national road safety stakeholders.

Finally, it is essential that the EU Member States accept and support the development of systematic monitoring of the KPIs and define sustainable national funding models. At the initial stage, the EC should encourage and offer financial support to the Member States. After the initial stage, the EC should define recommendations for financing and potential benefits of data management (provide value to end users), educate the stakeholders and set national KPI targets, include strict monitoring of road safety situation, etc.

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