Challenges and opportunities of open science in transport research

Afroditi Anagnostopoulou
Hellenic Institute of Transport
Centre for Research and Technology Hellas
Piraeus, Greece
a.anagnostopoulou@certh.gr

Maria Boile
Hellenic Institute of Transport
Centre for Research and Technology Hellas
Athens, Greece
boile@certh.gr

Abstract—**The current technological advances and the rapid development of new collaborative tools have endorsed an on-going transformation of transport research enabling research information sharing. This systematic change of transport research covers a wide range of aspects, from evaluation of research, open access to research results, and relevant data infrastructures, all aiming at making science more efficient, better reproducible and more responsive to societal and economic expectations. In an attempt to address the above, this paper presents an action list of the different main aspects of Open Science in transport research of the European area exploiting previous initiatives and mapping among research areas with longer experience and more "mature" research fields. The novelty of the proposed action list is to contribute in implementing Open Science approaches in transport research enabling stakeholders to share and use all available knowledge at an earlier stage in the research process. The focus is given on the identification of guidelines that transport research stakeholders have to use to integrate open science in their current operations. This opening up of science and research is expected to lead to a European community of transport research stakeholders willing to work together and speed up the path from research to innovation and promote citizen's engagement in the scientific process.**

Keywords- open science, transport research, action list, guidelines

I. INTRODUCTION

Open Science is a modern movement that represents a new approach to practicing science, in a way that increases openness, integrity and reproducibility of research. It aims at making scientific process and results more transparent and accessible at all levels and to everyone. The rapid growth of digital technologies and new collaborative tools become enablers of Open Science, allowing speed up the process of adopting open habits and facilitating the sharing of large volumes of information, study materials and data. Europe has a culture and ability to share research activities across national boundaries, which along with its remarkable research and knowledge base put it in a leading position in the world to promote and expedite the new Open Science way of working. In fact, nearly 10% of the budget allocated for the Horizon 2020 Work Programme 2018-2020 [1] is channeled to direct or indirect support of Open Science and towards this direction, the European Open Science Cloud (EOSC) [2] has been developed to *enable sharing and re-use of research data across disciplines and borders, taking into account relevant legal, security and privacy issues.*

In the context of transport, the European Commission Transport Research and Innovation policy intends to foster Open Science through user engagement enabling dynamic knowledge circulation [3]. Hence, research, technology and innovation actions in the transport sector face new challenges linked to the aspects of Open Science. Technical interoperability, data and information interoperability, deployment of new skills, development of new schemes for research evaluation and adoption of collaborative ways of working are some of the main challenges of building Open Science platforms in transport research, with information always open to major groups of transport stakeholders from research, public and private organizations and the general public.

As the way in which science and research are carried out has changed, open science brings new opportunities in transport research and creates challenges that should be addressed. Collaborative processes and infrastructure constitute key factors in making transportation researchers share, reuse and reproduce science as well as in bringing such a critical sector closer to the society for enabling open innovation and citizen science. However, open data and information are more challenging than simply collecting and elaborating your own data as different forms need to be expressed in a computer understandable way. In addition, terms and legal guidance needed to manage data protection, intellectual property rights and security aspects.

In this context, this paper discusses the main initiatives behind the Open Science and presents the benefits offered to scientists and citizens as well as the borders that must be overcome in the integration of Open Science in transport research of the European area. The remainder of the paper is organized as follows: Section 2 discusses technical background, policy information and shared available knowledge of Open Science. Then, the main opportunities and challenges are presented in Section 3 describing the process that should be undertaken along the way of enabling Open Science in the transport research of the European area. It is an attempt to provide an action list and proper guidelines promoting Open Source in the transport research for the first time to the best of our knowledge. Finally, in Section 4

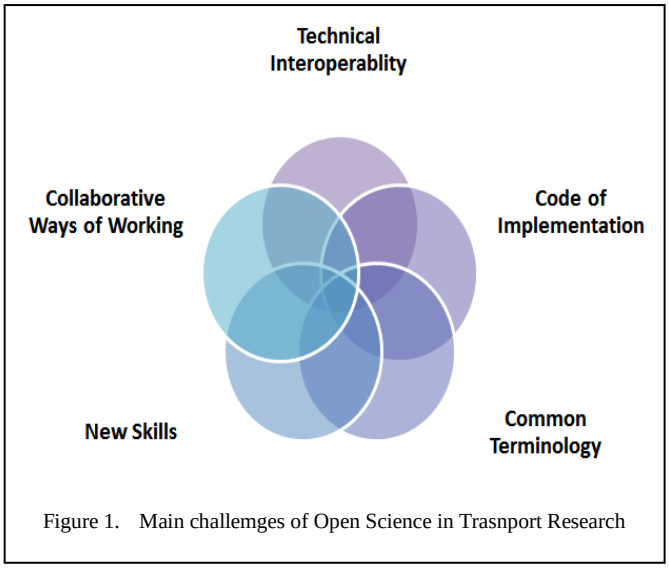

Figure 1. Main challemges of Open Science in Trasnport Research

conclusions are drawn and pointers for future research are provided.

II. Open Science Initiatives

In recent years, the need for open data, unified standards and flexible infrastructures in the research area continues to grow at ever faster rates and thus, a number of initiatives have developed technical background, policy information and shared knowledge in different domains of transport sector. The main initiative of the European Commission for promoting Open Science in the research area is the operation of the EOSC which addresses the interconnection of the existing research infrastructures fostering interdisciplinary big data exchange among researchers, industry community and the general public. It will integrate existing networks and data and it will exploit current infrastructures in the European area based on the Internet Engineering Task Force (IETF) [4] and it will contribute to the future, international bottom-up initiative for global Internet of data and services as stated in the Global Internet Policy Observatory (GIPO) [5].

In the field of data interoperability and data sharing, two initiatives are worth mentioning: the Research Data Alliance (RDA) [6], a global forum in the model of IEFT where "infrastructure experts "come together through focused global Working and Interest Groups to develop and adopt infrastructure that promotes data-sharing and data-driven research, and accelerate the growth of a cohesive data community that integrates contributors across domain, research, national, geographical and generational boundaries", and the GO-FAIR initiative [7] which addresses the practical implementation of making FAIR data and services.

In an attempt to identify the new skills and competencies for practicing Open Science, the working group on 'Skills' proposed a European Skills and Qualifications Matrix for Open Science [8] that provides a guide for the required skills of the researchers at all career stages. In terms of disseminating scientific results and research outcomes, the European Commission proposes the European Commission Open Research Publishing Platform that will provide open access to scientific publications in a reliable, easy and fast way (foreseen to be launched). This will enhance transparency and knowledge sharing among researchers developing a valuable database of scientific context complementing the current policy in Horizon 2020.

Another useful report for providing researcher assessment and career framework on the basis of Open Science is the final report of the working group on 'Rewards' which was produced on July 2017 [9]. A wider group that advises the European Commission (EC) on how to develop Open Science policy is the "Open Science Policy Platform" group which has representatives of the broad constituency of European Open Science stakeholders to operate as a dynamic, stakeholder-driven mechanism to support policy implementation and actions required to provide advice and recommendations on any cross-cutting issue affecting Open Science.

In the field of Open Science in transport research, an important coordinated approach of the European Commission is the launch of the Transport Research and Innovation Monitoring and Information System (TRIMIS) [10] developed by the Joint Research Centre (in the framework of a DG-MOVE funded project) which aims at becoming the EC's tool for mapping technology trends and research and innovation capacities in the transport field. It is designed as an open-access information and knowledge management system that also provides different roadmaps of innovation and new technology in transport. Moreover, the establishment of the "Expert Group on Open Science – Transport Research Cloud" (December 2017) [11] is the most recent action of the EC to cover the transport thematic pillar of the EOSC and assessing the need to create a transport research cloud.

The latest attempt of the European Commission is the new "Implementation Roadmap for the European Science Cloud" (March 2018) [12] which presents the results from an extensive and conclusive consultation process started with the Communication European Cloud initiative. The document describes measures taken under Horizon 2020 and tries to finalize the governance framework for the initiative in the earnest. As such, this could be used as a basis for further consultation with the transport stakeholders and other relevant key actors (from transport industry and research community, European Commission and society in general) on the next steps for coordinating, supporting and promoting services and tools of Open Science in transport research.

In the context of Open Science in transport research, most of the previous work is appeared in open access initiatives. Publishing companies realized that opening up European research could stimulate greater movement of knowledge and promote excellence improving cooperation between research community and industry. As such, the Springer Publishing Company launched open access journals (i.e. European Transport Research Review (from 2009) [13], Journal of Modern Transportation (from 2011) [14] and the Urban Rail Transit (from 2015) [15]) to serve as important sources to find scientific work in the general area of transportation. The Elsevier Publishing Company offers the International Journal of Transportation Science and Technology (from 2012) [16], the recently launched Transportation Research Interdisciplinary Perspectives [17] and the Transportation Research Procedia

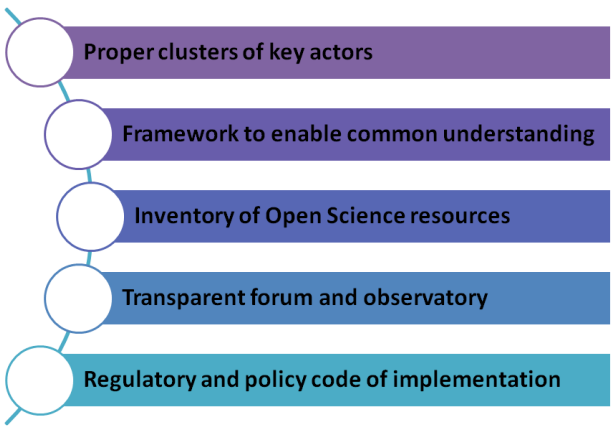

Figure 2. Action List for Promoting Open Science in Trasnport Research

(from 2014) [18] for publishing enabling fast dissemination. Moreover, Hindawi Publishing Company offers the open access Journal of Advanced Transportation [19] from 2017 as part of a publishing collaboration with John Wiley & Sons, Inc to provide open global access to its published research in transport area.

III. Action List for Open Science in Transport Research

A deep review of scientific sources (journal, congress proceedings, books, papers, other publications) is important for identifying the main actors and related organizations / associations active in each area (i.e. legal/regulatory, technological, transport planning, business modelling, socio-economic and environmental), and determining how the scientific production and their related research questions have progressed along during the last decades. Science platforms and tools in the transport domain, by defining a unified transport terminology and related research and investigation instruments should be developed to allow definite analysis and comparisons of the scientific production. These could also provide comparisons of the scientific production which will offer understanding of the evolution of scientific works and how it has influenced thein concrete progresses in the transport ecosystem. Without a common scientific basis, it will be difficult to benchmark studies and assess results, even more in comparison with past trends when older scientific works should be reviewed for assessing subsequent impacts of the mobility scenarios.

This opening up of science and research is expected to lead to a community of transport research stakeholders willing to work together and speed up the path from research to innovation and promote citizen's engagement in the scientific process. However, open data and information sharing require a commonly agreed code of implementation covering ethical concerns, privacy aspects and legal issues. This regulatory and ethical guidance is needed to operationalize Open Science principles at regional, European and international level and should follow the agreed ambition of stakeholders for a flexible and integral approach of building Open Science platforms for transferring knowledge and experiences. As such, proper regulatory schemes should be developed to enhance sustainability of Open Science actions in transport research area.

Having the opportunity to use open data from several sources is of significant value if they are efficiently and secured transferred. Software and technology specify the critical constraints and basic bottlenecks that appeared as for example data has a dual dimension and can be either private for industry or public when they are used for improving citizen's mobility. Hence, technical interoperability of tools, services and infrastructures should be put in place during research activities in order to define common structure in the transport domain.

Moreover, the collected information should be in a unified format in order to ensure compatibility of different sources and quality of content and make them suitable for interpretation and further analysis. Fig. 1 summarizes the main challenges in sharing data and knowledge (i.e. technical interoperability for covering compatibility of data and information from different sources, deploying of new skills and competencies for practicing Open Science, new schemes for research evaluation, membership and governance of new open observatories and forums, collaborative ways of working among different stakeholders, and privacy and legal issues) to make free of all restrictions on access and free of many restrictions on use.

To foster Open Science in transport research, systematic actions should be implemented and a grid of guidelines should be produced to facilitate new schemes for research evaluation, technical and information interoperability, legal compatibility as well as collaborative ways of working. Respective constraints and bottlenecks are necessary to be analyzed and a detailed roadmap to be concluded in order to support flexible planning by matching short-term and long-term goals with specific solutions that will offer long-term benefits to the stakeholders. Moreover, complementary activities of strategic planning and networking between different countries and research programmes need to be also proposed. These will result in the awareness-raising and enhance communication accompanying dissemination of transport research initiatives.

As transport research covers different modes (i.e., road, rail, water, air) and sub-sectors, and touches upon different types of mobility (i.e., freight, passenger) there is a need to identify and record in a systemic way the needs and wants of a broad range of key actors in the domain (transport stakeholders), set the necessary context of current and emerging scientific production and determine how this relates to Open Science. The spectrum of stakeholders relevant to transport research including public and private organizations, research and education community, industry, pubic bodies, and the society/citizens will provide proper clusters of key actors in transport research determining their particular needs and defining a unified transport research terminology.

Open Science needs pragmatic and participatory means to make it work, even though the diversity of modes and uses in transport research and the cultural variety of Europe could not accept one solution for all. Consequently, a framework to enable a common understanding of all stakeholders could realize the use of Open Science in the transport domain and

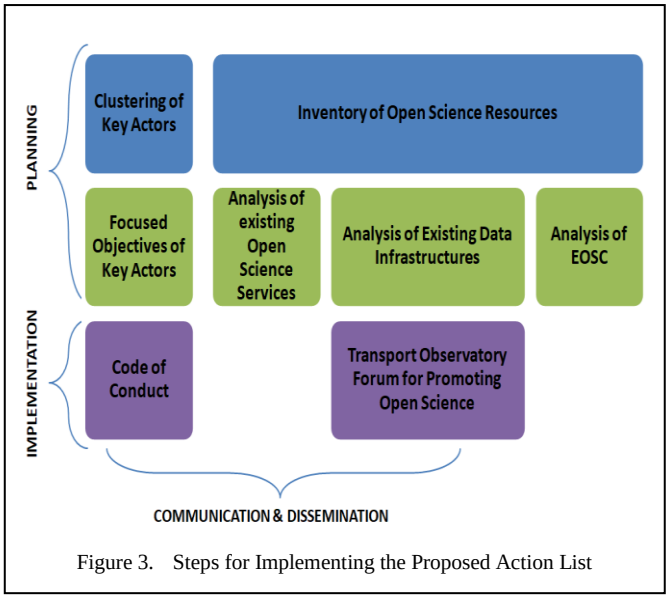

Figure 3. Steps for Implementing the Proposed Action List

provide focused objectives and needs of the key categories of actors. It could gather common principles, definitions and technical data for enhancing the movement to make scientific research accessible and will produce proper methodologies to optimize the effectiveness of "Open Science" actions studying best practices and effective modern technologies.

In the transport domain, there are several existing or emerging Open Science practices and resources and a mapping exercise is necessary to determine how transport research fairs in open science and how it fits with the EOSC developments. As such, an inventory of Open Science resources in transport research with focus on Open Access to publication and data, FAIR (Findable, Accessible, Interoperable and Re-usable) data, open software, data skills, open peer review processes, open education or citizen science initiatives could be built with a focus on the so called Big data and the General Data Protection Regulation (GDPR) to identify gaps in making them FAIR. In view of their integration within the EOSC, governance and operational/business models to provide better data access in transport research would be provided.

Capitalizing upon the initiatives of the European Commission and with the support of the aforementioned actions, a transparent forum and observatory should be developed to act as an evidence-based, community driven sharing of knowledge and experiences. This forum and observatory could enable strategic planning and networking between different countries and research programmes covering the entire transport research network and leading to an agreed ambition and smart coordination services for building Open Science platforms in transport research. Moreover, it will provide the tools to foster an evidence-based discussion and cross-fertilization of ideas amongst researchers in transport on the national, European and global scene.

A regulatory and policy code of implementation has to be developed to provide the legal and ethical guidance needed to operationalize Open Science principles at regional, European and international level. This could follow the agreed ambition of stakeholders for a flexible and integral approach of building Open Science platforms for transferring knowledge and experiences. It could offer guidelines for adopting Open Science in transport research in the European area capturing security terms, data protection, technology transfer as well as intellectual property rights, ethical and legal issues. Recommendations could also be provided for promoting Open Science in transport research considering the main challenges, bottlenecks and opportunities for implementing them, including proper KPIs for Open Science in transport evaluation and skills.

The proposed action list (Fig. 2) aims to i) standardize existing Open Science services and infrastructures verified by the relevant stakeholders, ii) regulate proper schemes regarding legal and privacy issues that are required to make Open Science actions sustainable, and iii) promote Open Science platforms building at regional, European and international level capable to promote communication and networking among stakeholders in the transport research area. Finally, proper indicators will support Open Science purposes and a monitoring process will be used to address information management, internal coordination, external coordination, risk management and other relevant dimensions in order to facilitate continuous improvements in Open Science exploitation.

In this context, the respective guidelines are presented in Fig. 3 summarizing the critical steps that have to be taken to integrate open science in current operations of transport stakeholders. The steps of the proposed methodology are focused to capitalize upon existing initiatives so as to enable Open Science formulation allowing key actors to coordinate and support actions for promoting Open Science policies, services and infrastructures in the transport research domain by involving them in planning and implementation and enabling them to learn from direct experience, previous knowledge and other relevant stakeholders. Moreover, they aim to facilitate a common understanding among actors identifying common definitions, principles and methodologies for promoting Open Science and prioritizing existing initiatives and actions at regional, European and International level.

In particular, the first step of the planning phase involves the clustering of key actors according to transport modes (road, rail, air, water, cross-modal) and in parallel, the creation of an inventory of the available Open Science resources such as data repositories, platforms of open access papers and books, open networks etc. This step will provide focused objectives for each class of actors as there are significant differences among them even though they all belong in transport sector. Moreover, a thorough analysis of existing Open Science services, data infrastructures and the EOSC should be achieved to summarize how they could be used efficiently and provide input regarding the code of conduct and the transport observatory and forum. The implementation phase involves the last step for implementing the proposed action list, in which a commonly agreed code of conduct and the transport observatory and forum will be developed to promote Open Science in transport research. Communication and dissemination actions will further promote this opening up of science in transport research.

IV. Conclusions

The proposed action list (Fig. 2) of the different main aspects of Open Science in transport research provides a grid of guidelines (Fig. 3) that have to be taken to integrate open science of transport stakeholders.. The main goal is to present critical processes that should be followed in order to make science more efficient, better reproducible and more responsive to societal and economic expectations. The derived outcomes are synopsized to the implementation of a commonly agreed code of conduct and to the development of a transport observatory and forum which could provide valuable tools for promoting Open Science in transport research in Europe. The main contribution of the proposed action list is that deals with the Open Science in transport research following the agenda of the EC strategy and exploits previous initiatives in Open Science promoting collaboration schemes among industry, research community and citizens in order to speed up the path from research to innovation. Furthermore, it promotes citizen's engagement in scientific process by working together for improving societal value via the proposed transport observatory and forum.

According to the analysis of the technical background, review of EC policies and the shared available knowledge of Open Science, the proposed action list (Fig. 2) and the corresponding guidelines of implementation as they described in section III, present how a common understanding of Open Science among key actors could set the basis to exploit current initiatives at regional, European and International level following a monitoring process in order to improve and enable research information sharing. In an attempt to increase the efficiency of transport science, proper rules (i.e. clusters of key actors, framework to enable common understanding, regulatory and policy code of implementation) and tools (i.e. inventory of Open Science resources, transparent forum and observatory) should be developed as indicated by the proposed action list and elaborated further in the proposed steps (Fig. 3).

Besides the aforementioned observations, consideration is also given on future research and directions are drawn. An important perspective is based on future use cases for all transport modes (road, rail, air, water, cross-modal) affecting Open Science trends and related industrial developments in the transport arena. Towards this direction, a systematic review of current scientific production of all transport modes by assessing activity of current European technology platforms (i.e. ERTRAC, ERRAC, WATERBORNE ETP, EIRAC, ACARE, ESTP, ALICE) and main influential organizations (such as ECTRI, EURNEX, EATEO, WEGEMT) could provide an overall assessment of scientific production against innovation uptakes. As such relevant recommendations for the definition of future Open Science services and infrastructures will be delivered in an attempt to support operationalizing Open Science in transport research of the European area.

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