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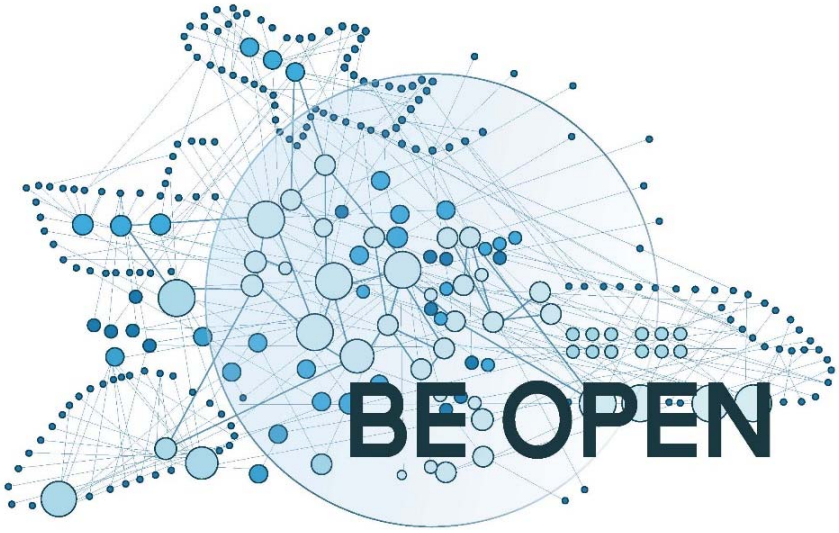

European forum and oBsErvatory for OPEN science in transport

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D5.4 Roadmap and guidelines to promote Open Science in transport research

Final Version

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Abbreviations and Terminology

ALLEA	All European Academies
Be OPEN SC	BE OPEN Steering Committee
CoC	Code of Conduct
EOSC	European Open Science Cloud
ESF	European Science Foundation
EWCOSET	Expert Working Committee on Open Science and Ethics in Transport
FAIR	Findability, Accessibility, Interoperability, and Reuse
GDPR	General Data Protection Regulation
IEC	International Electrotechnical Commission
ICSU	International Council for Science
IPR	Intellectual Property Rights
ISO	International Standards Organization
MoC	Memorandum of Cooperation
MoU	Memorandum of Understanding
OSTR	Open Science in Transport Research
RTO	Regional Transport Offices
SWOT	Strengths, weaknesses, opportunities and threats
TOPOS	TOPOS, the Transport fOrum / Observatory for Promoting Open Science

Executive summary

Deliverable 5.4 – Roadmap and guidelines to promote Open Science in Transport Research encompasses the vision of the community of Open Science in transport research and the strategy and framework conditions towards fulfilling the vision by 2030. In 2030, Open Science is a reality in transport research, the TOPOS Observatory has been already developed and is being used. TOPOS observatory is recognized as the Open Science platform for transport research that supports the transformation of mobility towards safety, security, decarbonisation, openness, inclusivity and seamlessness of journeys.

The document describes the challenges (i.e. technical interoperability, data and information interoperability, deploying of new skills, new schemes for research evaluation and collaborative ways of working, privacy and legal issues) between the future vision and the status quo, the planned milestones and recommended action as well as guidelines and principles to promote the required cultural shift towards Open Science. The EOSC Strategic Research and Innovation agenda sets the framework for necessary skills, fundamental principles and infrastructure to promote Open Science in Europe until 2027. Since the coordination and support action BE OPEN is acting in close collaboration with the European Open Science Cloud (EOSC) Partnership, it harmonized its milestones with the given timeframe of the EOSC Strategic Research and Innovation Agenda and relates to the goals Strategic Transport Research and Innovation Agenda for air-, road-, rail and maritime and cross-modal transport towards clean, competitive and connected mobility.

The milestones are aligned in four steps, from connecting the community and establishing the TOPOS Observatory and Forum (2021), up-taking the practice of Open Science in transport research in research organisations and academia (2023), embracing collaboration with citizens, industry, authorities to achieve Open innovation for required transport solutions (2025), to the internationalisation of the community, principles, standards and practices ((2027) in order to support the global transformation of mobility towards decarbonisation, safety and security and inclusive mobility that serves the people and the planet until 2030.

The roadmap offers recommendations along Key Success Factors, mainly focussing on the training and education, and the dissemination of principles and practical aspects through the promotors for the entire community (academia, researchers, research organisations, authorities, NGOs, citizens, and many more), standardization of data, provision of resources and capacities to conduct Open Science as well as effective incentives to trigger a cultural shift to share-re-use- and reproduce research, build-up of security measures, development and innovation in open infrastructures and methods. Finally, the coordination, support and accompanying research is suggested alongside the uptake of Open Science in transport research to constantly learn and improve practices and assess its impacts in order to be able to adapt strategies.

The document is set up, typically for roadmaps, to work as a living document that can be updated through the growing community regularly in order to react to new developments influencing Open Science practice in Europe.

1 Introduction

1.1 Purpose of the document

The BE OPEN project is a coordination and support action funded by the European Commission ("EU Commission") in the Horizon 2020 research and innovation programme under the grant agreement No 824323. BE OPEN aims to promote Open Science in transport research and assist in regulating Open Science aspects and standardising them. The overarching vision of BE OPEN is to create a common understanding on the practical impact of Open Science and to identify and put in place the mechanisms to make it a reality in transport research. The main objectives of the BE OPEN project are:

- To develop a framework in order to establish a common understanding of operationalising Open Science in Transport;
- To map existing Open Science resources and see how transport research fits in;
- To facilitate an evidence-based dialogue to promote and establish Open Science in Transport;
- To provide the policy framework and guidance for Open Science implementation in transport;
- To engage a broad range of stakeholders in a participatory process for Open Science uptake.

Deliverable 5.4 – Roadmap and guidelines to promote Open Science in Transport Research encompasses the vision of the community of Open Science in transport research and the strategy and framework conditions towards fulfilling the vision by 2030. The document describes challenges i.e. technical interoperability, data and information interoperability, deploying of new skills, new schemes for research evaluation and collaborative ways of working, privacy and legal issues between the future vision and the status quo, the planned milestones and recommended action as well as guidelines and principles to promote the required cultural shift towards Open Science.

The EOSC Strategic Research and Innovation agenda [1] sets the framework for necessary skills, fundamental principles and infrastructure to promote Open Science in Europe until 2027. Since the coordination and support action BE OPEN is acting as an arm of the European Science Cloud (EOSC) Partnership, it harmonized its milestones with the given timeframe of the EOSC Strategic Research and Innovation Agenda and relates to the goals Strategic Transport Research and Innovation Agenda[2] for air-, road-, rail and maritime and cross-modal transport towards clean, competitive and connected mobility.

[1] EOSC (2020): EOSC Strategic Research and Innovation Agenda. Retrieved from: https://www.eoscsecretariat.eu/sites/default/files/eosc-sria-v09.pdf. Last access: 21nd June 2021.
[2] European Commission (2017): Commission Staff Working Document. Towards clean, competitive and connected mobility: the contribution of Transport Research and Innovation to the Mobility package. Retrieved from: https://ec.europa.eu/transport/sites/default/files/swd20170223-transportresearchandinnovationtomobilitypackage.pdf. Last access: 21nd June 2021.

As shown within the BE OPEN project, Open Science in transport research has the power to re-use existing knowledge and work jointly – not isolated – to face complex problems of the transport system itself and to mitigate effects today´s transport system causes to the society and ecology by emphasizing it means to connect Europe and to provide mobility for all Europeans. In the light of Horizon Europe, the 9th framework program of the European Union 2021 to 2027, a fundamental shift has been programmed and triggered: It requires the entire research community to conduct Open Science. Because each scientific discipline faces unique challenges, while they share other rather general ones, this roadmap is equipped with guidelines to make Open Science in transport research to work in a best possible way: It empowers the community to share-reuse-reproduce research results through the established TOPOS Observatory to act as the Common European Data Space in the discipline and to develop Open Science practice further through a constructive dialogue in the TOPOS Forum. Through the implementation of the displayed strategies towards a cultural and structural shift in science, the community of Open Science in transport research will be supported to serve the European vision of a safe and secure, inclusive and seamless transport system by 2030.[3]

The document is set up, typically for roadmaps, to work as a living document that can be updated through the growing community regularly in order to react to new developments influencing Open Science practice in Europe. All stakeholders are invited to discuss the strategy and contribute to the further development of the strategy.

1.2 Objectives of the task

The **objective** of Task 5.4 "Roadmap and Guidelines to promote Open Science in transport research" is to harmonize the joint activities from the different stakeholder groups towards a joint vision. Perpetuating the community building through the BE OPEN project and building upon the framework of common understanding, it was the task to design and conduct a participative road mapping-process that enables relevant stakeholders to exchange and agree jointly on a vision based on desired impacts of Open Science as well as specific goals, challenges on the way towards them, milestones to describe the way forward as well as guidelines and principles to practice Open Science.

[3] The vision was suggested among others by the Mobility4EU project based on a participatory approach with transport stakeholders and mobility users. The vision map can be found here: Mobilty4EU (2016): Vision Map. Retrieved from: https://www.mobility4eu.eu/?wpdmdl=2160. Last Access: 21nd June 2021.

2 Methodology

2.1 What is a roadmap?

A roadmap is a strategic plan showing a desired or different pathway from the present towards a future goal. Product/service/process roadmaps can be applied as a plan to develop innovative processes, services or products to align complex development process across teams or departments, strategic research and developments or innovation roadmaps are used to harmonize actions of stakeholders of innovation ecosystems vertically and horizontally to achieve a jointly agreed or politically pre-given vision.

The following strategic innovation roadmap is based on the following framework (see figure 1):

Firstly, the roadmap shows the framework of common understanding of Open Science in transport research (see chapter 3). Secondly, it is important to understand the **context** by defining the targeted community and by consequently analysing current developments and trends in the context of (Open) science and transport (research) and to assess the relations of these developments on the community (see chapter 4). Further, potential positive and negative impacts of the practice of Open Science in transport research are forecasted (see chapter 5). On the basis of the context and impact assessment, a **vision** for 2030 is drawn (see chapter 6). A vision is understood in this roadmap as the description of a future state comprising goals and desired impacts of these goals in the context of other initiatives and activities from the European Commission, science, industry and societal needs. The derived **challenges** shed light on the **key success factors** to implement the vision (see chapter 7). To stimulate and sustain the cultural shift towards Open Science, fundamental **guidelines and principles** are outlined. To break down the endeavour of promoting Open Science in transport research in transparent steps, **milestones** are proposed (see chapter 9). Core to the vision is the sustainability and continuous optimization of the TOPOS observatory. Finally, **actions,** i.e. measures, to reach each milestone and the vision are recommended (see chapter 10).

Figure 1 TOPOS-Roadmap

2.2 Road mapping-Process

The participative road mapping process has been moderated by VDI/VDE-IT in order to guide the experts from Open Science in transport research, law, dissemination/community building/diffusion and technology/infrastructure/security. The process is accompanied by desk research phases to prepare the workshops.

The roadmap process is based on four consecutive steps (see figure 2)

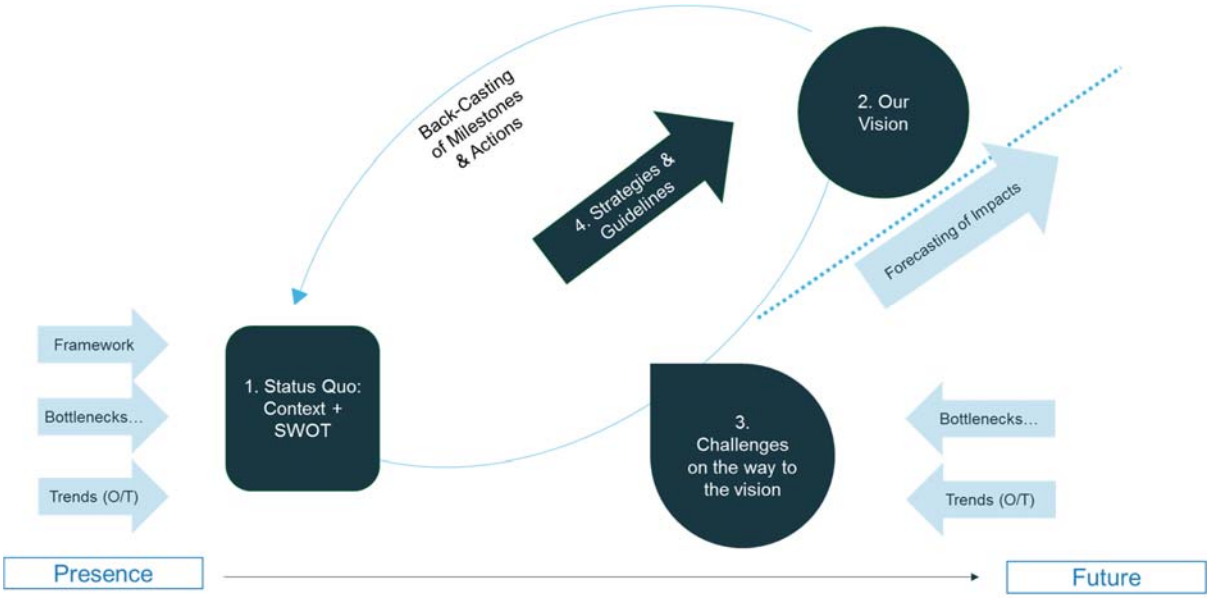


Figure 2 Roadmap Process & Inputs

1. **Understanding Context**
   To understand contextual developments around the matter of Open Science in transport research, the following task are conducted:
   - Definition of the community
   - Analysis of political, technical, societal and ecologic trends, economic conditions and existing community needs with the context map (see figure 4)
   - Identification of uncertainties

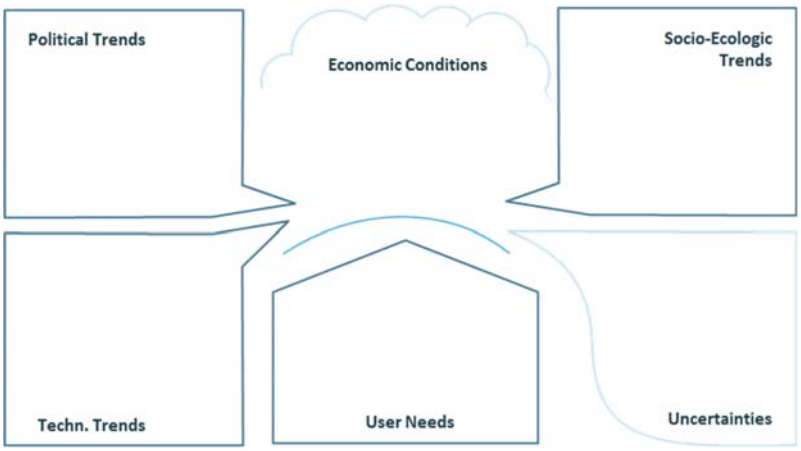


Figure 3 Context Map

2. **Forecasting Impacts and Creating the Vision (2 workshops)**
   To envision the goals for 2030, the following tasks are undertaken:
   - Identification of potential positive and negative impacts, selection of the desirable impacts and the ones to be avoided on policy, transport, society, ecology and economy
   - Derivation and evaluation of mechanism to achieve these impacts
   - Definition of a core vision

3. **Analysing the Status Quo and Identifying the Challenges (1 workshop)**
   To identify the challenges on the way to the vision, the following tasks have to be accomplished:
   - Analysis of strengths, weakness as well as opportunities and threats (SWOT) in front of the background of the context analysis
   - Derivation of gaps between the categories and formulation of challenges
   - Clustering challenges and reformulation to Key Success Factors (KSF)

Figure 4 SWOT Analysis

4. **Back-casting of Milestones and Actions (2 workshops)**
   To define milestones and actions, the following tasks are conducted:
   - the envisioned future state was defined and then worked backwards to identify objectives and actions that will connect that specified future to the present., (see figure 2)
   - Identification of actions to reach the steps (see figure 5)

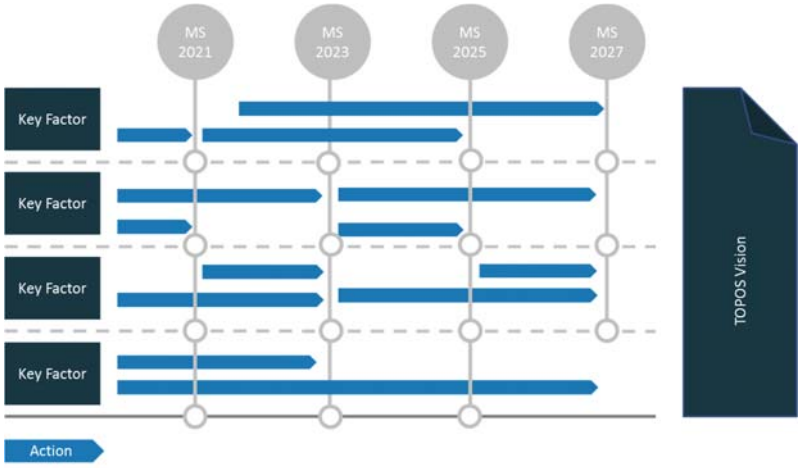


Figure 5 TOPOS-Roadmap Scheme

3 Open Science in Transport Research

3.1 Basic Concept

Open Science: It is the movement of making science more accessible to all levels of society – both amateurs and professionals. Openness should be attempted on several different areas such as data, access, infrastructure, methodology, peer review or Citizen Science[4]. One of the main goals of Open Science is it to share, re-use and reproduce scientific results to improve the quality of science and to use results further, make it transparent to stakeholders.

Core sub-concepts are:

Open Access: Open Access (OA) is in general known as the process of managing copyright and licensing terms, that in some cases remove barriers such as price (including subscriptions, licensing fees, pay-per-view fees) and permission (e.g. copyright and licensing restrictions), in order to enable free, online access to full-text information.[5]

[4] BE OPEN project (2021): Impact assessment of Open Science in Transport. Retrieved from: https://beopen-project.eu/storage/files/beopen-d53-impact-assessment-of-open-science-in-transport.pdf. Last access: 23.06.2021
[5] BE OPEN project (2021): Impact assessment of Open Science in Transport. Retrieved from: https://beopen-project.eu/storage/files/beopen-d53-impact-assessment-of-open-science-in-transport.pdf. Last access: 23.06.2021

Open Data: Open Data – Open Data are online, free of cost, accessible data that can be used, reused and distributed provided that the data source is attributed.[6]

Open Source Software: Open Source Software (OSS) is a software with a source code that anyone can inspect, modify, and enhance. OSS applications have been increasing over the last decades and expanding in new key areas, such as transportation, tourism, health, etc. (BE OPEN, D2.2). OSS applications follow the general principles of "open source" and embrace all principles of open exchange, collaborative participation, rapid prototyping, transparency, meritocracy, and community-oriented development.[7]

Citizen Science: Citizen Science is a way to connect professional scientists and the public in which the public directly contributes to the production of knowledge, sometimes restricted to data collection or simple analysis but also involving more substantial activities. Citizen science has been on the increase since the 1990s and it is also known as community science or described as public participation in scientific research. The purpose of citizen science could be to improve the scientific communities' capacity, to increase the public's understanding of science, and to democratize scientific processes.[8]

When applying these concepts to transport research positive impacts and benefits Open Science in Transport Research can bring towards society, ecology, economy and to policy will be explained in the forecast of impact (see chapter 5).

3.2 Community of Stakeholders of Open Science in Transport Research

The relevant stakeholders that either can affect or be affected by the implementation of an Open Science framework in transport research have been identified and categorised across various BE OPEN deliverables. A taxonomy of the key actors has been performed in the BE OPEN deliverable D1.1[9]. The stakeholders were categorized into two groups, the primary and secondary stakeholders, as follows (see figure 6):

[6] BE OPEN deliverable D 1.2 "Open Science framework, terminology and instruments".https://beopen-project.eu/storage/files/beopen-d12open-science-framework-terminology-and-instruments.pdf. Last access: 23.06.2021
[7] European Commission (EC), 2020. Open source software strategy. Available from: https://ec.europa.eu/info/departments/informatics/open-source-software-strategy_en Last access: 13th May 2021
[8] European Commission (2020): Best Practices in Citizen Science for Environmental Monitoring. https://ec.europa.eu/environment/legal/reporting/pdf/best_practices_citizen_science_environmental_monitoring.pdf. Last access: 23.06.2021
[9] BE OPEN deliverable D 1.1 "Taxonomy of actors, terminology and experimental tools". https://beopen-project.eu/storage/files/beopen-d11-taxonomy-of-actors-terminology-and-experimental-tools.pdf Last access: 23.06.2021

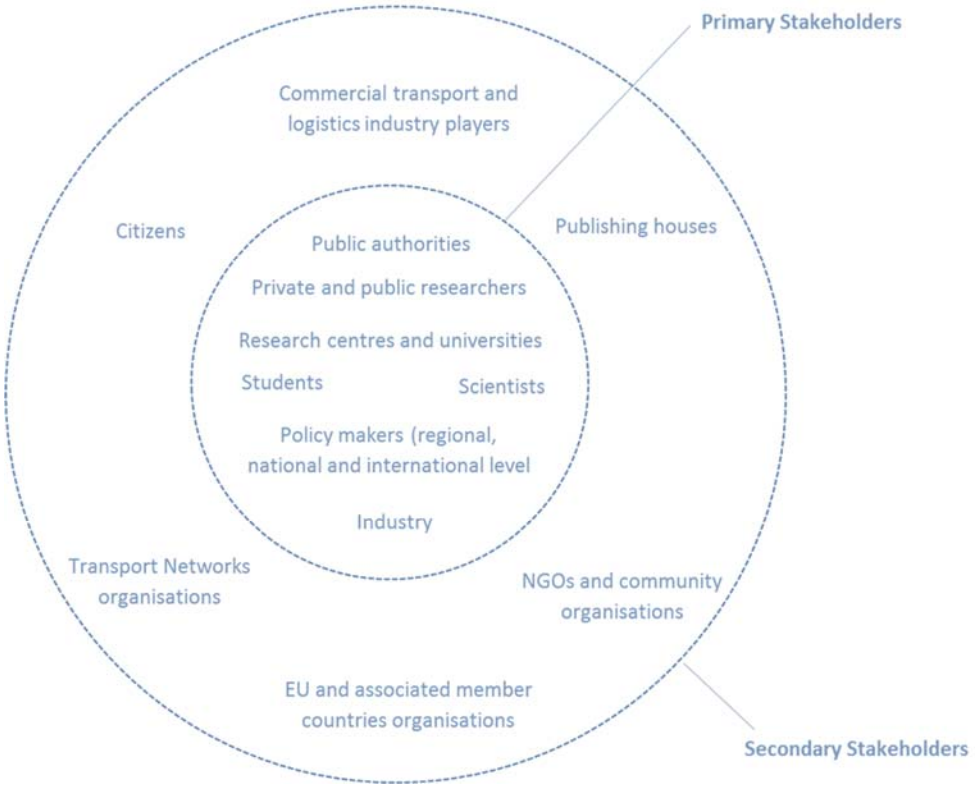


Figure 6 the community of Open Science in transport research

It is crucial for Open Science that these two big stakeholders groups are in constant exchange, shown with the dotted line. E.g. citizens benefit from Open Science results through more transparency (BE OPEN Deliverable D5.3), while they are key for conducting Citizen Science. Thereby, they take in a hybrid role within the stakeholder map.

Furthermore, the taxonomy of the key actors was also performed for each of the competence areas, in which the transport sector appears to be formed, as defined in the BE OPEN deliverable D1.1. In the BE OPEN Deliverable 1.2[10] an analysis of primary stakeholders (i.e. stakeholders who are directly influenced) and secondary stakeholders (i.e. stakeholders who are indirectly influenced by the topic/ project/ strategy/ regulation in question in a specific competent area) was conducted, leading to the following results:

[10] BE OPEN deliverable D 1.2 "Open Science framework, terminology and instruments".https://beopen-project.eu/storage/files/beopen-d12open-science-framework-terminology-and-instruments.pdf. Last access: 23.06.2021

Competence Area	Primary stakeholder	Secondary stakeholder
Legal/Regulatory	Policy makers and public authorities, with the participation of transport networks and commercial and logistics industry players	Research centres and universities together with researchers and students
Technological	Research centres and universities together with commercial transport and logistics industry players followed by transport network and policy makers	Transport network and policy makers
Transport planning	Public authorities, transport networks and policy makers	Commercial transport and logistics industry players and research centres and universities.
Business modelling	Policy maker, Public authority, Transport networks, Commercial and logistics transport players"	Research centres and universities
Socio-economic	Public authorities, commercial transport and logistics industry players and transport network	Transport network
Environmental	Research centres and universities, public authorities, commercial transport and logistics industry players and policy makers	NGOs and community organizations together with citizens

Table 1 Stakeholders influenced based on competence areas (Source: BE OPEN Deliverable 1.2)

3.3 Framework of Common Understanding

Open Science comprises all of the research process, from discovery to publication and dissemination. In such an ecosystem, stakeholders from different transport modes, competence areas and levels should be included to foster a framework of common understanding that accounts for the needs of all of them, and allows to benefit from the potential of implementing Open Science. In the BE OPEN project, a framework for Open Science in transport research data was proposed. It is concluded in the Deliverable 1.2[11]. The main goal of the framework is to create common understanding and to propose a feasible framework which fosters Open Science by addressing identified challenges by means of available opportunities to use Open Science in the field of transport research in/across all modes of transport. The proposed framework, among the stakeholder needs and challenges, considers the European Commission recommendations to foster and to remove barriers from Open Science, to develop research infrastructure and to embed open science in the society.

[11]beopen.project.eu. D 1.2 "Open Science framework, terminology and instruments". https://beopen-project.eu/storage/files/beopen-d12-open-science-framework-terminology-and-instruments.pdf Last access 21.06.2021

As the basis of a successful framework, three main topics have been deemed important: common understanding of Open Science terminology, understanding of stakeholder experience and needs and main challenges, which needs to be tackled. The survey on the first-hand experience of stakeholders from different transport modes provided insight into the overall picture (see **Error! Reference source not found.**), usage, knowledge and stakeholders' needs for Open Science in the field of transport research.
The outcome allowed to identify the needs to be addressed by the framework to overcome possible limitations and enhancing a user-centred approach: Like the stakeholders' **main needs** common policy and clear guidelines to ensure the quality of data could be identified, measures and actions for data protection and security have to be made clear. A funding scheme to provide the necessary resources to support stakeholders in their contribution to Open Science needs to be put in place. Implementing technical solutions and focusing on automation processes would help to reduce stakeholders' cost and time. For all the aforementioned actors, support from European as well as national level is needed.

Stakeholders mentioned **limitations** to Open Science such as reciprocity for opening data and science, Concern about world-wide Open-Data sharing, Risks of losing IP, high workloads and insufficient funding as well as lack of metadata and datasets descriptions leading to a future misuse of data.

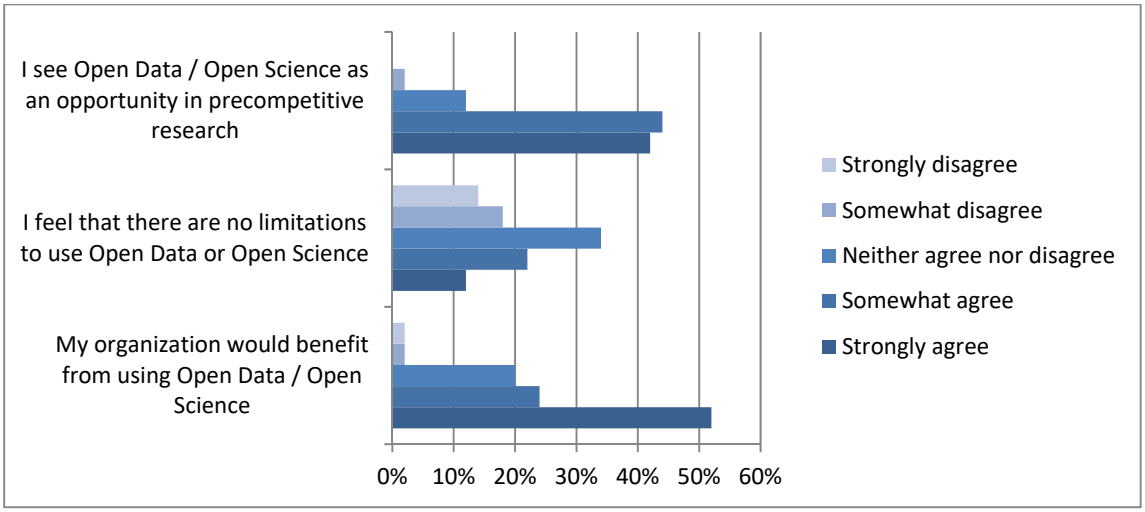


Figure 7 Possibilities for Open Science

Furthermore, an important part for the Open Science Framework are the identified challenges, based on the survey results and the literature review. The following challenges have been previously identified by the European Commission Studies and Report "Analysis of the state of the art, barriers, needs and opportunities for setting up a Transport Research Cloud"[12]: fragmented data and large variety of stakeholders, enhancing data security and privacy principles, funding, data quality, lack of

[12] op.europa.eu. Analysis of the state of the art, barriers, needs and opportunities for setting up a transport research cloud. Retrieved from:https://op.europa.eu/en/publication-detail/-/publication/93f647a7-ee08-11e8-b690-01aa75ed71a1/language-en. Last access 21.06.2021

skilled experts and legal challenges. Furthermore, the high volume of data collected in the field of transport that is ever-growing due to the implementation of disruptive technologies such as automation and connected vehicles, lets the community face the challenges of Big Data such as special handling concerning storage space and computer processing capabilities, building up a technological challenge.

Those challenges were confirmed through a stakeholder survey, which main outcome a strong need for common was understanding in Open Science, this common need requires the creation of a supportive framework.

The basic common understanding of Open Science in transport research paves the way for the creation of a successful framework. The major inputs for the structure, as shown in **Error! Reference source not found.**, consisted of the identified challenges which describe the main topics of interest to be addressed by the framework in order to satisfy the user needs and overcome anticipated issues, and Open Science sources, which demonstrate the potential for implementation of Open Science in transport research.

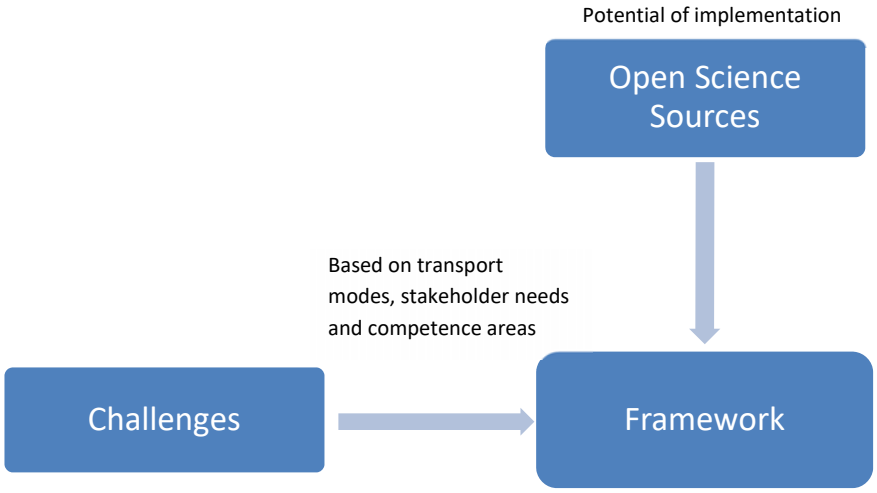


Figure 8 Schematic of framework inputs

Based on the work done in the D1.2, the framework addresses seven topics, derived from the identified challenges (see **Error! Reference source not found.**Figure 9): Policy, Dissemination, Financial models, Support and services, Training, Data protection, Guidelines.[13]

[13] Helena Gellerman, Erik Svanberg, Yvonne Barnard. Data sharing of transport research data. s.l. : Science Direct, 2016.

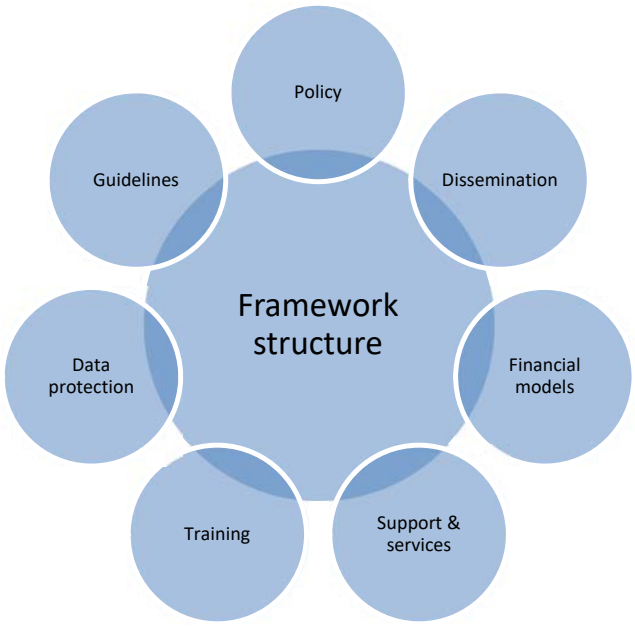


Figure 9: Proposed framework structure

The complete framework is shown in BE OPEN Deliverable 1.2

4 Status Quo of Open Science in Transport Research (OSTR)

In this section, the results of the analysis of the contextual trends relating to open science in transport research are outlined. The current situation and trends by various perspectives are described in order to better understand the ecosystem and developments. The analysis covers political trends, the socio-ecological trends, the technology trends, the economic trends and the current needs of community in open science based on an expert panel.

4.1.1 Political trends

In Europe, over the last years, from the side of the European Commission there is a clear willingness to promote Open Science, and in fact the most relevant trend is open access to research outputs and especially to publications. The Horizon 2020 EU research and innovation framework programme, in the spirit of the EU's strategy to boost international co-operation in research and innovation, promotes 'borderless research' that is open to researchers from all over the world, and openness in the sharing of results. Within this context, the EOSC[14] is under preparation, while also several EU projects (e.g. OPENAIRE, BE OPEN, OSCAR, etc.) have been conducted in order to prepare the ground for open

[14] eosc-portal.eu. Retrieved from: https://eosc-portal.eu/ Last access 21.06.2021

science. Horizon Europe, the new framework programme envisages that all resulting publications will become openly and freely available, and researchers are also encouraged to make available the underlying data. It has to be explained in the proposals if data cannot be opened.[15] Additionally, the importance of involving citizens in decision-making and incorporating citizens' views in science and technology policies[16] has also been stressed. At national level, different status of open science framework is appeared among the EU Member States, however, more and more OpenGov systems are developed, reflecting the willingness of the central national authorities to share openly national data.

4.1.2 Socio-ecological trends

At societal level, there is a trend of slowly increased cultural and political segregation in the EU, especially by specific social or political groups who want to leave the European Union. Contrary to this trend a sharing culture of knowledge and solutions among European citizens is growing slowly as a response. There is also an increased need from the side of citizens to play a more active role and to participate in science and policy not only at national but also at EU level.[17] Open data and open science aim to respond to the need of society for transparency in decision making, as well as in the efficient use of available budgets, used for the well-being of citizens. Concerning the transport sector, inclusive, seamless and sustainable mobility is required, covering also remote areas as well, with the most serious challenge facing the transport sector to significantly reduce its emissions[18].

4.1.3 Technology trends

A revolution in transport is witnessed over the last years, which is anticipated to grow further in the future. New, smart technologies are transforming not only vehicles, but also mobility choices and travellers' behaviours, which will consequently lead to a necessary upgrade of the transport system. In the road transport sector, certain technological innovations are expected to drive major changes. These innovations concern digitalisation, automation, artificial intelligence (AI), and the decarbonisation of transport[19]. Moreover, hand held mobile devices are being increasingly used, providing enormous amount of data, which change business strategies and create new ideas and businesses but also bring opportunities to involve citizens in science. Indeed, over the last years, major technology companies have captured a large part in the field of personal mobility and transport-

[15] European Commission (2014). 'Horizon 2020 in brief. The EU Framework Programme for Research & Innovation'
[16] European Commission (2014). 'The Future of Europe is Science'
[17] Buergerrat.de (2020). Local Citizens' Assemblies in Germany. Retrieved from: https://www.buergerrat.de/en/news/local-citizens-assemblies-in-germany/. Last access: 23.06.2021.
[18] European Commission (2021). Sustainable and Smart Mobility Strategy - Putting European transport on track for the future
[19] Raposo et al. (2019). The future of road transport - Implications of automated, connected, low-carbon and shared mobility, EUR 29748 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-14318-5, doi: 10.2760/668964, JRC116644.

related data[20]. This leaves room for the discussion of how to use and analyse the data to face major societal issues related to transport. Technological developments have also contributed to the development of methods and tools for open science (e.g. EOSC based on the OpenAire graph Meta data, methods to analyse metadata), while also methods to ensure data privacy and security are optimised.

4.1.4 Economic Conditions

Technological developments have significantly accelerated innovation in the context of the fourth industrial revolution (also known as 4IR or industry 4.0) worldwide. There is a major shift towards a fully data-driven economy, with the US being the world leader, followed by Europe and Japan. However, the steep development of innovative activity of China and South Korea has caused Europe to lose ground[21]. Over the last years, industry is becoming more open-minded towards Open Innovation, however, there are still many companies not willing to adopt an open sharing policy, mainly due to loss of advantage over their competitors. Further collaborations between the research organisations and industry may be profitable, however, it seems that industry keeps the profit, while economic incentives for researchers to open data are rarely provided.

4.1.5 Community needs

A closer analysis of the community needs can serve as important groundwork for the development of the roadmap to promote open science in transport research. Valuable input can be found in the stakeholder survey performed in the BE OPEN deliverable D 1.2[22]. Based on this survey, the main needs of the community are to have a common policy and clear guidelines to ensure the quality of data. Additionally, proper measures and actions for tackling the various legal and ethical issues (e.g. data protection and security) have to be made clear for the more efficient use of open science. Funding schema to provide the necessary resources to support stakeholders in their contribution to Open Science need be put in place. Implementing technical solutions and focusing on automation processes would help to reduce stakeholders' cost and time. For all the aforementioned actors, support is needed not only at European and national level, but also at institutional level, by providing proper training in searching and producing open data, software and publications.

[20] BE OPEN deliverable D5.1 "Main challenges and opportunities, constraints and bottlenecks of Open Science in transport research". https://beopen-project.eu/storage/files/beopen-d51-main-challenges-and-opportunities-constraints-and-bottlenecks-of-open-science-in-transport-research.pdf Last access: 23.06.2021

[21] European Patent Office (2020). "Patents and the Fourth Industrial Revolution - the global technology trends enabling the data-driven economy"

[22] BE OPEN deliverable D 1.2 "Open Science framework, terminology and instruments".https://beopen-project.eu/storage/files/beopen-d12open-science-framework-terminology-and-instruments.pdf. Last access: 23.06.2021

5 Forecast of Impact

The purpose of the impact analysis in BE OPEN Deliverable 5.3 was to analyse potential impacts of Open Science confirmed and supported by other studies of Open Science, and that will be true beyond the transport sector (see figure 10)[23]:

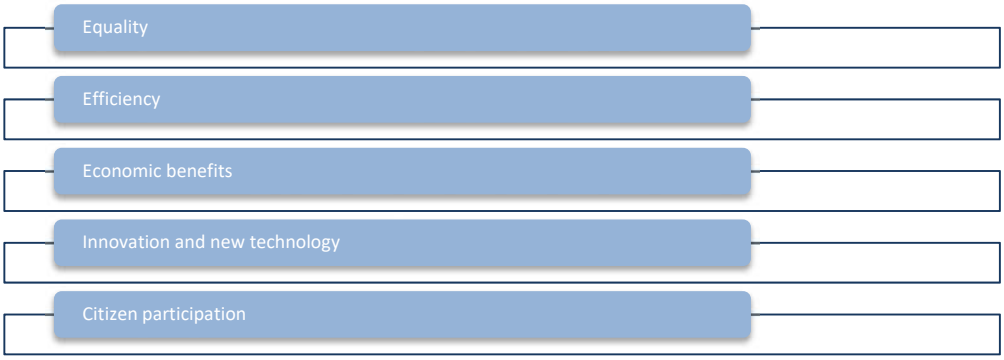


Figure 10 Sectors impacted by Open Science

One dominant impact of Open Science is to create more **equality** due to 1) better access to research for more people/countries/institutions through open access publishing, 2) creating equal competition through new policies for data management and 3) creating equal opportunities through free use of Open source software.

Secondly Open Science will increase **efficiency,** through 1) less time spent on data collection/ needlessly duplicating work, 2) better efficiency for end-users due to reduction in operational cost, 3) solving complex problems faster due to access to more data.

Thirdly, **Economic benefits** through 1) more efficient budgeting because of transparency 2) less time spent on needless duplication of work and collecting data, and 3) improved knowledge exchange 4) increased funding due to better marketing of research

Fourth, Open Science will lead to **innovation** and **new technology**. Economic savings will free a lot of resources that can be relocated to innovation activities. Also, the increased availability of data will lead to potentially faster innovation and also arise the usage of AI technology to handle the amounts of data.

Lastly**, citizens' participation** will bring citizens closer to policy making processes and hence raise awareness in the general public, simplifying the process of implementing new policies.

[23] BE OPEN project (2021): D5.3 Impact assessment of Open Science in Transport. Retrieved from: https://beopen-project.eu/storage/files/beopen-d53-impact-assessment-of-open-science-in-transport.pdf. Last access: 23.06.2021

However, the BE OPEN Deliverables D5.3 also found transport specific impacts (figure 11) of Open Science through literature research.

Figure 11 Specific Impacts of Open Science

Socially and environmentally **lower emission** will improve quality of life and air quality. **Faster travel time** will also increase quality of life, saving costs and improving cities competitive advantage. Possibly, **artificial intelligence** will create better mobility services and faster commuting. However, AI systems also have unknown risks. AI systems will also possibly **improve traffic safety.** Lastly, **increased awareness** could potentially increase acceptance of transport solutions/policy decisions on transport and faster changes in perceptions and behaviour i.e. important to change travel behaviour to reduce emission.

Most former research and the general attitude towards Open Science reflects positive outcomes. However, negative impacts are important to keep in mind in order to make Open Science as sustainable as possible. Task 5.3 highlighted the following:

- **Job loss due** to 1) loss of competitive advantage when there is an unequal playing field with actors who are joining the Open Science paradigm and those who do not and 2) increased use of artificial intelligence.
- **New types of risks** 1) hacking & malicious users creating software bugs 2) potential system failures (AI) with larger unknown consequences.
- **Increased cost** due to 1) infrastructure needs 2) malicious users creating software bugs 3) decision making based on data where the users have a lack of knowledge of how to use open data, low quality data, data bias
- **Increased conflicts** more participants involved in research will not only bring positive outcomes, this can also increase conflict.
- **Time delays** because more people need to agree
- Lastly, when putting in place new infrastructure there is always an **increase in energy consumption.**

A workshop was conducted with several transport experts in Europe looking at future implications of Open Science in transport research. Open data, Citizen Science, Open Source Software and Open Access where the subjects in focus, using the Future Wheel methodology to look into the effects of increased Open Science in transport. Some findings are listed below (see Figure 12):

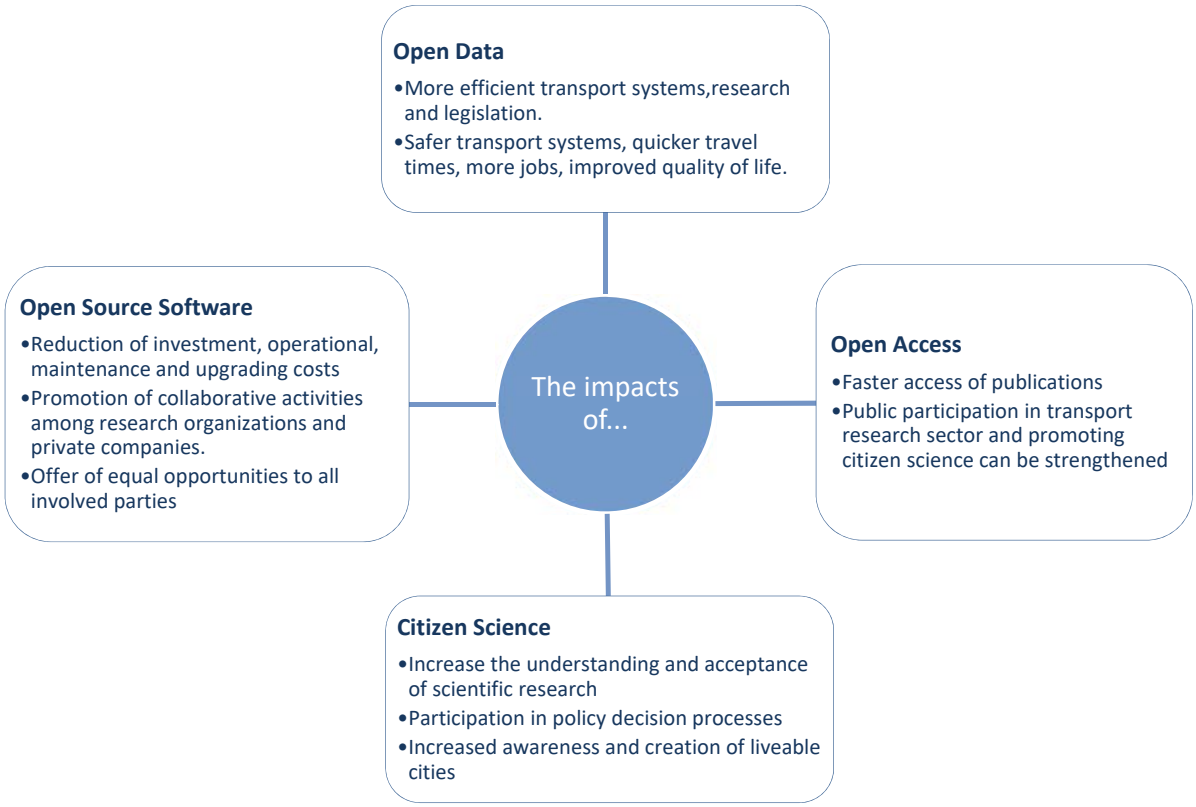


Figure 12 Main Impacts of Open Data, Open Access, Citizen Science, Open Source Software (BE OPEN-D5.3)

6 Vision for Open Science in Transport Research in Europe 2030

In 2030, Open Science is a reality in transport research and TOPOS supports the transformation of mobility towards safety, security, decarbonisation, openness and inclusivity and seamless journeys through the promotion of Open Science in transport research. Transportation Researchers share-reuse-reproduce science and transport sectors are working closer to the society, achieving open innovation and citizen science. As such, proper digital services and products are offered based on data and information gathered at the TOPOS Observatory, making it the Common European Data Space for Open Science in transport research. Through the TOPOS Forum & Observatory the community will have managed to create a common understanding of the practical impact of Open Science in transport research and current transport systems, exchange ideas on new trends, challenges and solutions openly utilizing modern tools and formats that provide higher value and accuracy to societal needs and a better quality of life.

The TOPOS Forum & Observatory offers tools to the research community, industry and society aligned with the global targets against climate change and in support of sustainable development. The Open

Science practice utilizing the TOPOS Observatory contributes to the development of new transport services and business models based on the increased connectivity between infrastructure, transport means, travellers and goods which contribute to seamless door-to-door mobility across borders, and the transfer of best practices to other cities, regions and member states.

In addition, citizens and transport research stakeholders use commonly the offered services of the TOPOS Forum & Observatory as awareness of and trust in scientific research in society has been increased. More effective decision making has also accomplished utilizing in an open way scientific tools and approaches. Strategic planning of transport research is also improved engaging all relevant stakeholders (i.e., research community, industry and public authorities) and achieving an increase in the return on public investment in science. Finally, scientific community improve the impacts dealing with societal challenges (such as COVID-19 pandemic, climate emergency) as TOPOS Forum & Observatory supports international collaboration and provide services that allow stakeholders to work together and exchange knowledge, data, publications, software and other relevant information about transport research.

The further development of EU legislation, consisting of regulations, directives, decisions, recommendations and opinions will serve as basis for the harmonisation of EU Member State laws. With the legal landscapes between EU Member States growing rapidly together, there will be positive effects for Open Science in Transport. Through this harmonisation of the laws, stakeholders throughout Europe will feel safe to share data and participate in Open Science in Transport activities.

In addition, European laws, such as the GDPR for the processing of personal data, will have become the gold standard in countries beyond the borders of the EU. This leads to legal certainty and a strategic advantage for stakeholders in Europe and spreads the word of Open Science globally. Specifically, Intellectual Property Rights will have greatly been adapted to the digital-era and harmonised throughout and beyond Europe. This will serve to create incentives to share and make available data on a large scale even for the very competitive transport domain.

Grounded on a people's perspective, the TOPOS Forum is used for constructive dialogue among students, researchers, experts and the public. Strong and successful case studies are analysed and the use case catalogue for best practices of Open Science in transport research is provided through the TOPOS Observatory.

Further, TOPOS promotes the “European Code of Conduct on Open Science in Transport”. The code of conduct acts as a policy framework between the stakeholders and sets out basic ground rules and a common understanding on essential aspects of fundamental research principles, ethical principles and legal compliance principles. By doing so, the ideas and ideal of Open Science are promoted on the basis of mutual trust in the quality of the data, the integrity and fairness of all committed stakeholders as well as growing confidence about the legal compliance. In conclusion, TOPOS can act as an accelerator for the further development and growth of Open Science in Transport Research to improve efficiency, quality, and integrity and to speed up the path from research to innovation and promote

citizen's engagement in the scientific process as well policy decision process based on the scientific results.

7 Challenges and Key Success Factors

The challenges of open science in transport research have been widely explored in the BE OPEN project and have been recorded in various deliverables. Valuable input can be found in the BE OPEN deliverables D2.1[24], D4.1[25], D4.2[26] and D5.1[27]. Additionally, an expert workshop was held in the context of the Task 5.4, aiming to identify and prioritize open science challenges. The combined analysis of the above sources led to the following broad thematic categories, in which the open science challenges are categorized, the so called Key Success Factors. These are areas where actions are required to realize the vision by 2030.

Key Success Factors	Challenges
Research Community	• Resources and organizational issues • Incentives to researchers • Reform the reward system • Funding Schemes/ Business models for research infrastructures & individual scientific achievements • Not efficient business models • Systematic Unification of Policy Terms • Potential of open data not fully realized • Cost of purchasing the data • IT Sector in Transport research is weak - Lack of technical skills • Skills, Capacities and Capabilities • Personnel time to update and maintain data as needed • Research Culture
Data Issues (creation/usage)	• Low will for sharing data • Digital divide (Age, places without much technology) • Metadata and service interoperability across transport modes • Data Ownership • Low quality and reliability of data

[24] BE OPEN deliverable D2.1 "Open access publications and the Performance of the European transport research". https://beopen-project.eu/storage/files/beopen-d21-open-access-publications-and-the-performance-of-the-european-transport-research.pdf Last access: 23.06.2021

[25] BE OPEN deliverable D4.1 "Open Science in transport research: legal issues and fundamental principles". https://beopen-project.eu/storage/files/beopen-d41-open-science-in-transport-research-legal-issues-and-fundamental-principles.pdf. Last access: 23.06.2021

[26] BE OPEN deliverable 4.2 "Transport Open Data" https://beopen-project.eu/storage/files/beopen-d42-transport-open-data-properties-and-specifications-for-open-science.pdf Last access: 23.06.2021

[27] BE OPEN deliverable 5.1 "Main challenges and opportunities, constraints and bottlenecks of Open Science in transport research" https://beopen-project.eu/storage/files/beopen-d51-main-challenges-and-opportunities-constraints-and-bottlenecks-of-open-science-in-transport-research.pdf Last access: 23.06.2021

Key Success Factors	Challenges
	• Ease of data discovery • Understanding and maintaining open data feeds • Machine readability of data • Complex nature of transport data and information when re-using or combining data sets
Education and Training	• Lack of supportive culture, incentives and training • Harmonisation of training programs/courses across EU countries • Training in data security and privacy • Training in data management • Training in open license practices • Training in database design and computer programming
Collaboration with industry, society and policy	• High economic competition and "selling data" attitude • Too much economic pressure leads to protectionism • Lobbies managing the production of research • Lack of understanding between transportation experts and data scientists • Lack of financing or business models • Potential of open data not fully realized • Fragmented data and large variety of stakeholders • Contractual restrictions from other partners
Legal/ Ethical issues	• Lack of transparency • Reservations regarding open science • Protection of personal privacy /GDPR • Protection of proprietary data • Misinterpretation and illegitimate unintended secondary use • Dual use • Unequal distribution of research results • Commercialisation • Restriction of scientific freedom • Protection of commercial/confidential data
Security issues	• Data leakage • Hacking • Phishing • Fake data leakage • Adequate data encryption protocols
Infrastructure and Tools	• Lack of infrastructure for storage • Costs for infrastructure • Maximising the collection and archiving of real-time data • Lack of appropriate software/hardware

Table 2 Main Challenges

Resources and organisational issues are a significant challenge mainly for the research institutions, but also for all data providers and users, who need further organisational capabilities (leadership roles, proper decision making groups, etc.) in order to better integrate the philosophy of Open Science into

their organisations. In this context, they should also modify their recruiting criteria or develop training programs to increase the capabilities of their management and analytics teams. More skilled experts are thus needed with experience in the field of analytics, together with understanding the best use of datasets to add value to research data.

Making data publicly available needs supporting infrastructures to allow easy access to research data and to make it reusable and easily findable. There is a need to find resources for the necessary infrastructures, as well as efficient and sustainable business models, ensuring the continuation of an open science policy.

Besides the necessary financial and human resources needed, individual researchers should be convinced to share their data and results. However, there are no incentives given to that direction, while without proper training, extra personnel time will be required not only to access open data, but also to update and maintain data as needed.

Concerning transport data, there is a large variety of stakeholders from different modes of transport. They produce different types of data and it would be in their interest to re-use research data from all transport modes. Also, available research data is fragmented, being stored in different catalogues, repositories and platforms. All those factors are making data analyses and accessibility complex. Therefore, interoperability between different databases and repositories is needed. Additionally, due to fragmentation of the data and lack of explicit guidelines to store the metadata and datasets in transport research, the risk of low data quality and validity exists, which are considered important to allow for data reuse and to engage stakeholders from different fields.

Significant challenges for the implementation of an open science policy framework also arise in the case of collaboration of research institutions mainly with industry, but also with political bodies and society. The high economic and commercial competition in most cases make the data providers reluctant to share their data, while researchers are often committed to contractual restrictions, which do not permit them to apply open science principles.

Storing sensitive information in a cloud creates challenges to protect and secure the data. Therefore, there is a need to solve data privacy, legal liability and IP related issues. In addition, partnership agreements need to be put in place between original researchers before sharing the data so that it would be understandable and suitable for everyone – original researchers as well as the future researchers who would use the data. Finally, collecting transport research data from different modes of transport, different countries and including sensitive data restrictions sets legal barriers. There is a need to standardize regional as well as international rules for data privacy including support from European legal regulation, covering security and privacy especially. Also, data made available online

should be ethically used – it is important to set up a mechanism to observe that the regulations are being followed[28].

Furthermore, protectionism must be avoided to strengthen the openness among all stakeholders, also from the private sector.

8 Guidelines & Principles

8.1 FAIR-Principles

The FAIR Guiding Principles for scientific data management were published in 2016 with the intention to provide guidelines to improve the **Findability, Accessibility, Interoperability, and Reuse** of digital assets. According to the BE OPEN Deliverable 2.2 Open/FAIR data, software and infrastructure in European transport research, the FAIR principles allow the creation of new knowledge, that lead to innovation and creation of value, through a guidance that supports the combination of datasets. It is possible only if data is available in convenient and open formats that enable a faster and easier intermixing from the different sources.

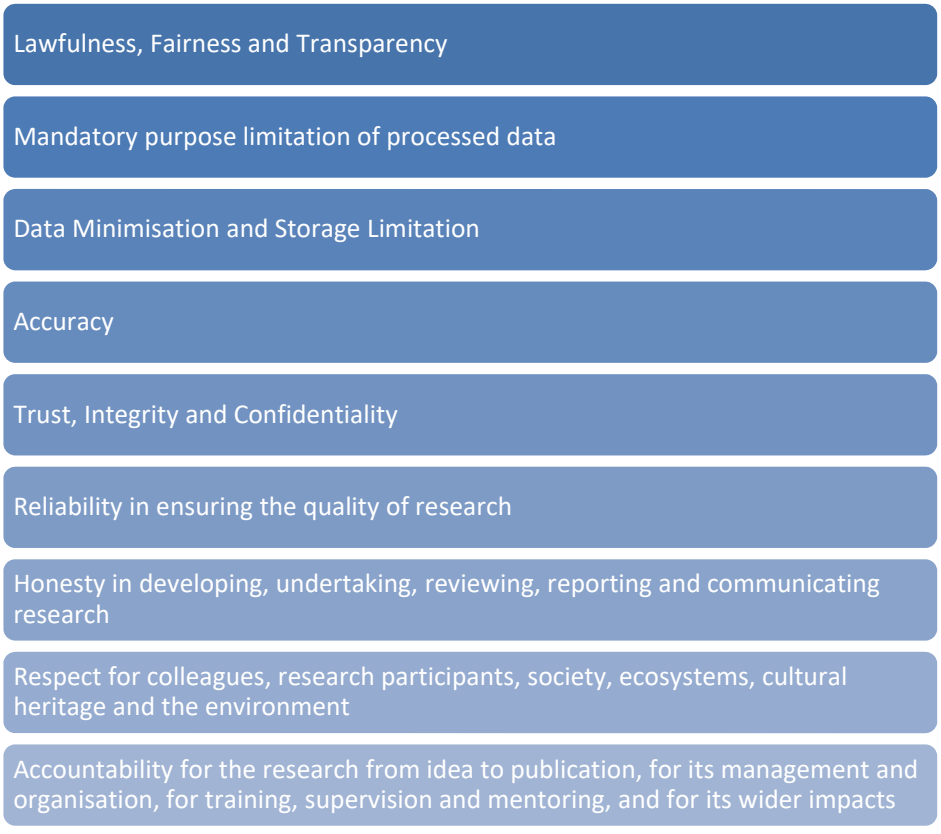
As described on the GO FAIR official website[29], metadata and data should be easy to find for both people and machines. The information should be machine-readable to allow automatic discovery of datasets and services (**Findability**). Once the Information is filtered by machines, the researchers need to know how they can access to it. It might be possible that authentication or authorisation are required (**Accessibility**). To support the creation of new combinations of data, it should be easy to combine with other types of data (**Interoperability**). Lastly, data should be well-described to facilitate its replication and combination in different settings (**Reusability**).

The main difference between completely open data and FAIR data is that FAIR data can be restricted depending on the purpose or its life-cycle (e.g., during research phase data is private but turns public upon publication).[30] The FAIR principles refer to three types of entities: data (or any digital object), metadata (information about that digital object), and infrastructure[31]. In order to apply the Fair principles the GO FAIR community has developed the Three-point *FAIRification Framework* that provides a practical "how to" guidance to the interested researchers.

[28] BE OPEN deliverable D1.2 "Open Science framework, terminology and instruments". https://beopen-project.eu/storage/files/beopen-d12open-science-framework-terminology-and-instruments.pdf Last Access: 16th June 2021.
[29] Go-Fair (2021). Home. Retrieved from: www.go-fair.org. Last Access: 16th June 2021.
[30] BE OPEN (2021): D2.2 Open/FAIR data, software and infrastructure in European transport research. https://beopen-project.eu/storage/files/beopen-d22-open-fair-data-software-and-infrastructure-ineuropean-transport-research.pdf Last Access: 16th June 2021.
[31] Go-Fair (2021). Fair Principles. Retrieved from: https://www.go-fair.org/fair-principles/. Last Access: 16th June 2021.

8.2 Legal and Fundamental Principles of Open Science

The legal and fundamental principles of Open Science in transport research (**Error! Reference source not found.**13) are described in detail in the deliverable D4.1 of the BE OPEN project. They are based on the GDPR essential Data Processing Principles [32] and they are also evaluated by transport stakeholders (i.e., representatives of research centres or universities, private researchers or students, representatives of public service providers for transport research and representatives of private service providers for transport research) within the deliverable D4.4. Based on the derived results, transport stakeholders strongly agree to the (i) **"Lawfulness, Fairness and Transparency"**, (ii) **"Trust, Integrity and Confidentiality"**, (iii) **"Accuracy"**, (iv) **"Reliability in ensuring the quality of research"** and (v) **"Honesty in developing, undertaking, reviewing, reporting and communicating research"**. On the other hand, they disagree with the concept of "Data minimization and storage limitation" and are rather neutral with the "Mandatory purpose limitation of processed data". It should be noted here that these are statutory and mandatory requirements which need to be followed by law when handling any personal data.



[32] Art 8 Para 2 Charter of Fundamental Rights of the European Union.

Figure 13 Legal and fundamental Principles Open Science in transport research

8.3 Research Principles related to Open Science in Transport

Analysing the ALLEA Code of Conduct and the EOSC Rules of Participation, eight research principles were defined in the context of the deliverable D4.4 of the BE OPEN project to support the implementation of BE OPEN, the development of the Code of Conduct and the sustainability of the TOPOS Observatory and Forum. Figure 1414 summarizes the main research principles that will set the basis for the development of the roadmap which aims to provide guidelines to promote Open Science in transport research. The "Research Environment" principle sets proper policies, procedures and infrastructures capable to promote Open Science and to ensure a culture of research integrity. In addition, the "Training, Supervision and Monitoring" principle covers issues regarding the proper training and rules that are required in order to enhance research integrity for sharing or reusing data and other relevant research material. The updates on the research procedures are necessary (expressed by the "Research Procedures" principle) to publish research results in an open way respecting in parallel, confidentiality of data or other sensitive information. The "Safeguards" principle covers issues about differentiations that should be respected and how researchers should also follow legal and ethical provisions. Transport researchers should apply the FAIR principles defined by Open Science supporters, they should acknowledge the used data and they should provide transparency of data and other relevant material according to the "Data Practices and Management" principle. Analysing the "Collaborative Working" principle, it is obvious that transport researchers should commonly agree on communicating their project results openly. Another important principle is focused on "Publication and Dissemination" which covers how transport researchers should communicate their work openly to the general public and research community following the same guidelines (e.g., citations, rules etc.) as in simple publications. The last principle is focused on "Reviewing, Evaluating and Editing" which indicates that open peer reviews and evaluations in the transport research sector should be conducted in a transparent and justifiable way following also common procedures used in the research sector.

Figure 14: Research Principles related to Open Science in Transport

8.4 Summary of the Code of Conduct and how it is further developed

The overarching objective of the BE OPEN project is creating a common understanding about the practical impact of Open Science, as well as identifying and putting in place the mechanisms to make it a reality in Transport Research. An essential element of reaching this vision through the BE OPEN project is developing a policy framework to establish and promote the ground-rules that will enable all stakeholders, existing tools and platforms, as well as resources and content to become an integral part of the Open Science in the Transport Research domain. The objective of such a policy framework is achieved as a code of conduct through deliverable D 4.4, serving as basis to establish the "European Code of Conduct on Open Science in Transport" as a living document.

Based on the experience gained in the various BE OPEN deliverables, the practical experience of the involved BE OPEN beneficiaries as well as the active support by the BE OPEN Advisory Board, the initial version of the code of conduct has been established. It is subject to ongoing adaption and change as a living document (more on that later).

Substantively, the material aspects of the code of conduct cover fundamental research principles, ethical principles and legal compliance principles. It is addressed at all stakeholders, consisting of researchers and students, private researchers, research institutions, organisations and universities, policy makers (on regional, national and international levels), transport networks, NGOs and community organisations, commercial transport and logistics industry players as well as citizens for all their Open Science in Transport activities. It consists of three Chapters:

Chapter 1: Fundamental Research Principles

Through the code of conduct, stakeholders can commit themselves to the fundamental research principles derived from the All European Academies (ALLEA) good research practices as well as the European Open Science Cloud (EOSC) Rules of Participation, which have been adapted and specified. The commitment to the fundamental research principles should particularly aim to avoid breaches of ethical principles predominantly arising from but not limited to unintended secondary use and misappropriation of research results or data in general as well as ethical risks resulting from dual use, unequal distribution of research results, commercialisation and any restriction of scientific freedom.

This Chapter 1 of the code of conduct holds nine Articles in total:

- Article 1 Research Environment
- Article 2 Training, Supervision and Mentoring
- Article 3 Research Procedures
- Article 4 Safeguards
- Article 5 Data Practices and Management
- Article 6 Collaborative Working
- Article 7 Publication and Dissemination
- Article 8 Reviewing, Evaluating and Editing
- Article 9 Diversity, Inclusion and Equality

Chapter 2: Legal Compliance Principles

For all Open Science in transport activities, legal compliance and security should be a core concern for all stakeholders in order to establish and ensure mutual trust in Open Science in Transport. All activities in Open Science must be carried out in compliance with the provisions of EU and Member States laws including relevant sector-specific regulations. However, adherence to the principles formulated in the Articles of the code of conduct does not release the stakeholders from the obligation to adhere to the existing moral or legal norms or applicable laws; in particular, the statutory laws of the EU and the EU Member States remain untouched.

This Chapter 2 of the code of conduct holds six Articles in total:

- Article 10 Intellectual Property Rights
- Article 11 Principles of Data Security
- Article 12 Organisational Measures for Data Privacy Compliance

- Article 13 Complying with EU Data Privacy Principles and Obligations
- Article 14 Processing under Privilege for Scientific Research
- Article 15 Awareness of- and complying with e-Privacy Laws

Chapter 3: Final Provisions

The last Chapter contains only two Articles and mainly constitutes the aforementioned living document characteristic.

8.5 Handling security problems

Various security issues can arise as result of a vast number of different reasons. Security aspects can be both, of legal and non-legal nature and may consist of ethical aspects.

Standards and certification schemes act as important intermediaries between these legal and non-legal security aspects and can facilitate compliance with requirements arising from both worlds. As such, the ISO/IEC 27000 series issued by the International Standards Organization ("ISO") and the International Electrotechnical Commission ("IEC") are of particular practical importance and help stakeholders demonstrate to the regulators and to their customers that appropriate security measures and organizational processes have been implemented. Mandatory security aspects can arise from various different legal angles. All security certifications have in common, that they cannot replace mandatory regular assessment of whether or not legal requirements subject to regular adjustment are sufficiently up-to-date.

Furthermore, all legal security aspects require a risk assessment and have in common, that they require an adequate balance of compliance with legal requirements, application of sufficient technical and/or organizational measures as well as resulting costs of implementation and maintenance of efficient security aspects. Although security issues can (most likely) never be avoided completely, they can very well be mitigated effectively. The “European Code of Conduct on Open Science in Transport” holds baseline controls for appropriate technical and organizational security measures for all data. Where personal data is involved, technical and organizational safety measures must specifically provide for transparent and accurate information, securing the mandatory contractual privacy structures, safeguarding proper handling of (potential) data breach incidents, data protection impact assessments, maintaining proper records of processing and fulfilling data subject requests.

The GDPR follows a risk-based approach of adopting mandatory technical and organizational measures without explicitly mentioning a full set of requirements. On the technical side, the GDPR requires implementing privacy-by-design and privacy-by-default measures. On the organizational side, the GDPR mainly requires the implementation of effective organizational procedures for providing transparent and accurate information, securing the mandatory contractual privacy structures, safeguarding proper handling of (potential) data breach incidents, data protection impact assessments, maintaining proper records of processing and fulfilling data subject requests.

In essence, the required level of technical and organizational safety measures gets higher with the rising risk of a processing activity for the rights and freedoms of natural persons.

8.6 Handling ethical problems

It is very important that individuals and organizations involved in Open Science in Transport activities commit to good practices, working methods and respect ethical principles associated with their field. Violations of these aspects may lead to a disrespectful environment among the stakeholders and can eventually lead to severe professional and potentially even legal consequences. Most commonly, such violations have the potential to damage existing procedures among stakeholders, degrade relationships among them, undermine trust in and the credibility of research and may expose research subjects, users, society or the environment to unnecessary harm.

Ethical concerns related to Open Science in Transport research have been greatly discussed in various deliverables of the BE OPEN project. In most cases, the ethical concerns have been recorded as barriers that should be taken into account and be overcome for the implementation of Open Science policies at institutional, national and European level. The deliverable BE OPEN D 4.1 has provided a definition of ethical concerns and has separated legal and non-legal aspects of ethical concerns. However, this should not obscure the fact that in most legal systems there is a close connection between ethical aspects and legal jurisdiction. In the field of Open Science, this strong connection between legal and ethical aspects is mainly found in the legal aspects of IPR, data protection and data confidentiality.

Essentially, ethical concerns connected to legal aspects can easily be avoided by obeying the law. However, as far as the non-legal ethical aspects are concerned, ethical concerns can be mitigated by establishing the good research practices related to Open Science in transport based on ALLEA good research practices and following the EOSC Rules of Participation. The fundamental research principles entailed therein have been applied to the Open Science in transport domain and are as such an essential aspect of the “European Code of Conduct on Open Science in Transport”.

Notwithstanding, evolving ethical issues should be dealt with by amending the code of conduct and adding specific provisions if necessary.

9 Milestones on the Way to the Vision 2030

2021: The TOPOS observatory and forum are in operational service to support the uptake of OSTR in Europe based on a framework of common understanding of OSTR and the Code of Conduct

- Identified and implemented mechanisms to connect the community of Open Science in transport research.
- TOPOS developed and released in 2021
- Dissemination through several events
- Common understanding on the practical impact of Open Science established and promoted

2023: European academics and RTO´s apply and promote Open Science in transport research

- TOPOS "Speakers" in Universities across Europe promote OSTR
- 5th TOPOS community meeting took place with a growing number of enthusiastic practitioners
- Transport data becomes FAIR due to the new standards and interoperability guidelines promoted through TOPOS

2025: Collaboration between citizens, policy, industry and researchers improves the European mobility system through open innovation, constructive dialogues and new funding schemes in Europe

- Big transport companies joint the new trend of fully sharing open data
- Citizens take part regularly in big research projects in Europe to co-create the mobility system of 2030
- TOPOS has supported a wide European network of cities, service providers and researchers to develop new mobility solutions and share best practices
- Results from the TOPOS observatory lead leaps in science
- As a living document, the "European Code of Conduct on Open Science in Transport" will be subject to ongoing amendments based on changing EU or EU Member State laws, evolving technology or further development of ethical aspects along with associated effects on fundamental research principles. The BE OPEN Steering Committee (Be OPEN SC) will consult to shape the Expert Working Committee on Open Science and Ethics in Transport (EWCOSET) that will be concerned with a wide range of "internal" (within the transport research community) and "external" issues (relations between science and society) and respect existing ethical guidelines. Since ethical considerations have been an essential component in the consolidation of a united Europe, EWCOSET will be established in order to bring together experts from transport research and Open Science in academia across Europe and provide them with a platform (TOPOS Observatory & Forum) for continuous debate on transport research ethics and integrity. The EWCOSET will meet and will convene thematic meetings in wider settings, typically in partnerships with other relevant organizations such as the European Commission, the European Science Foundation (ESF), the European Open Science Cloud (EOSC) Governance Board, and the International Council for Science (ICSU), and UNESCO, among many others. The members of the EWCOSET will rely on their extensive network of experts and institutions for the successful execution of the revision process needed for the "European Code of Conduct on Open Science in Transport".

2027: New methods and international collaboration lead to joint research action on the transformation of mobility globally

- Increased research quality has made transport research a popular field in which to invest money

- An optimization of cross-modal connections changes the means of transport in a trans-European network with less than 10mins stops
- TOPOS help prevent nature to collapse - achieved through place-specific solutions for low-emission transport across Europe
- Because of the reduction in the number of cars, pollution levels have gone down dramatically.
- TOPOS enhances the development of new skills for transportation professionals
- The TOPOS Community model goes beyond the EU borders
- Researchers use the TOPOS observatory to create new visions for transport

10 Recommendations for Actions

10.1 Support TOPOS on the way to become the Common European Data Space for Open Science in Transport Research

The sustainability measures mentioned in the following list are measures that can improve the sustainability of TOPOS. For a complete set of measures, please refer to the BE OPEN Deliverable 3.1 TOPOS Declaration, BE OPEN Deliverable 3.6 TOPOS Sustainability Analysis and the BE OPEN Deliverable 3.5 Strategy for pan-European diffusion and global links:

- **Resources:** There are mainly four different financial models TOPOS possibly could undertake:
    - Public funding (international, national or regional)
    - User-payment
        1) Paying for data
        2) Paying for infrastructure
    - Stakeholders: Annual Organisational membership fees

  The advantage of international public funding (EU) is that the Commission is regarded as a trustworthy organization with a heavy influence on a broad geographical level, possibly making the users of TOPOS more interested in the platform. If wanting to increase Open Science through "obligation", this is more likely to be accomplished if TOPOS is funded by the European Commission.
- **Organizational:** To make TOPOS sustainable a sharing culture is also needed. If TOPOS can offer a pool of data available, sharing might also be easier for others, as there is already available data for them to use as well. In order to do this, TOPOS could focus on getting data from public stakeholders first, as they have less to lose in terms of competitive advantage when sharing data. At least at a lower geographical level.

  Also, demonstrating that participating in Open Science at an early stage could potentially give benefits in terms of competitive advantage. Some organisations benefit from creating open data/infrastructure in terms of (1) becoming famous for their data/systems etc. which (2) in turns generates more projects and project invitations.

- **Information:** Funding for a quality control organ and continuous dissemination is needed to make TOPOS sustainable. Possibly further Cooperation with TRIMIS.
- **Legal:** Taking advantage of the increased focus on GDPR, TOPOS could offer a two-way log in system for parts of the cloud, making it extremely secure. Making this available to use for sensitive data, if user is paying for storage.
- **Technological:** TOPOS could take advantage of the use of a Semantic Portal to improve the quality of communication between the information provider and the user and supporting self-sustainability
- **Diffusion and Community Building**: To extend the user community, early adopters have to be identified within each mode of transport, early adopters of TOPOS. These would be organizations already engaged in and implementing open science principles e.g. universities and research centers etc. These early adopters should be provided with user manuals on TOPOS and information sheets on implementation. Through the promotion of Open Science, e.g. through Horizon Europe, the presentation of TOPOS in the respective channels, new users will be approached. Webinars would make the use of the tools simple. Later on, other groups of the primary stakeholder circle, e.g. individual researchers, policy makers and industry could be approached. To internationalize the community and to realize the vision of a global Open Science in transport research community, it is important that the networks grow through collaborative research, and by this to introduce the benefits of the tool and the large variety of data sets to researchers outside Europe.

10.2 Promotion of Open Science in Transport Research

To promote Open Science in transport research according to the aforementioned vision and milestones, the following set of actions are recommended per Key Success Factor:

Education/Training:
The creation and dissemination of trainings and training material (manuals, tutorials, webinars and mentoring programmes) for each Stakeholder group are of core importance, since Open Science requires new skills from planning research, conducting analysis, and data collection to the publishing of FAIR data. To reach Open innovation as in the Milestone 2025, it is important to teach and train researchers how to re-use and transfer results from other research projects and how to fulfil Open Science standards to provide research results that are not just easy to access but which follow the principles of Open Science in transport research (see chapter 8.3).

Specifically in Europe´s Academia landscape, it is important to establish a speaker per transport faculty who promotes and assists in applying OSTR. Open Science and new methods (research, analytics), that are developed through Open Science, should promote diversity, gender-sensitivity in research methodology design, and do-no-harm principles. The skills should be part of University curricula or vocational training programmes for professional researchers covering topics in data management, open licence practices, data security and privacy, etc.

To promote Citizen Science, it is of importance to train practitioners to pursue Citizen Science effectively, and to communicate science in way that the desired participants can understand and participate without exclusions. On the contrary, education for citizens and companies should be focused on how to provide and research through Open Data and the benefits of participating in such activity.

Research Community and Research Organisation:

Getting the commitment from research establishments (MoU/ MoC) to ensure continuous engagement with Open Science and TOPOS, it is important to coordinate and support community building through exchange formats (e.g. yearly conferences, workshops, dialogues within the TOPOS Forum) and the promotion of Open Science-focussed research and development projects funded by the European Commission. These should also increasingly address international collaborations to spread practice and principles in use. By the experience of the open collaboration of different stakeholders and through the active demonstration of the advantages of Open Science through dissemination, workshops, and seminars/webinars, cultural change can be initiated. Within this context, a supportive culture and framework should be created, with the establishment of incentives for a shift not only in research culture but also in the structures and work processes of organisations. Since Open Science is time-consuming for participants when first entering the field, researchers as well as organisations have to be equipped with financial resources and a skilled workforce with proper technical skills. As an interim step, it could help if organisations are supported to provide an expert to assist researchers in preparing Open Science plans and to think research projects through from the proposal stage until the review process. To supervise the uptake of Open Science practice in the community, European and international working groups in Open Science for the transport sector have to be put in place to promote Open Science in transport research in each country until 2027.

Data Creation/Usage

The EC should create Open Data standards that can be followed by transport researchers and others. These Data standards should consider data creation, usage, storage, and maintenance (e.g. establish a group of experts from different stakeholder groups). Ideally, such an expert group needs to develop an easy-to-understand guide on how Data protection legislation works for researchers, companies and citizens.

Collaboration with Industry, Society and Policy

To promote the development of innovative products/patents/results through an Open Science framework, researchers, companies and citizens should be empowered to take part in Open Science/Citizen Science projects. This would include areas such as communication, motivation, teaching, and reward. It would be important to make access to the platform easy and safe for all the stakeholders and to ensure that they can connect to each other through the platform. Additionally, is important to establish an expert group to revise the European Code of Conduct for OSTR and to act as Open Science ambassadors that promote the TOPOS Forum, to exchange knowledge and ideas with transport research stakeholders on the development of BE OPEN results, and to gather research topics from all the stakeholders to ensure that all necessary issues are covered. To avoid protectionism,

rewards have to conceptualize and tested to foster the cultural shift needed to deliver Open Science solutions.

Legal & Ethical

As for these aspects, is important to define how GDPR and property rights are being respected with TOPOS, to promote the Code of Conduct within the transport research community and to promote OSTR best practices through TOPOS tools & dissemination activities to develop Open Science culture. The transport community needs to be trained in order to be sensitive to ethical issues and in following both principles for Open Science in transport research and also general research principles such as the do-not-harm-principle.

Security

The core of this aspect is about a central data collecting system within repositories, that manages data management in a more transparent way, has different levels of security rules adapted to different data criticalities, and to the needs of the stakeholders and is continually assessed and upgraded for any new legal and technical risks. A general risk assessment for both TOPOS and the research organisations as well as other stakeholders conducting Open Science has to be put in place. Guidelines should be given to national and/or European authorities.

Through the promotion of the Code of Conduct and its adoption, the transport research community is informed about the proper way for securing the mandatory contractual privacy structures, safeguarding proper handling of (potential) data breach incidents, data protection impact assessments, and maintaining proper records of processing and fulfilling data subject requests. Since transport research is a field that requires special safety and security attention, it must be of the highest priority to safeguard and secure society and ecology from experiencing harm. Thus, a European risk management initiative should assess how data can be miss-used in different contexts. Following this, it would be important to elaborate scenarios and measures to prevent or handle these issues if they happen.

Infrastructure & Tools

First, is important to map out any missing infrastructures and necessary tools in research establishments. Infrastructures must contribute to the goals of EOSC and align with EOSC activities and support the development of new services. Additionally, tests are necessary to validate the issues of functionality and user-centric design in different contexts and with different stakeholders/users, to ensure that all developments meet specific user requirements. Finally, e-infrastructures and necessary tools need to be constantly upgraded in order to keep up with current trends and needs in order to provide a Common European Data Space for Open Science in transport research.

In conclusion, the challenges in transport for the next decade are huge. This community can only face them jointly. Thus, it is recommended to coordinate and support this growing community and its ecosystem as well as the development and implementation of legal and technical framework conditions. To do so, it is important to keep listening the needs, desires and individual initiatives of all the stakeholders, so they are constantly involved in the community building process. In this way, a

cultural shift can be promoted through teaching, experiencing Open Science and the exchange of best practices. Furthermore, accompanying research could assess the up-take of Open Science practice in the transport sector and its impacts on ecology, society, policy-making and the economy. In this way, the community will become more able to improve its strategy for the promotion of Open Science in transport research.