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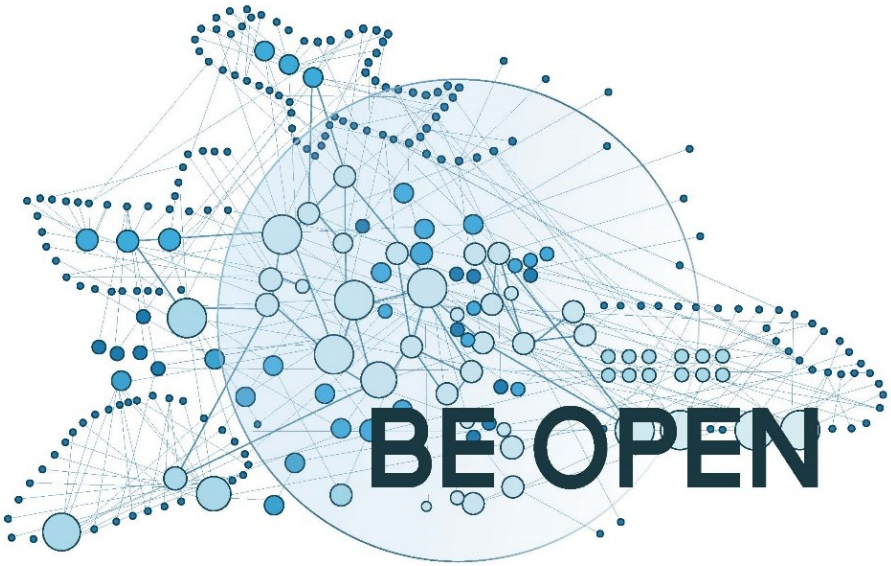

European forum and oBsErvatory for OPEN science in transport

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D2.2 Open/FAIR data, software and infrastructure in European transport research

Final

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Abbreviations and Terminology

RIs	Research Infrastructures
ESFRI	The European Strategy Forum on Research Infrastructures
ERIC	European Research Infrastructure Consortium
OSS	Open Source Software
FAIR	Findable, Accessible, Interoperable, Reusable
ICT	Information and Communication Technologies
OFD	Open and FAIR Data
EOSC	European Open Science Cloud
OGD	Open Government Data
DMP	Data Management Plan
CERN	European Organization for Nuclear Research

Executive summary

The objectives of the BE OPEN project are 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 deliverable D2.2 (Open/FAIR data, software and infrastructure in European transport research) is produced within Work Package 2 (Mapping of existing Open Science sources in transport) of the BE OPEN project under Task 2.2 (Existing Open Science research sources). The purpose of this deliverable is to study and analyse the main areas of Open Science in transport research. The activities were accomplished through desk research and a web-based survey which was sent to a number of organisations.

First, a literature review on Open Science Research Sources of European research was carried out. The review focused on the Open and FAIR Data (OFD), Open Software/source, Infrastructure, Open Education and Open Citizen Science. Secondly, a review was carried out on existing Open Science Research sources in Transport Research. The analysis was done in the main areas of Open Science in transport research: Open and FAIR data, Open Software/source and Infrastructure. Then, a mapping was carried out to compare the performance of the three main areas (Open Data, Open Software and Open Infrastructure) in the different key areas (Legal/regulatory, technological, transport planning, business modelling, socio-economic and environmental). A designed survey, a questionnaire about Open Data, Open Software and Open Research Infrastructure, was sent to stakeholders who helped to identify use of, barrier, policies, strategies in relation to Open and Fair data, Software/source and Open Science Infrastructure. Also, a comparison of the Transport research sector on OFD and Open source, as well as general European research was conducted. Finally, the main idea was to present the lessons to be learned and the barriers for research sources not used in the transport research yet.

A summary of the review results shows that the majority of transport institutes (approximately 60 %) do not conduct much their research based on open and FAIR data (between 0-25 %), because of the material's reliability. However, the majority (72 %) of transport research organizations produce a lot of open/FAIR data themselves, but only 6% of them allow the use of open source software for the majority of time due to lack of knowledge and low security. In addition, most of the used open source software (OSS) comes from initiatives outside EU (USA, China).

Analysing Open software/sources, indicated that most transport research organizations allow use of open source software, but only 7 % of the organizations allow use of open source software use more than half of their time on open source software. Most institutes encourage use of open source software due to flexibility and low cost.

In parallel, research infrastructure (RI) sharing is commonly encouraged between transport research institutions and organizations, as 51 % of the organizations share their infrastructure with other organizations and 79 % of all organizations use infrastructure from other organizations. At the same time there is a lack of information on structured transport-related RIs across Europe, as a very small number of projects were found to tackle transport specific RIs (compared to other sectors).

1. 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, academics and non-academics alike. The rapid growth of data and its elevated use as a first citizen in all research processes, as well as the development and uptake of digital technologies and new collaborative tools, become enablers of Open Science, allowing to speed up the process of adopting open habits and facilitating the sharing of large volumes of information, study materials and data.

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 organisations and the general public.

The BE OPEN project is a coordination and support action (CSA) funded by the European 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 standardizing it. 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 operationalizing 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

The main purpose of the present deliverable is to map existing Open Science resources and see how transport research fits in it. In order to meet the objectives of this task, the review was/is (?) targeted to:

- Open Science research Sources of European Research which includes a general overview of Open and FAIR data, Open Software/source, Infrastructure, Open Education and Open Citizen Science.
- Existing Open Science Research Sources on Transport Research, including the use and experience of Open FAIR data, research data management practices, Big data and GDPR issues. In addition, mapping of Open software relevant for transport research, use of Open software in transport research following the key areas. Finally, desk studies about existing of shared research infrastructures as well as open education and Open Citizen Science.

Consequently, this document aims to benchmark the key open science resources in transport research against comparable European research sources in order to identify opportunities for reuse of existing e-

Infrastructures and build synergies with them towards inclusion of transport research in the implementation of EOSC.

2. Review of Open Science Research Sources of European research

2.1. Open and FAIR data

Open data is defined in the Open Definition project as data "that can be freely used, modified, and shared by anyone for any purpose" (1). Availability and access, reuse and redistribution of data, and universal participation are the key factors of Open data and content (according to the Open Data Handbook) (2). Open data benefits range from transparency (e.g., allowing researches to be reproduced) to increasing innovation. European Open data portals are available, with several EU countries having their own Open data portal in place (3).

FAIR data should be Findable, Accessible, Interoperable and Reusable. The main difference of Open and FAIR data involves the accessibility of the data. While both state that data should be as open as possible, FAIR data access can be restricted if necessary (4). This necessity can change according to the purpose or life-cycle of the data (e.g., during research phase data is private, becoming public upon publication).

Open and FAIR data have in Big Data both a motivation and a challenge. The increased amount and variety of data, if made available, allows the creation of value and knowledge through the combination of datasets. To archive this, data should be available in convenient and open formats, enabling the intermixing of data from the different sources and therefore promoting the innovation and creation of such value (2). To ensure that data can be found, systems must know the metadata formats, standards and schemas used for research data, allowing the interoperability and accessibility of the data. Long-term preservation of data is another topic of interest for Open and FAIR data, since any sustainable data infrastructure must ensure the long-term availability and accessibility of the research data (8). This means that any trusted data repository must have in place a well-documented preservation plan, that accounts for possible risks and changes that not only can cause data corruption, but can also endanger accessibility to it (e.g., data may be in a format that is no longer readable with available programmes).

Open Government Data (OGD) is a large resource of open data due to the public nature of the governmental data (data collected with public resources by public entities). The value created with OGD can improve transparency, innovation, government services and have a large impact on policies evaluation, besides the creation of knowledge from the combination of datasets (2). There are, however, cases where data cannot be made public due to ethical or security reasons (e.g., personal data).

Recently, the European Commission created the Open Research Data Pilot (5), which plans to enable open access and reuse of research data generated by Horizon 2020 projects. Part of the project was the creation of a Data Management Plan (DMP) template that instructs researchers on how to make sure their data is FAIR (6). A European Open Science Cloud (7) is being implemented for research data in Europe, following the FAIR data principles. The European Commission also created the Open Science Monitor to obtain quantitative and qualitative insights about Open Science development, which includes several indicators related to open research data. Figure 1 shows one of those indicators, in this case, obtained through a

survey about open data (9), containing information concerning the researchers' attitude towards data sharing, more explicitly, its benefits.

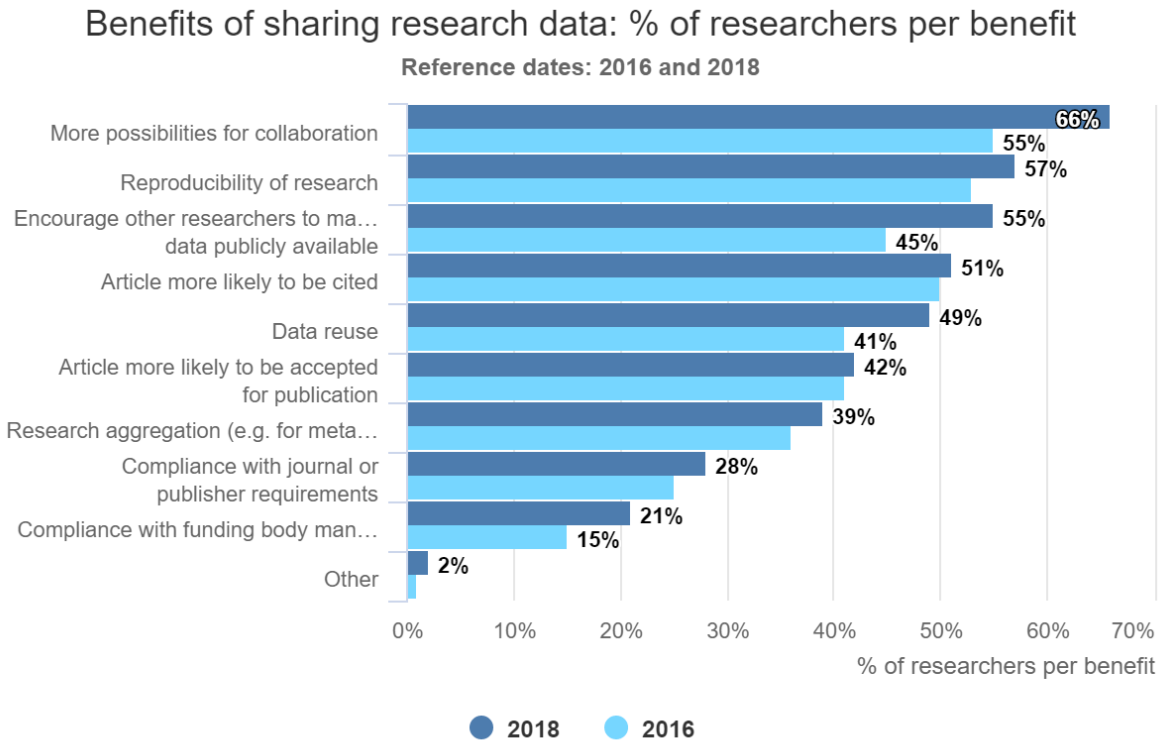

Figure 1 Benefits of sharing research data: % of researchers per benefit (10)

2.2. Open Software/source

"Open source" refers to available information sources that can be used, modified, shared by everyone and are publicly accessible (11). Today, "open source" designates a broader set of values. Open source projects, products, or initiatives, embrace and celebrate principles of open exchange, collaborative participation, rapid prototyping, transparency, meritocracy, and community-oriented development (12).

In more detail, "Open source software (OSS) is a software with a source code that anyone can inspect, modify, and enhance." Open source software applications have been increasing over the last decades and expanding in new key areas, such as transportation, tourism, health, etc... According to the OpenForum Europe (OFE) organization, OSS is a powerful tool supporting innovation as well as economic growth (13). Open Source Software (OSS) can benefit all users with control options, training opportunities, system's security and stability (11). On the other hand, OSS initiatives produce problems related to software patents and its regulatory framework (14). Currently OSS creators and contributors follow the European Public License version 1.2 framework (EUPL), which OpenForum Europe (OFE) and Free Software Foundation Europe (FSFE) assist the European Commission to keep track of their open source initiatives and how they fulfil the existing action and legal framework.

Following the latest European Commission's action plan, significant focus has been deployed into the widespread of open source data and software usage, and the creation of a research-friendly environment.

Latest actions drive to further increase the role of open source software for many of its key ICT services and software solutions, and the renewed strategy puts a special emphasis on procurement, contribution to open source software projects and providing more open source software in the Commission (12). European Open Source Software initiatives include several repositories, access in licenses and communities developing forums, discussions and software projects.

2.2.1. Initiatives for embedding software in the research process

Force11 Software Citation

FORCE11 is a community of scholars, librarians, archivists, publishers and research funders that has arisen organically to help facilitate the change toward improved knowledge creation and sharing. This community aims to bring about a change in modern scholarly communications through the effective use of information technology (15). The community created working groups to establish the implementation of software citation principles. At first, the software citation working group was a cross-team committee leveraging the perspectives from a variety of existing initiatives working on software citation to produce a consolidated set of citation principles in order to encourage broad adoption of a consistent policy for software citation across disciplines and venues (16). Lastly, an implementation working group was formed in order to work with relevant stakeholders (publishers, funders, repository developers, other community forums with related working groups, etc.) to develop sets of guidelines for implementing the principles, help implement the principles and test specific implementations of the principles (17).

Software Sustainable Institute

Software Sustainable Institute is a leading international authority on research software sustainability, working with researchers, funders, software engineers, managers, and other stakeholders across the research spectrum. It has been firstly established in Edinburgh (UK) and currently has several branches across the world. The institute has established a wide research network and worked in over 50 projects to provide stakeholders superior software services for research science development. Their framework focuses on access to software development training material, recognition of software systems credibility and enable an efficient software development environment on the academic sector but suggesting industrial practice where applicable (18).

RDA

The Research Data Alliance (RDA) is a community-driven initiative by the European Commission, the United States Government's National Science Foundation and National Institute of Standards and Technology, and the Australian Government's Department of Innovation. Their goal is focused on building the social and technical infrastructure to enable open sharing and re-use of data. RDA has a grass-roots, inclusive approach covering all data lifecycle stages, engaging data producers, users and stewards, addressing data exchange, processing, and storage (19).

RDA addresses the need for open and interoperable sharing of research data and builds the social, technical and cross-disciplinary links to enable such sharing on a global scale. RDA Members come together through focused Working Groups and Interest Groups, formed by experts from all around the world – from academia, private sector and government. Regarding open source software (OSS) disciplinary use and development there have been currently created two different groups, software source code interest group and identification working group.

The software source interest group provides a forum to discuss issues on management, sharing, discovery, archival and provenance of software source code and pays special attention to source code that generates research data and plays an important role in scientific publications (20).

In parallel, the software source identification working group pursues to bring together a broad panel of stakeholders directly involved in software identification. Bringing these stakeholders together will accomplish to suggest concrete recommendations for the academic community. These recommendations will ensure that the solutions that will be adopted by the academic players are interoperable (21).

FOSS

"Free and open-source software" (FOSS) is an umbrella term for software that is simultaneously considered both Free software and open-source software. FOSS (free and open-source software) allows the user to inspect the source code and provides a high level of control of the software's functions compared to proprietary software. FOSS community maintains the software user's civil liberty rights and corresponds to open-source license principles. Free Software Foundation (FSF) and Open Source Initiative (OSI) are several initiatives towards the expansion of FOSS community and the alignment of open source software providers and users with the existing General Public Licenses (22). In general, FOSS community ensures the appropriate environment for users to develop and share a wealth of software projects and applications in various research areas, such as social sciences, ICT applications and scientific/engineering projects.

OpenGovIntelligence

OpenGovIntelligence is a European Union's Horizon 2020 research and innovation programme, which aims at stimulating sustainable economic growth in Europe through fostering innovation in society and enterprises. Towards this end, OpenGovIntelligence suggests a holistic approach for the modernization of Public Administration (PA) by exploiting Linked Open Statistical Data (LOSD) technologies. This includes new business processes, policies, and tools that will enable the active participation of the society and enterprises in data sharing and in the co-production of innovative data-driven public services (18).

2.2.2. Infrastructure

SourceForge

SourceForge is an open source community resource dedicated to helping open source projects be as successful as possible (17). This platform promotes community collaboration to help users to create a premiere resource for open source software development and distribution. Inside the community, users develop and share a wealth of software projects and applications in various research areas, such as social sciences, ICT applications and scientific/engineering projects.

GitHub and GitLab

Both, GitLab and GitHub are web-based Git repositories, which are central place where developers store, share, test and collaborate on web projects (25). More specifically, GitHub is a Git-based repository hosting platform with 36 million users and 100 million repositories. Public repositories on GitHub are often used to share open source software and can be used for issue tracking, documentation, and wikis (26). On the contrary, GitLab is a repository manager which lets teams collaborate on code from project planning and

source code management to CI/CD and monitoring. Written in Ruby and Go, GitLab offers some similar features for issue tracking and project management as GitHub (27). GitLab has more than 1,400 open source contributors nowadays and together with GitHub form a global repository management network to connect all stakeholders under an organized open source software (OSS) umbrella.

Software Heritage

The aim of the Software Register is to collect, preserve and share all software that is publicly available in source code form (16). On this foundation, a wealth of applications can be built, ranging from cultural heritage to industry and research. Within this context, a large archive of software source code has been built, which is indexed, organized and broadly accessible.

Zenodo and figshare

Considering the continuous increasing number of research studies and open source data and software, all this information uses Digital Object Identifiers (DOI) to ensure the academic reference and the integration of metric systems inside their scientific work. As GitHub is the most commonly used OSS repository hosting platform, there has been created a specified process to make codes citable to other scientific data repositories, such as Zenodo and figshare (29). In short, a DOI alias is created that connects a specific GitHub repository with a desired Science repository or Institutional archive and thus the software is registered. In this way, the concept of software citation has outburst over the recent years, allowing software developers and maintainers to get academic credit for their work (30).

The European Commission together with CERN, an OpenAIRE partner and pioneer in open source, open access and open data, provided Zenodo in May 2013. In support of its research programme, CERN has developed tools for Big Data management and extended Digital Library capabilities for Open Data. Through Zenodo, these Big Science tools could be effectively shared with the long-tail of research. Data, software and other artefacts in support of publications are the core materials associated with conferences, projects or institutions (31).

Accordingly, figshare was established in 2011 with the support of major publishers, such as Wiley, Springer Nature, Taylor and Francis, PLOS. figshare has developed tools for Big Data management and extended Digital Library capabilities for Open Data. Through this repository, publications, data and software are the core materials associated with projects and partner institutions, publishers and researchers (32).

OpenAIRE Explore

Aggregator and Linked Open Data: OpenAIRE Explore is developed by the European Commission under the OpenAIRE initiative to provide an integrated research centre for everyone (19). This platform contains publications, datasets, software and other open source research products. This online platform collaborates with a compatible software repository (GitHub, Zenodo, Software Heritage etc.). Within this context, a large archive of software source code has been organized and broadly accessible.

Joinup

Joinup is a collaborative platform created by the European Commission and funded by the European Union via the Interoperability solutions for public administrations, businesses and citizens (ISA²) Programme. It offers several services that aim to help e-Government professionals share their experience with each other. We also hope to support them to find, choose, re-use, develop and implement interoperability solutions. The platform has three main functions:

- Sharing of information, by publishing news, case studies and listing relevant events;
- Cataloguing re-usable interoperability solutions such as software, taxonomies, vocabularies, code-lists, licences, organisational assets and guidelines;
- Allowing public administrations, businesses and citizens to collaborate with each other on development projects.

FOSSHUB

As it was mentioned previously, FOSS community initiated several actions to promote the use of OSS initiatives. In this context, FOSSHUB is a free open software hub providing download and hosting for free open source projects (35). These projects reach a variety of categories with special focus on data management, file sharing, operating systems, and communication and developer tools.

2.3. Infrastructure

According tothe European Commission , Research Infrastructures (RIs) are facilities that provide resources and services for research communities to conduct research and foster innovation (36). They can be used beyond research e.g. for education or public services and they may be single-sited, distributed, or virtual. They can include: major scientific equipment or sets of instruments, skilled personnel engaged in services, competence development and outreach; knowledge-based resources such as collections, archives or scientific data; and e-infrastructures, such as data and computing systems and communication networks and any other research and innovation infrastructure of a unique nature which is open to external users (36, 37).

The European Strategy Forum on Research Infrastructures (ESFRI) plays a policy-making role on Research Infrastructures in Europe. ESFRI is a strategic instrument created to develop the scientific integration of Europe and to strengthen its international outreach. The competitive and open access to high quality RIs supports and benchmarks the quality of the activities of European scientists, and attracts the best researchers from around the world. ESFRI operates at the forefront of European and global science policy and contributes to its development translating political objectives into concrete advice for RIs in Europe (38). ESFRI together with Member States and the Community institutions, and the various actors within the European research community such as undertakings, research centres and universities expressed the need of additional efforts in order to stimulate the development of new structures by creating an appropriate legal framework which should facilitate their establishment and operation at the level of the Community (39). In the frame of that need, The European Research Infrastructure Consortium (ERIC) was established. ERIC is a specific legal form that facilitates the establishment and operation of Research Infrastructures with European interest. The primary objective of an ERIC is to establish and operate of new or existing Research Infrastructures on a non-economic basis. The establishment of an ERIC is regulated by Council

regulation (EC) No 723/2009 of 25 June 2009 on the Community legal framework for a European Research Infrastructure Consortium (ERIC) (4) and ERIC practical guidelines, Legal framework for a European Research Infrastructure Consortium (40). At the time of writing twenty ERICs were established (41):

- SHARE-ERIC (Survey of Health, Aging and Retirement in Europe);
- CLARIN-ERIC (Common Language Resources and Technology Infrastructure);
- EATRIS-ERIC (European Advanced Translational Research Infrastructure in Medicine);
- ESS-ERIC (European Social Survey);
- BBMRI-ERIC (Biobanking and Biomolecular Resources Research Infrastructure);
- ECRIN-ERIC (European Clinical Research Infrastructure Network);
- Euro-Argo ERIC (key player in the international global Earth observing systems);
- CERICERIC (Central European Research Infrastructure Consortium);
- DARIAH-ERIC (Digital Research Infrastructure for the Arts and Humanities);
- JIV- ERIC (Joint Institute for Very Long Baseline Interferometry);
- European Spallation Source ERIC (the world's next-generation neutron source);
- ICOS-ERIC (Integrated Carbon Observation System);
- EMSO-ERIC (European Multidisciplinary Seafloor and Water Column Observatory);
- LifeWatch ERIC (e-Science and Technology European Infrastructure for Biodiversity and Ecosystem Research);
- CESSDA ERIC (Consortium of European Social Science Data Archives);
- ECCSEL ERIC (European Carbon Dioxide Capture and Storage Laboratory);
- INSTRUCT-ERIC (Integrated Structural Biology);
- EMBRC-ERIC (European Marine Biological Resource Centre);
- EU-OPENSCREEN ERIC (European Infrastructure of Open Screening Platforms for Chemical Biology);
- EPOS ERIC (European Plate Observing System).

2.3.1. e-Infrastructures

e-Infrastructures are key in future developments of research infrastructures, as activities go increasingly "online" and produce vast amounts of data. e-Infrastructures address the needs of European researchers for digital services in terms of networking, computing and data management. e-Infrastructures foster the emergence of Open Science, i.e. new working methods based on the shared use of ICT tools and resources across different disciplines and technology domains, as well as the sharing of results and an open way of working together. Furthermore, e-Infrastructures enable and support the circulation of knowledge in Europe online and therefore constitute an essential building block for the European Research Area (ERA).

These powerful e-Infrastructures address the needs of European researchers for digital services in terms of networking, computing and data management empowering millions of researchers with easy and secure online access to facilities and resources, and enable them to deliver reusable and reproducible research and innovation outputs. It gives an opportunity to learn about the transnational communication networks, high performance and high throughput computing, multidisciplinary data management and collaborative scientific software that make up these e-Infrastructures (59), (60).

OpenAIRE

OpenAIRE's mission is closely linked to the mission of the European Commission: to provide unlimited, barrier free, open access to research outputs financed by public funding in Europe. OpenAIRE fulfils the EOSC vision substantially, as its operations already provide the glue for many of the user and research driven functionalities, whether these come from the long tail of science (repositories and local support) or domain disciplined research communities or Research Infrastructures. Addressing the scholarly communication aspects of the research life cycle, OpenAIRE offers a suite of services for all key stakeholders: researchers, institutions, funders, content providers, etc... OpenAIRE provides tools and methods to monitor research impact effectively and links publications to data and to all research artefacts (5).

EUDAT

The EUDAT CDI is essentially a European e-infrastructure of integrated data services and resources to support research. This infrastructure and its services have been developed in close collaboration with over 50 research communities spanning across many different scientific disciplines,involved at all stage of the design process. The establishment of the EUDAT CDI is timely with the imminent realization of the European Open Science Cloud which aims to offer open and seamless services for storage, management, analysis and re-use of research data, across borders and scientific disciplines (61).

EUDAT has created an important infrastructure for the European Research Area, by providing solutions for managing electronic data that would be difficult for some research communities to provide on their own. This effort that EUDAT is carrying out contributes to shape the European policy landscape. In particular EUDAT contributes to (61):

- the European Data Initiative;
- the European Open Science Cloud;
- Research Data Management;
- Open Access.

EGI

EGI is a federated e-Infrastructure set up to provide advanced computing services for research and innovation. The EGI e-infrastructure is publicly-funded and comprises hundreds of data centres and cloud providers spread across Europe and worldwide.

EGI offers a wide range of services for compute, storage, data and support. EGI delivers advanced computing services to support scientists, multinational projects and research infrastructures. The EGI Services are provided by EGI's federated cloud providers and data centres. The services can be requested by everyone involved in academic research and businesses via the EGI Marketplace.

EGI provides access to +1,000,000 computing cores and +740 PB of disk and tape storage.
EGI is a federation of computing and storage resource providers united by a mission to support research and development. The federation is governed by the participants represented in the EGI Council and coordinated by the EGI Foundation.

The EGI federated e-infrastructure is publicly funded and provides compute and storage resources to support research and innovation (62).

EGI resources are provided by (62):

- The EGI Federated data centres. The EGI Federation comprises hundreds of data centres offering computing and storage resources to researchers. The EGI Federation data centres are located mostly in Europe, in countries represented at the EGI Council. Additional data centres are hosted by other European countries and integrated resource in Canada, USA, Latin America, North Africa and the Asia-Pacific region.
- The EGI Federated Cloud providers. The EGI Federated Cloud is an IaaS-type cloud, made of academic private clouds and virtualised resources and built around open standards. Its development is driven by requirements of the scientific community. The result is a new type of research e-infrastructure, based on the mature federated operations services that make EGI a reliable resource for science. When using EGI Federated Cloud resources, researchers and research communities can count on:
    - Total control over deployed applications;
    - Elastic resource consumption based on real need;
    - Immediately processed workloads – no more waiting time;
    - An extended e-Infrastructure across resource providers in Europe;
    - Service performance scaled with elastic resource consumption.

GÉANT

GÉANT is a fundamental element of Europe's e-infrastructure, delivering the pan-European GÉANT network for scientific excellence, research, education and innovation. Through its integrated catalogue of connectivity, collaboration and identity services, GÉANT provides users with highly reliable, unconstrained access to computing, analysis, storage, applications and other resources, to ensure that Europe remains at the forefront of research.
Through interconnections with its 38 national research and education network (NREN) partners, the GÉANT network is the largest and most advanced R&E network in the world, connecting over 50 million users at 10,000 institutions across Europe and supporting all scientific disciplines. The backbone network operates at speeds of up to 500 Gbps and reaches over 100 national networks worldwide (63).

PRACE

The mission of PRACE (Partnership for Advanced Computing in Europe) is to enable high-impact scientific discovery and engineering research and development across all disciplines to enhance European competitiveness for the benefit of society. PRACE seeks to realise this mission by offering world class computing and data management resources and services through a peer review process.
PRACE also seeks to strengthen the European users of HPC in industry through various initiatives. PRACE has a strong interest in improving energy efficiency of computing systems and reducing their environmental impact.
PRACE is established as an international not-for-profit association (aisbl) with its seat in Brussels. It has 26 member countries whose representative organisations create a pan-European supercomputing infrastructure, providing access to computing and data management resources and services for large-scale scientific and engineering applications at the highest performance level.
The computer systems and their operations accessible through PRACE, are provided by 5 PRACE members (BSC representing Spain, CINECA representing Italy, ETH Zurich/CSCS representing Switzerland, GCS representing Germany and GENCI representing France). Four hosting members (France, Germany, Italy, and Spain) secured funding for the initial period from 2010 to 2015. In 2016, a fifth Hosting Member, ETH Zurich/CSCS (Switzerland), opened its system via the PRACE Peer Review Process to researchers from academia and industry. In pace with the needs of the scientific communities and technical developments, systems deployed by PRACE are continuously updated and upgraded to be at the apex of HPC technology (64).

PRACE systems are available to scientists and researchers from academia and industry from around the world through 2 forms of access:

- Preparatory Access is intended for short-term access to resources, for code-enabling and porting, required to prepare proposals for Project Access and to demonstrate the scalability of codes. Applications for Preparatory Access are accepted at any time, with a cut-off date every 3 months.
- Project Access is intended for individual researchers and research groups including multi-national research groups and can be used for 1-year production runs, as well as for 2-year or 3-year (Multi-Year Access) production runs.

FREYA

FREYA is a 3-year project funded by the European Commission under the Horizon 2020 programme. The project aims to extend the infrastructure for persistent identifiers (PIDs) as a core component of open research, in the EU and globally. FREYA will improve discovery, navigation, retrieval, and access to research resources. New provenance services will enable researchers to better evaluate data and make the scientific record more complete, reliable, and traceable. By engaging with the global community through the Research Data Alliance (RDA) and other research infrastructures, we work together to realise the vision of fully accessible data. FREYA follows on from the successful THOR project.
The three pillars of FREYA

- The PID Graph connects and integrates PID systems, creating relationships across a network of PIDs and serving as a basis for new services.
- The PID Forum promotes engagement with the global community via pidforum.org, and through organising conferences, workshops and other PID-themed events.The PID Commons addresses the sustainability of the PID infrastructure resulting from FREYA beyond the lifetime of the project (65).

2.3.2. Other initiatives for support for Open Science

ORCID

ORCID is part of the wider digital infrastructure needed for researchers to share information on a global scale. It enables transparent and trustworthy connections between researchers, their contributions and affiliations, by providing an identifier for individuals to use with their name as they engage in research, scholarship, and innovation activities.

ORCID is a not-for-profit organization, sustained by fees from member organizations. ORCID works are open, transparent, and non-proprietary. ORCID is guided by the principles of privacy and researcher control, and the vision of identifier-enabled research information infrastructure. ORCID makes decisions collaboratively, involving staff and Board, those who support ORCID mission, and the researchers and community that are the purpose of work (66).

DataCite

DataCite is a leading global non-profit organisation that provides persistent identifiers (DOIs) for research data and other research outputs. Organizations within the research community join DataCite as members to be able to assign DOIs to all their research outputs. This way, their outputs become discoverable and associated metadata is made available to the community.

DataCite is a membership organization. Organizations within the research community join DataCite as members to be able to assign DOIs to all their research outputs. This way, their output becomes discoverable and associated metadata is made available to the community. DataCite then develops

additional services to improve the DOI management experience, making it easier for our members to connect and share their DOIs with the broader research ecosystem and to assess the use of their DOIs within that ecosystem.

DataCite's strength is rooted in its active membership. DataCite's global community, from more than 20 countries, includes data centres, libraries, government agencies, research universities and more. DataCite members are the voting body of the organisation. Membership is open to all organisations that share our data sharing mission. DataCite's members work with data centres, stewards, libraries, archives, universities, publishers and research institutes who have responsibility for managing, holding, curating, and archiving data. DataCite does not allocate DOIs directly; this activity is undertaken by many of DataCite's members, who act as DOI allocating agents. DataCite members enable data owners, stewards, or archives to assign persistent identifiers to research data (67).

2.4. Open Education and Open Citizen Science

2.4.1. Open education

Effective use of knowledge represents a key to economic success for individuals, companies and nations. Some sectors, like transportation, logistics and supply chain are subject to disruptive innovations which will radically change the essence of operations and therefore, for professionals from those sectors it is very important to change the traditional mindset toward the continuous learning and skills improvement. Open education initiatives represent an efficient way for promoting lifelong learning and can bridge the gap between non-formal, informal and formal learning.
Open education aims for sharing the educational resources free and openly for educators, students and self-learners for teaching, learning and research. Open educational resources include learning material, software tools to develop, use and distribute content and implementation resources such as open licences. The learning content includes educational material organised as courses, and mostly distributed as PDF files. The content may involve websites, text files, images, sound or videos in digital format.
The main facilitator of open education is the digitalisation in educational systems. Internet and other digital channels have been used at the faculties to develop and distribute educational material. However, much of the materials are still locked up with passwords within proprietary systems and unreachable for wider public. This is for example the case with High Speed Rail (HSR) learning system – a demonstration project that seeks to address gaps in knowledge related to HSR systems (45). The essence of Open Education Resources (OER) is to remove these barriers and to enable freely sharing content (OECD, 2007). Nowadays, a number of e-learning platforms appears, especially in tertiary education (for example edx.org by which for example free online courses from MIT are distributed – MITx – MicroMasters programme for supply chain management, among many others). In general, this way of learning represents very promising way forward which can contribute to decrease of costs and improve the education.
The main aspects that should be addressed for any of these initiatives are:

- Sustainability of cost/benefit models for open education initiatives;
- Intellectual property rights related to open education initiatives;
- Incentives and barriers for educational institutions to deliver their teaching materials to these open education initiatives;
- Improvement of the access and usefulness of the users of open education initiatives.

The main reasons for individuals and institutions to use, produce and share open educational resources are reflected in the following set of drivers:

- The technological drivers: improved, less costly and more user-friendly IT infrastructure, hardware and software;
- Economic drivers related to cheaper content, easier to produce, and costs that are reduced by sharing;
- Legal drivers which represent licencing schemes that support free sharing and reuse of content;
- Social drivers include an increased willingness to share.

Regarding the barriers, there are:

- Technical barriers reflected in lack of broadband availability;
- Economic barrier reflected in a lack of resources to invest in hardware and software for developing and sharing open educational resources;
- Social barriers reflected in a lack of skills to use the technical innovations and cultural obstacles against sharing or using resources developed by other teachers or institutions.

Regarding the teachers and researchers, the main motivation to participate in open education initiatives can be found in:

- Personal non-monetary gain – publicity, reputation within the open community;
- Economic reasons – free sharing as a way of getting publicity, reaching market more quickly;
- Sharing the resources can be of value for other people.

It should be noted that open education initiatives may affect curriculum, pedagogy and assessment in education institutions. Open education resources as free available courses from international education institutions accelerate changes in their teaching and provide comparison of teacher's curriculums by students. Also, increase in non-formal and informal learning can be expected to enhance the demand for assessment and recognition of competences gained outside formal learning settings.

Regarding sustainability of open education resource projects there are different initiatives. Some initiatives have institutional backing involving professional staff whereas other include communities of practitioners and rely on their voluntary work. A number of models for cost recovery are also identified in practice:

- Replacement model: open content replaces other uses and benefits from cost savings;
- Foundation, donation or endowment model in which funding for the project is provided by an external actor;
- Segmentation model in which the provider offers "value-added services" to user segments and charges them for these services;
- Conversion model in which the provider gives something away for free and then convert the consumer to a paying customer;
- Membership model which is based on paying members.

Regarding the education for transportation professions, Giannopoulos (2015) highlights that the concepts for education and training in the transport sector today lack the necessary cross-disciplinary context that the transport industry and transport applications require in today's world. A new paradigm has to be put in place in training and education that gives emphasis on the cross-fertilizing of the relevant disciplines and more focus must be given to "know-how" transfer actions from the transfer research professional to the industry and the public bodies. Open education initiatives may facilitate this by creating effective knowledge transfer and knowledge sharing mechanisms within the education and training system or cooperation and pooling of resources between education and training institutions on one side and industry on the other. Establishing a permanent system of information sharing and knowledge sharing between all relevant stakeholders in the transport sector represents a path toward significant skills improvement and knowledge empowerment of future transport professionals (47).

Capturing and sharing of business learning and lifelong learning in the context of maritime transport industry is considered by Grewal and Hangstetter (2007) (48). Given the dynamic nature of the maritime transport industry, knowledge and management learning are critical to its continued development. Managing of knowledge requires some formal process that provides easy access to the organizational

memory, or intellectual capital and simple methods to add to the knowledge bank (49). Therefore, the knowledge sharing becomes a critical capability for an organization in the maritime industry.

2.4.2. Open citizen science

Citizen science represents the inclusion of members of the public in some aspect of scientific research. It includes almost all scientific disciplines with multiple forms, depths and aims of collaboration (50). In Citizen Science there is a broad network of people which collaborate. Participants provide experimental data and facilities for researchers; volunteers acquire new learning and skills and gain a deeper understanding of the scientific work. This open networked and transdisciplinary scenario supports improvement of science-society-policy interactions (51).

Socientize (52) project aims at improving the understanding and uptake of the impacts associated with citizen science. Proposed solutions aim for actions on three different, interrelated levels:

- Macro level (policy makers, science founders): common strategies and coordinated plan around three key issues: public engagement, trust and education.
- Meso level (citizen science mediators and facilitators): Facilitation initiatives which should engage the different stakeholders into a shared framework with common means of communication.
- Micro level (researchers, communities): Creating support for the main actors which drive the citizen science to face challenges, stay motivated and engage others.

The advantage of cooperation with citizens has been recognised by academic scientists, because of the qualitative value of their local knowledge and their extensive social networks. Citizens have proven to be capable of asking their own research questions, setting up their own projects, educating themselves and managing complex projects (53).

Emerging trend toward open and collaborative science increases the quality of online educational resources. On the other side, Citizen Science aims to the inclusion of public in some aspect of scientific research offering the possibility for collaboration and quality improvement. However, most of Citizen Science related projects consider educational aspect as a secondary goal. Remaining part of this section summarizes recent contributions to bridging the concepts of citizen science and open educational resources.

Many organizations (like heritage organizations) have wiki-style platforms as a mean to collect knowledge from their user base, as wikis are a way to facilitate collaborative contributions and to track the history of successive contributions from many users (54). Using the open structure of a wiki researchers can create their own research questions and answer them using wiki resources. The most important issues in citizen science projects is the strategy attract users and retain them to the project (55).

To the best of our knowledge, a similar semantic wiki-based platform to facilitate the research in transportation, logistics or supply chain field and using citizens as scientists to create open education resources do not exist.

However, in other fields there are projects dealing with citizen science and educational goals. For example, CAISE project (56) represents one of the first projects which encourages public participation in scientific research that discusses aspects of informal science education in relation with citizen science.

Trove project (57) uses members of the public adding information to records as a method for libraries to enhance the detail of their collections. Trove is tracking also the behaviour of the users making these corrections.

Project exploreAT (58) uses citizens in much more complex actions. The project aims to publish linked open data that connects complex features with the global and European knowledge web. The citizens are performing a large range of tasks from crowdsourcing to co-design.

3. Existing Open Science Research Sources in Transport Research

3.1. Open and FAIR data

To better understand the Open and FAIR data opportunities and challenges in the transport research, it is important to understand the characteristics of transport data. Transport data relates to a highly complex set of dimensions of the transport sector, consisting of several transport modes (road, rail, air, etc…), their vehicles, geographic data and existing infrastructure, etc… This means that "transport data are characterized by a complex, multilevel topology corresponding to the various aspects of transport research, planning, design and operation" (1), which translates into a high volume and variety of research data.

A Transport Research Cloud (TRC) is being conceptualized by the European Commission, as part of the European Open Science Cloud (42). Benefits of having an open research data repository were presented in "Analysis of the state of the art, barriers, needs and opportunities for setting up a transport research cloud", with main focus to data availability, international data sharing and advance research in the transport field (see Fig. 2).

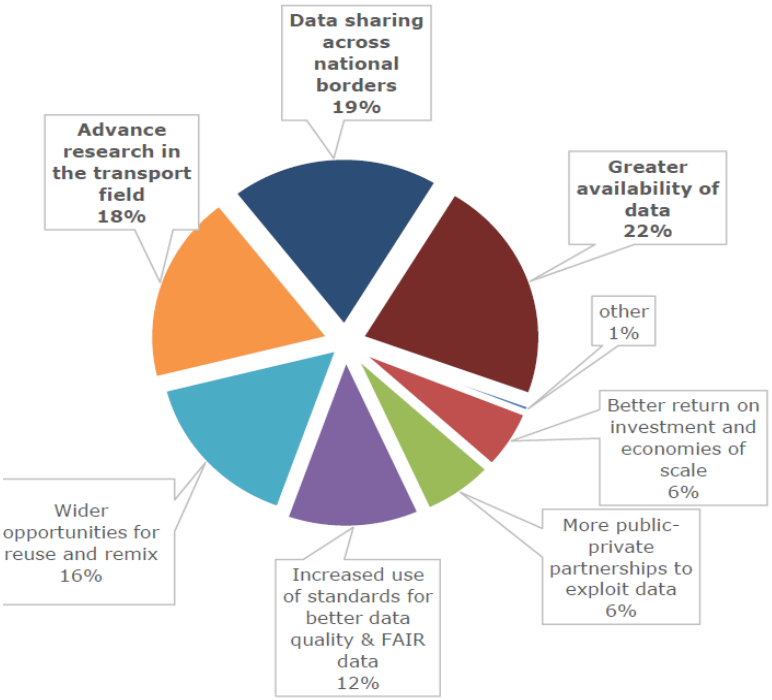

Figure 2 Research benefits of a TRC

OFD in the transport research is packed with challenges, mostly related, but not restricted, to Big Data and GDPR. The sheer volume and variety of data used in the sector creates several problems when storing, preserving, compiling or combining transport data. Data collected for transport research or by

governmental entities tends to be stored in distributed data silos, with different ownerships and data formats, which can cause difficulties when cataloguing, finding, accessing and using research data. Another barrier to the OFD is due the sensitiveness and privacy of the data. Following GDPR legal policies, data containing individual information and data that can affect the safety or security of something/someone should not be available for everyone (data control is needed), with ethical and commercial concerns also arising as a barrier to OFD. Other challenges can be found the usefulness of the data for research purposes, data quality and cultural barriers. Figure 3 presents barriers identified researchers and their perceived importance.

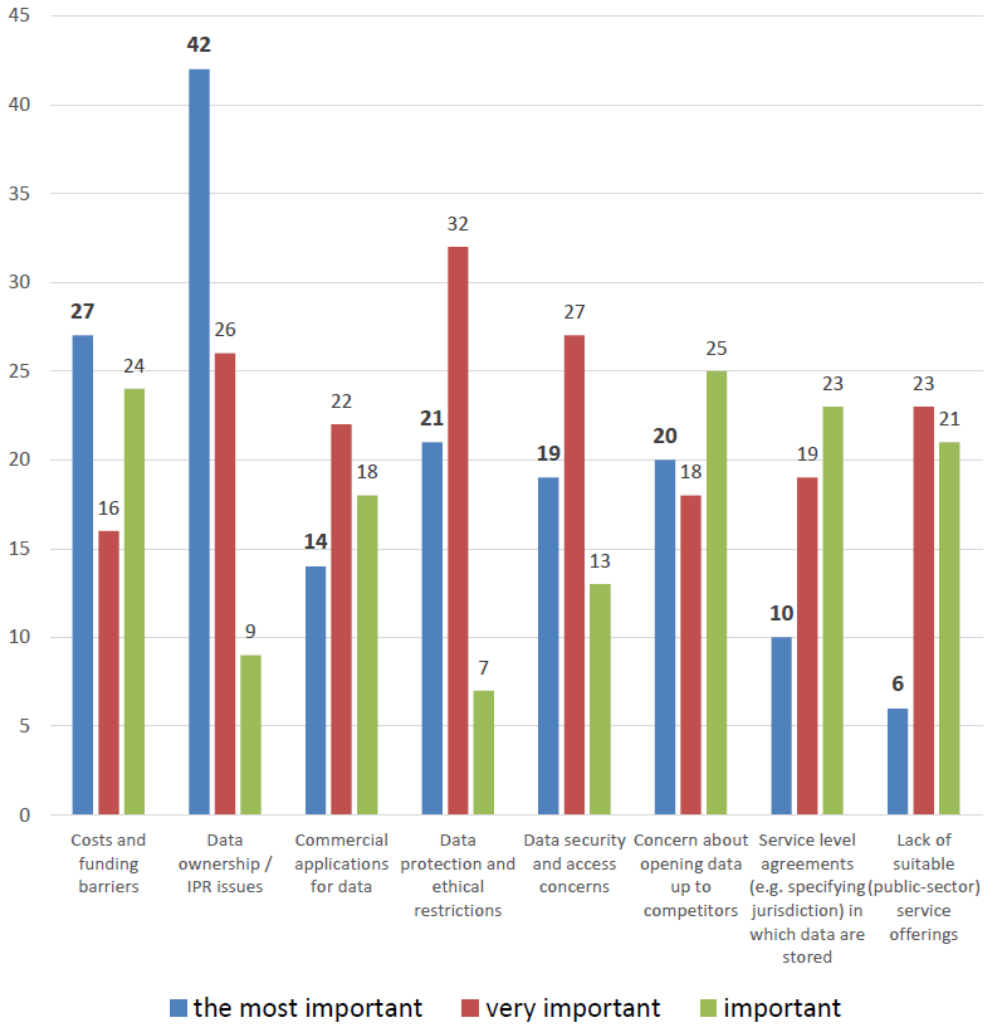

Figure 3 Barriers to data reuse

To ensure that members of the transport research community benefit from a TRC with OFD, standards are necessary. These standards define data formats, metadata needed to describe the data and formats of this metadata. This are critical to allow automated search engines to catalogue data from different sources and create these collections of OFD (42).

A list of sources for accessing datasets in transport:

- List of institutional repositories

  - https://www.re3data.org/search?query=transport
- EUROSTAT
  - https://ec.europa.eu/eurostat/search?p_auth=PcdOahJt&p_p_id=estatsearchportlet_WAR_estatsearchportlet&p_p_lifecycle=1&p_p_state=maximized&p_p_mode=view&_estatsearchportlet_WAR_estatsearchportlet_action=search&text=transport
- OECD iLibrary
  - https://www.oecd-ilibrary.org/finance-and-investment/data/itf-transport-statistics/transport-infrastructure-investment-and-maintenance_g2g55573-en
- EU open data portal (created by EC and EU funding)
  - https://data.europa.eu/euodp/en/data/dataset?q=transport&ext_boolean=all
- Similar initiative in US:
  - https://catalog.data.gov/dataset?vocab_category_all=Transportation
  - https://www.transportation.gov/data
- Similar initiative in Australia:
  - https://opendata.transport.nsw.gov.au/
- Similar initiative in India
  - https://data.gov.in/sector/transport
- Aggregator of European open data portals
  - https://www.europeandataportal.eu/data/?#/datasets?locale=el&query=transport
  - https://www.kaggle.com/datasets?sortBy=relevance&group=featured&search=tag%3A%27transport%27
  - https://data.world/datasets/transportation
  - https://intend-project.eu/access-to-the-transport-research-data-repository/
  - https://data.transformingtransport.eu/dataset
- National transport authorities: https://data.smartdublin.ie/dataset/public-transport-nta
- Other information https://www.nature.com/articles/sdata201889

3.2. Open Software/source

Transport research community targets to increase its impact on global economic, environmental and social sustainability. In the process of reaching more sustainable and optimized transport models, identification of best practices in transport has a vital role. The development of different kind of software is a common component of a best practice plan. Software implementation in different transport modes constitutes a promising auxiliary tool for the sustainable development of the transport sector. Through a literature search, it was identified that most of the software are related to transport management and transport engineering, highlighting the importance of supply chain and traffic management, as well as the significance of transport planning. To evaluate these outcomes, a desk research was conducted in order to identify different open software through the open repository OpenAIRE (33).

Through OpenAIRE platform we could reach other repositories and European platforms, which cooperate with the European Commission (Zenodo, Software Heritage, GitHub). In order to identify as many open software as possible, the desk research was organised in such way that different types of potential software to be explored. As an outcome, the research resulted in forty Open source software (OSS) related to transport research, developed in text formats (txt) or different code languages (Python, R language, Java, Matlab etc). These software programmes were developed in Europe, USA, China or Australia (only one software was found).

More specifically, the technological and the transport planning areas were the main competence areas covered through this open source software while the main keywords that led to a result included the words: transportation, traffic, aviation and automotive. Major effort has been put in the creation of models for combined transport modes and especially road transport. Following that, aviation and air transport had several use cases. However, maritime and rail sector have limited open source software applications. The sub-areas that the software covered included traffic engineering, social-economic, business modelling and control systems. These Open source software address to public authorities, research communities, commercial transport and logistics and private industries.

In order to evaluate the above results, a quick analysis on the most common open source software repositories (figshare and GitHub) was conducted using the same keywords as used above. In figshare, 49 software were identified, using the keyword transport, only eight of which were related to vehicle transportation. In the same way, eight software were identified using the keyword traffic, two of which were related to traffic engineering. From the eight software, appeared when the keyword automotive was entered, only one was related to automotive transport. Finally, no software related to maritime nor aviation transport was identified.

On the other hand, due to the fact that GitHub is a more widely used open software repository, 19.108 results appeared when we entered the transport keyword, 4870 when transportation, 31.553 traffic, 1673 automotive and 421 when maritime. It is obvious that a lot of software would not be relevant with the transportation itself, however a further detailed research study would enlighten the global research society.

3.3. Infrastructure

“Research infrastructures means facilities, resources and related services that are used by the scientific community to conduct top-level research in their respective fields and covers major scientific equipment or sets of instruments; knowledge-based resources such as collections, archives or structures for scientific information; enabling Information and Communication Technology-based infrastructures such as Grid, computing, software and communication, or any other entity of a unique nature essential to achieve excellence in research. Such infrastructures may be “single-sited” or “distributed” (an organised network of resources)” (41).

ESFRI – European Strategy Forum on Research Infrastructures

As seen in Chapter 2.3, while 20 European Research Infrastructure Consortia (ERICs) were established in 2009, to this date, no ERIC is related to transport research infrastructures. Moreover, until now, transport specific RIs do not appear in the ESFRI roadmaps (68). ESFRI, the European Strategy Forum on Research Infrastructures, is a strategic instrument to develop the scientific integration of Europe and to strengthen its international outreach. ESFRI produces and continuously updates a European roadmap on RI. The transport sector is tackled within ESFRI as part of an analysis on “Efficient clean transport”. Investments in transport services and infrastructure represent priorities for the Cohesion Policy during the 2014-2020 funding period (43) and emphasis is placed on the Member states adopting “a comprehensive transport plan” that shows how projects will contribute towards the development of the Single European Transport Area and the trans- European transport network. Moreover, ESFRI underscores the need for RIs in the context of electric and autonomous vehicles, to enable researchers to study the effects of the legal

framework as well as the physical infrastructure within which these will operate. It is clear that there is a need for a more structured approach within the transport sector to support new Research Infrastructures.

DETRA – Developing the European Transport Research Alliance

Nevertheless, transport mode-specific research infrastructures operate across Europe and were analysed part of the DETRA project (FP7, 2010). DETRA (Developing the European Transport Research Alliance) aimed to strengthen the European Research Area (ERA) objectives in transport, in order to address challenges such as climate change, energy, water and food, public health, ageing societies and globalization. A review of European and International Research Infrastructures was performed that led to the development of an online catalogue which contains more than 340 transport-related RIs (44). The catalogue includes both hard (physical) and soft (libraries, databases, models) RIs from the public and private sector. With regard to transport mode, the catalogue focuses mainly on surface transport but also contains RIs from waterborne and air transport.

In addition, the project outputs highlighted needs and requirements for RIs that have been only partially tackled until now, e.g. investment in world-class RIs requires cooperation between countries, efficient common databases are key, the importance of RIs depends on highly-qualified researchers at the facility. The project concluded that the main existing RIs are focused on other areas than the transport sector and that there is a need for establishing new RIs within the transport sector.

EUTRAIN – European Transport Research Area International Cooperation Activities

The international Study EUTRAIN – European Transport Research Area International Cooperation Activities (FP7, 2011) investigated the status quo of research infrastructures in the field of transport and their potential for scientific collaboration in USA, Japan, Tunisia, Egypt, Ukraine, China, Russia, India, Australia and South Africa. It turned out that data available on research infrastructures is very limited in these countries and international cooperation around research infrastructures was not developed at that time.

According to the authors of EUTRAIN project D2.1 “Current Practices Characteristics and Issues in Research Collaboration” Grand Challenges like “Sustainable Transport” in its complexity calls for interconnected research infrastructure being accessible for all researchers.

Transport faces multiple local, national and global problems to be solved that it calls for RI like test sites, urban labs, ITS, simulators, data bases etc… which should be interlinked, networked and used as hubs for national, European and international cooperation. High quality RI is considered also as a source of creativity and innovation, which offers researchers an appropriate environment to exchange and share knowledge and lift their results and findings to the next level.

As funds for research in general tend to get reduced even more so in the future, there is a strong need to organise research more effectively in order to reduce costs, to avoid duplication of investments in RI and parallel work on the same topics without exchange. High quality research infrastructures in general could strongly support scientific collaboration, raise quality of research results at the same time saving money.

RINGO – Research Infrastructures needs gaps overlaps

While limited information was found on coordinated transport-related RIs across Europe, an example of a structured approach is the project RINGO. RINGO (Research Infrastructures needs gaps overlaps) is Coordination and Support Action funded under the H2020 framework programme that aims to provide a cohesive approach for the identification and assessment of the aviation research infrastructures needed in Europe. One project output is an interactive map presenting the landscape of aviation research infrastructures available in Europe (69). No other projects or initiatives tackling transport mode-specific RIs were identified in our work.

ECTRI Survey of European RIs

In 2002, ECTRI [1], under the scope of strategic and open collaboration between its Members has entrusted its Member TNO (the Netherlands Organisation for applied scientific research) with performing a survey amongst the ECTRI partners, to identify major and unique research, development and testing facilities as well as other services that can be utilised to support R&D in the domain of the ECTRI programme. The survey constituted a basis for developing a framework for mutual access to these facilities and services and also to identify important gaps in the RI given the needs stemming from the contemporaneous joint R&D programme and subsequently propose the development of new facilities and services.

In parallel to this, a database of soft infrastructures was developed within ECTRI by the Working Group on Soft Research Infrastructures'. This Group had as mission to the establish a European transport research soft infrastructures agenda, notably for libraries, databases, datasets and identify elements contained in an integrated infrastructure initiative such as: opening, access, networking, integrating survey on adaptation or new needs and the scope of these elements. The database is online, hosted by CDV (the Czech Transport Research Centre (CDV) and is provide as a service within the organisation.

Again, as a service within the organisation, in 2017, ECTRI1 conducted a new survey to gather full and up-to-date information on its Members' research facilities and infrastructures. The survey aimed to identify research, development and testing facilities and infrastructures existing at each ECTRI Member's site(s) with the objective of increase collaboration between Members.

The research, development and testing facilities and infrastructures categories were defined as such:

- Test tracks and crash facilities e.g. dynamic impact or restraint test facility, catapult or full-scale crash facility.
- Simulators, other simulation facilities, models e.g. dynamic driving simulator, numerical simulator facility, road traffic simulator, instrumented cars, prototype for green vehicles.
- Field and other laboratories e.g. field operational test, photometric and visibility laboratory, virtual laboratory, real traffic/life test beds.
- Databases
- Libraries and literature databases

[1] ECTRI (European Conference of Transport Research Institutes) it is the first attempt to unite the forces of the foremost multimodal transport research centres across Europe and to thereby promote the excellence of European transport research. Today, it encompasses 27 major transport research institutes or universities from 20 European countries.

The last version of the (living) report, from July 31st, 2018, have identified:

Table 1 Type of facility or infrastructure

Facility/infrastructure	No
Test tracks and crash facilities	10
Simulators, other simulation facilities, models	33
Field and other laboratories	55
Databases	11
Libraries and literature databases	3
Other (e.g. Online Services Portal; Charging infrastructure; Powerful workstation; Intelligent multi-camera 3D system; Virtual Reality System, …)	27
Total	139

Table 2 Research application

Transport mode	No
Air	14
Rail	33
Road	122
Waterborne	10
Multimodal	38

Table 3 Topics

Topic	No
Freight and passenger transport by all surface modes	42
Traffic flow and driver behaviour in all modes	60
Safety analysis and vehicle control	74
Environmental impacts (particles, emissions, noise, fuels, energy efficiency, weather or water influence)	58
Green vehicles, including charging infrastructures	41
Traffic control centres for all modes	47
Automation to all modes	52
Smart cities environment (C-ITS)	56
Other	23

Most of these research infrastructure facilities and databases are open for external use, through research cooperation agreements and for training purposes. For the libraries and literature databases they are all open services.

4. Use of Open data, software and infrastructure in transport research

To answer the questions about use of open data, software and infrastructure in transport research, a survey (Annex) was developed and sent out to the research institutes of ECTRI, FEHRL, EURNEX, WEGEMT, EATEO and HUMANIST. The survey was also sent out to other BE OPEN partners that are research institutes. In total the survey was sent out to about 240 organisations and 51 research institutes from the transport sector have completed the survey.

Most of the respondents have technological research activities as their main research area, with transport planning as second most important.

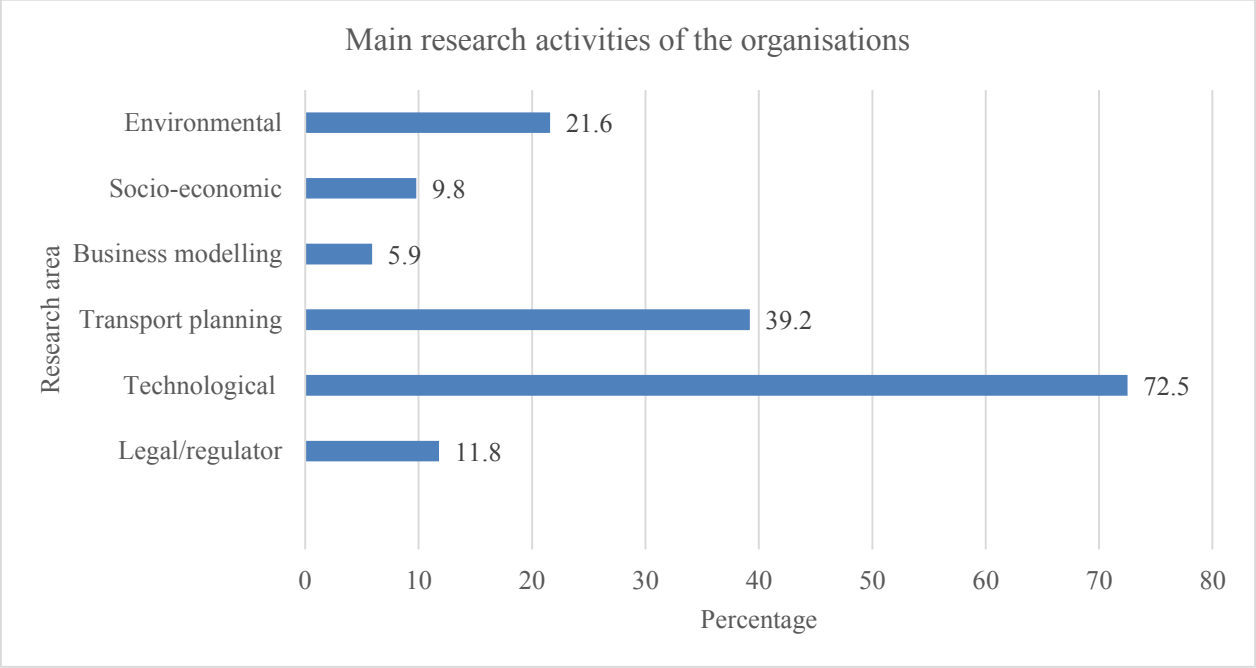

Figure 4 Main research activities in the selection, n = 51

4.1. Open and FAIR data

4.1.1. Use of open/FAIR data – challenges and advantages

Only 31 % of the respondents answer that they have any established strategy for the use and provision of open and fair data. This could be because most institutes do not conduct the main part of their research based on open and FAIR data (see figure 5). What is interesting however is that about 20 % of the research institutes conduct over 50 % of their research based on open/FAIR data.

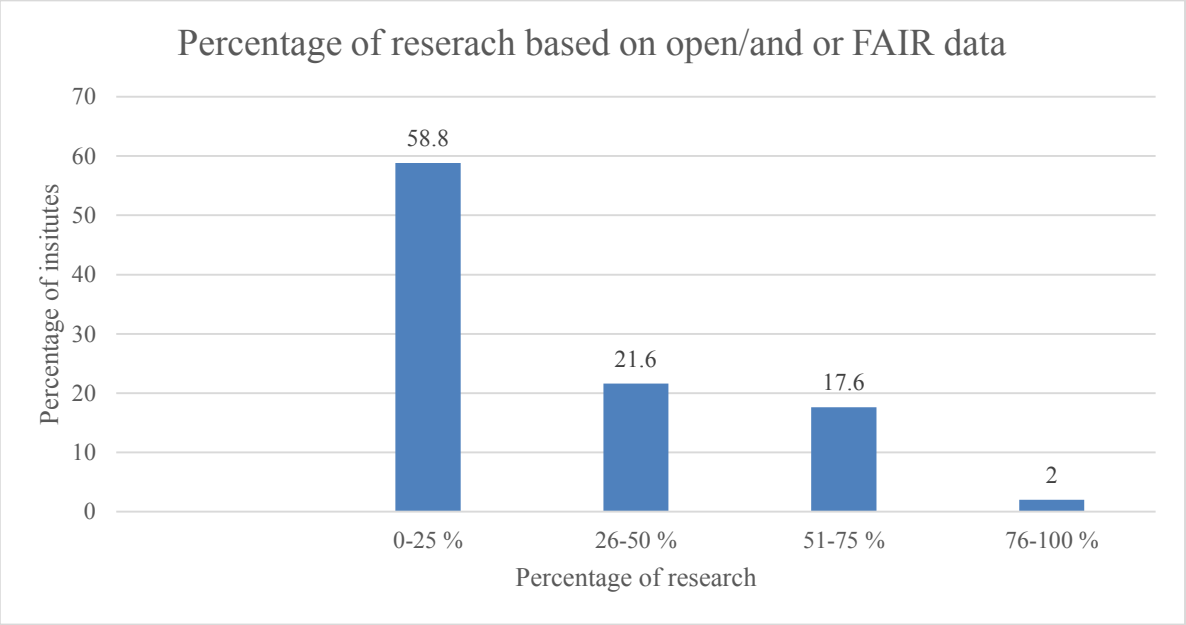

Figure 5 Percentage of research based on Open and/or FAIR data, n = 51

The main advantage for using open/FAIR data is accessibility (Fig. 6), but time saving, cost and the possibility of conducting time-series analysis is also mentioned by 20-30%. In the 'other category' knowledge dissemination, regulations of Federal Ministry, Requirements from EC and machine learning is mentioned as advantages. Reliability is the most important challenge for using open/FAIR data (Fig. 7), and accessibility and relevance of material is mentioned by 30-40 %.

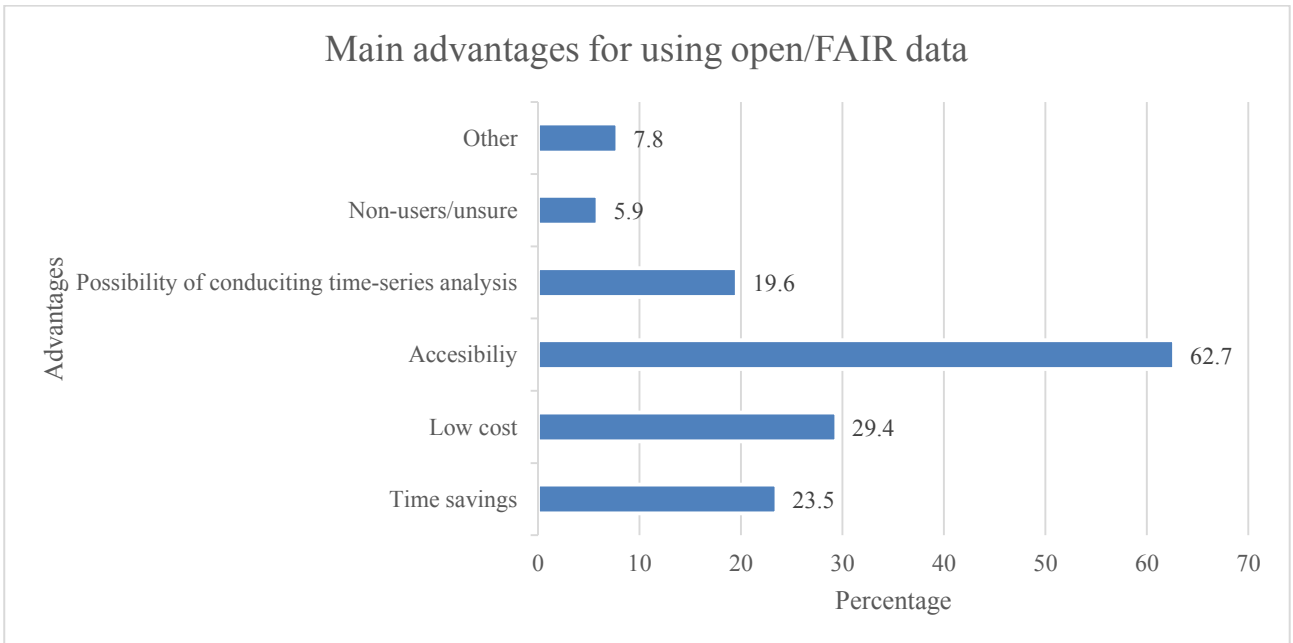

Figure 6 Main advantages for using open/FAIR data, n = 51

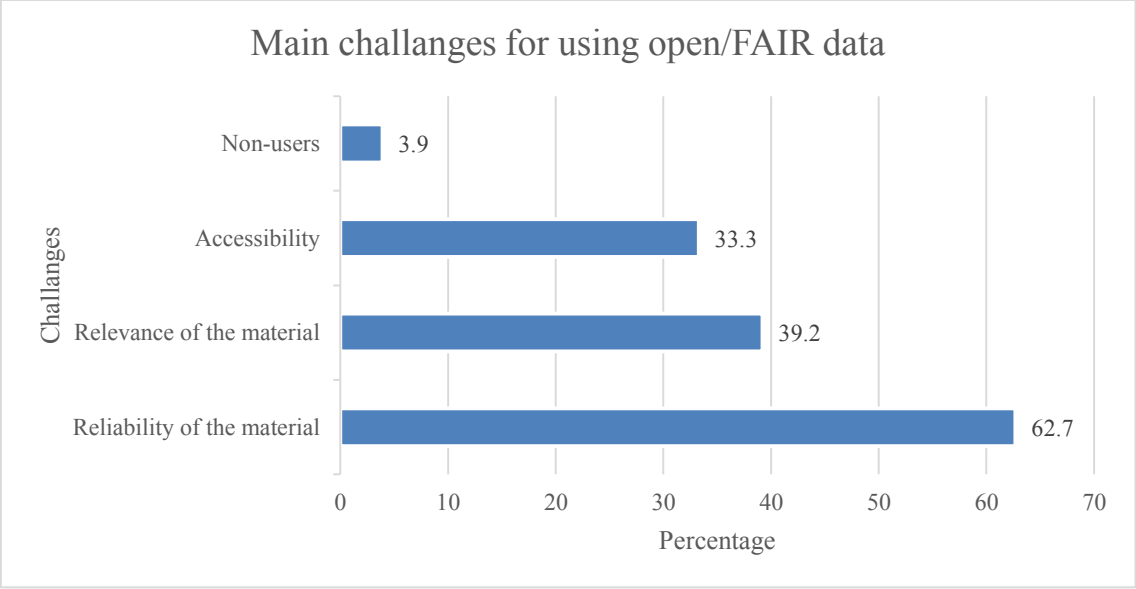

Figure 7 Main challenges for using open/FAIR data, n = 51

4.1.2. Production of open/FAIR data

Most respondents produce open/FAIR data themselves – 41.2% of the organisations produce it on ad hoc basis and 31.4 % produce it as part of the organizational strategy. The research areas they produce open data for is quite varied: technology, engineering, traffic management, transport planning, road safety, culture, education among some.

For the institutes that produce open/FAIR data (n=37), 87 % include a data management plan and/or budget plans for provision of open/FAIR data in non-EU projects on ad hoc basis and on certain projects. But only one respondent has this for all their projects.

The production of open and/or FAIR data has generated new administrative positions in the fields of data protection, general IT staff and database management expertise in 54 % of the organisations that produce open/FAIR data themselves.

The main barriers for producing open/FAIR data is divided between cost/time (43 %), GDPR (51 %) and competitiveness of the organization (35 %) (Fig. 8). Other reasons mentioned are lack of knowledge, lack of interest from researchers and not requested by contractors.

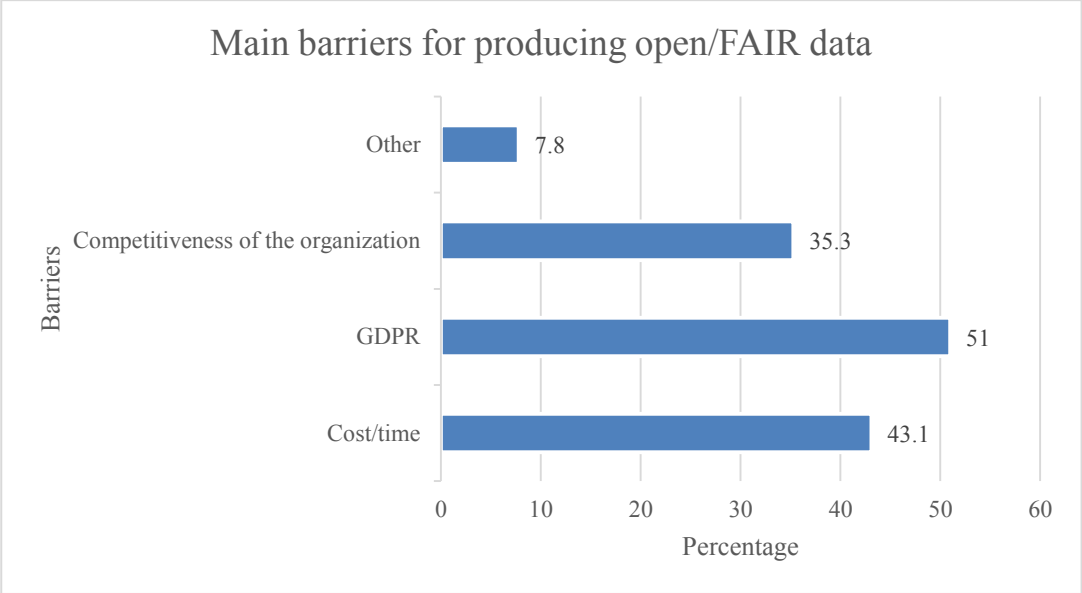

Figure 8 Barriers for producing open/FAIR data, n = 51

4.2. Open software

88 % of the institutes allow use of open source software, but only 7 % of these uses open source software more than half of their time using computer software (Fig. 9). 71 % of the institutes allowing use of OSS say that they encourage installation and use of open source software. The reason for why they encourage this is mainly due to low cost and flexibility. Transparency and interoperability are also mentioned as important reasons for why they encourage use (Fig. 10).

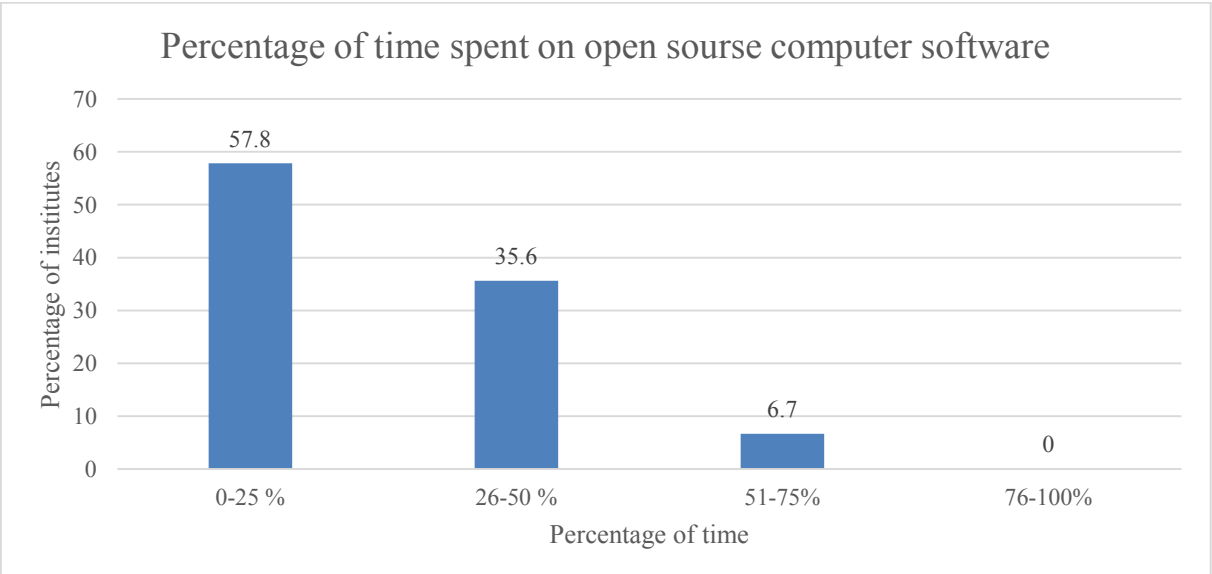

Figure 9 Open source software use, n = 45 (6 organizations do not allow use of open source software and did therefore not answer this question)

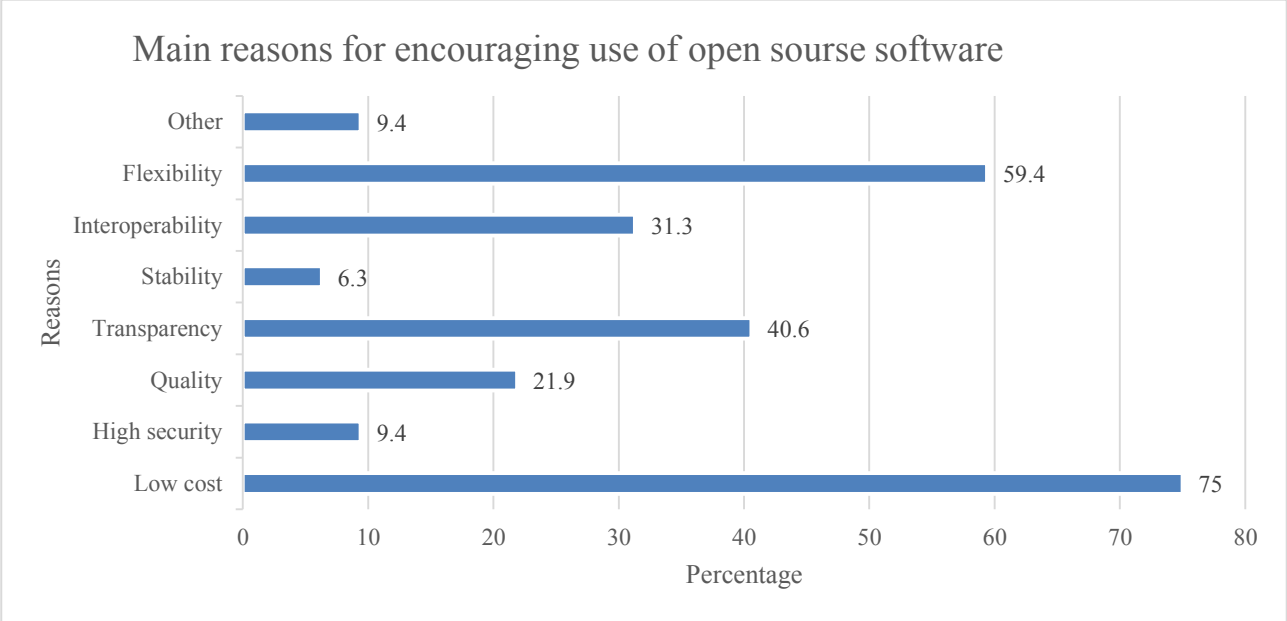

Figure 10 Main reasons for encouraging use of open source software, n =32 (only percentage of the people answering yes to encouraging)

The organisations that do not encourage use of open source software say the main reasons are low security and no existing open source software significantly relevant for their use. Lack of knowledge is also mentioned as an important factor (Fig. 11).

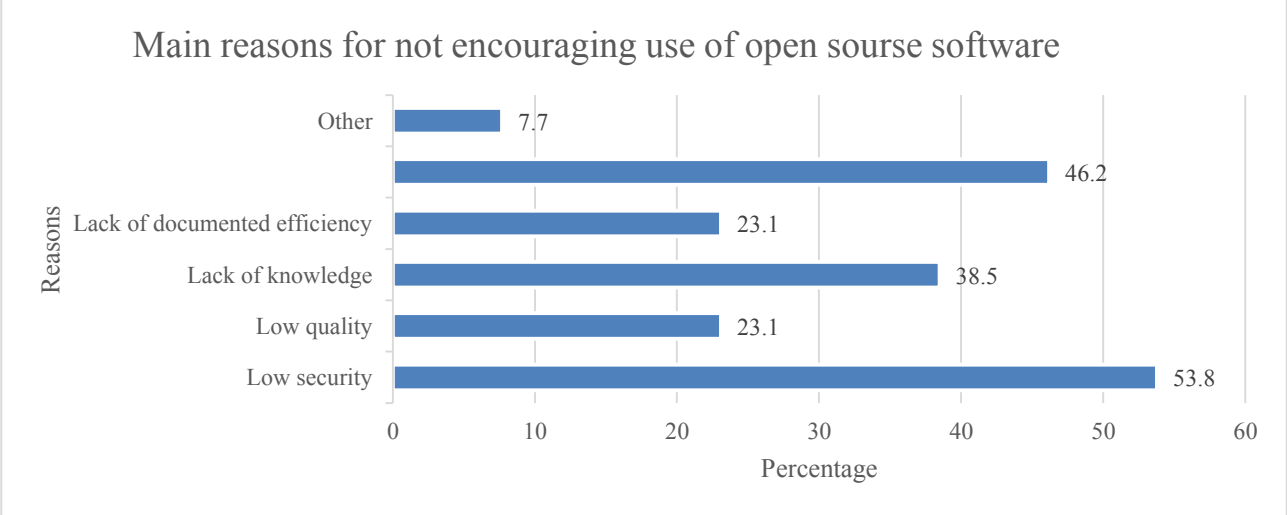

Figure 11 Main reasons for not encouraging use of open source software, n = 13

The attitudes towards use of open source data has become more positive in recent time among 66 % of the organizations that allow use of open source data. Especially the last 1-2 years the attitudes have become more positive. None of the organizations that allow open source software to have a more negative view of open source software than before.

There is a broad spectrum of open source software being used, with data processing software and word processing software being slightly more common (Fig. 12). Types of open software mentioned in the 'other'-category is business management software, statistical analysis software, project management software, picture editing/design software, operating systems and library systems.

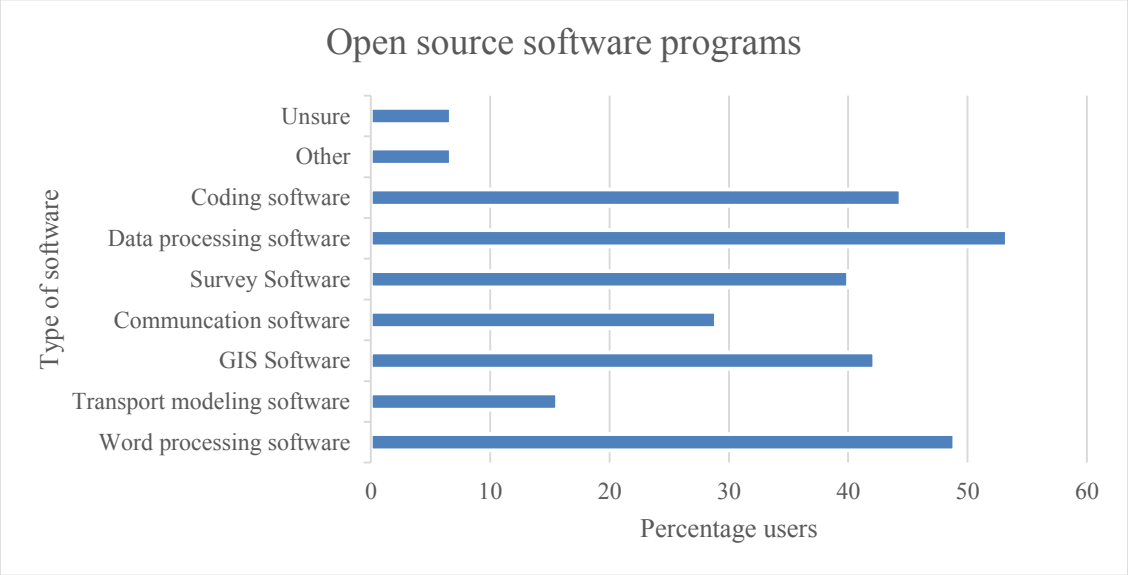

Figure 12 Open source software programmes, N = 45

4.3. Infrastructure

Almost all respondents have available open research infrastructure in form of laboratories, computing systems, databases and models (Fig. 13). 57 % of the organizations share their infrastructure with other organizations, mostly in specific projects (86%), but also networking around research infrastructure (28%) and sharing between different partners/countries (41 %).

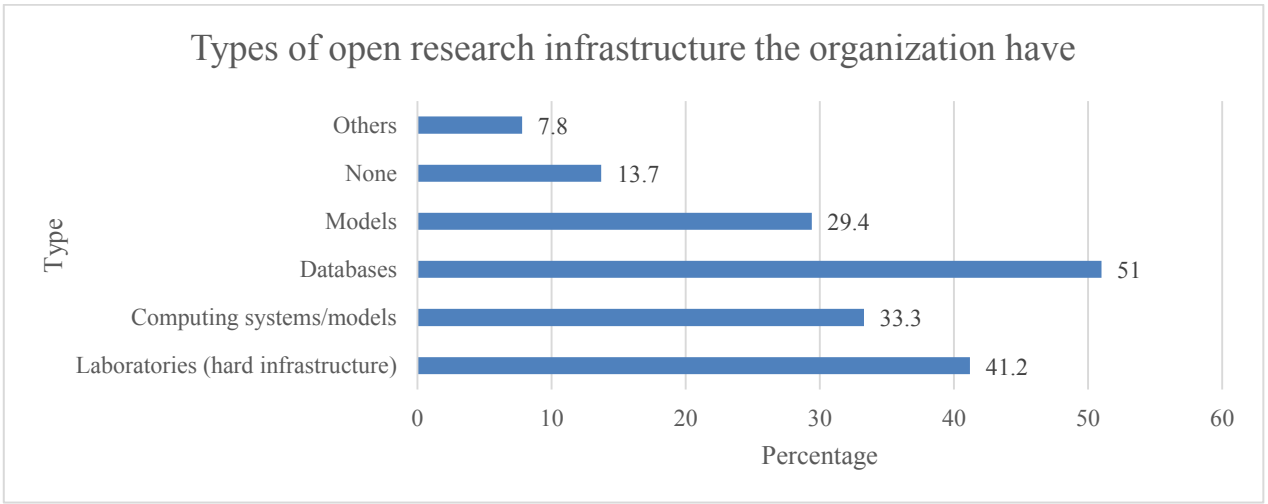

Figure 13 Types of infrastructure the organizations have for open research, n = 46

The way in which such infrastructure is priced varies, but most sharing of infrastructure is non-charge sharing (59 %), which we would expect as most sharing is done in specific projects. If charged, marginal cost-pricing is the most common (Fig. 14).

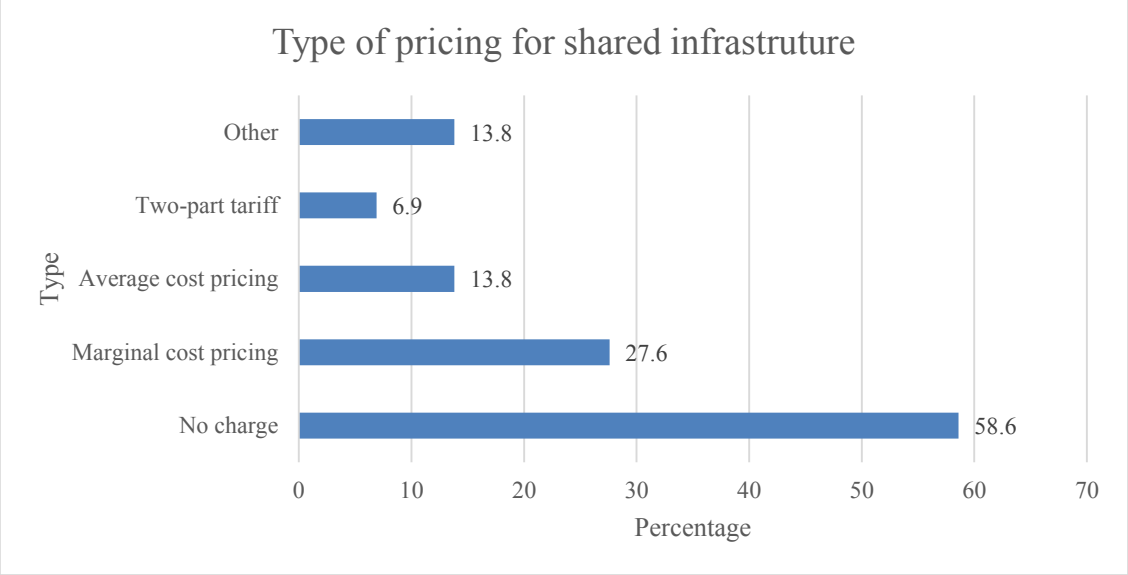

Figure 14 Type of pricing for shared infrastructure, n = 26

For the organizations that do not share infrastructure, competitiveness of the organization is listed as the most important barrier for sharing, but GDPR and cost/time is also quite important.

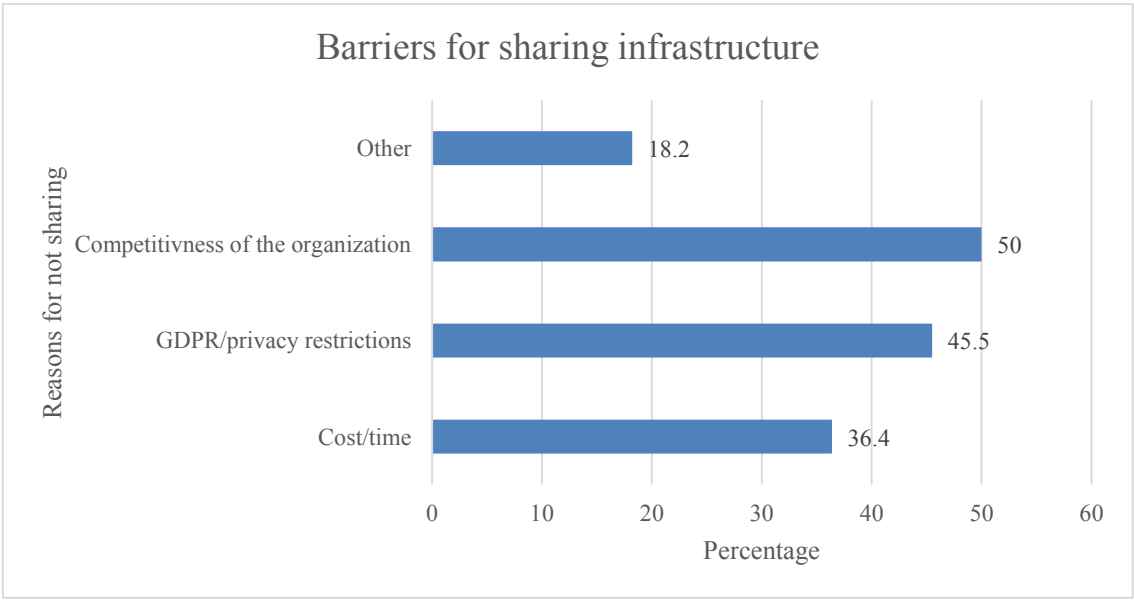

Figure 15 Barriers for sharing infrastructure among institutes that does not share (n=22)

74 % of all organizations also use infrastructure from other organizations.

4.4. Differences between key areas

The mapping of use of open data/fair data, open software and open infrastructure in transport research show that there are great differences between the three areas, but also between key area of research. Generally speaking, open software is least used, while open infrastructure is quite common. Key areas are divided in three groups: 'transport planning', 'technological' and 'other'. Legal/regulatory, environmental, socio-economic and business modelling had too few respondents to be divided into individual groups. Since all institutes could select more than one field, this percentage is somewhat neutralized by the institutes answering in more than one field. It is also important to be aware of the low n of the selection. This analysis therefore only shows general trends.

There is a higher percentage of institutes that conduct more than 50 % of their research based on open or/and fair data when the institute is in the field of transport planning (35 %) or technological research (22 %) than other key areas (9 %).

For open software there is less diversion between the different key research areas, where the percentage varies between 6-9 % for the institutes that use open software more than 50 % of their time using software.

Use of other institutes infrastructure is very common in the field of transport research. There is a higher percentage of institutes in the transport planning sector (85 %) and other sectors (82 %) that use other institutes infrastructure regularly or ad hoc than in technological transport research (73 %).

Table 4 Use of Open data, software and infrastructure in transport research

Key area	Open Data	Open Software	Open Infrastructure
Transport planning	35 %	6 %	85 %
Technological	22 %	9 %	73 %
Other	9 %	6 %	82 %

Green color signifies high use, yellow – intermediate, red - low percentage of use

5. Conclusions

Looking at transport research data as a subset of research data in general, the use of Open and FAIR data in transport research is subject to similar opportunities and challenges as the remainder of the research data. Big Data poses difficulties when dealing with OFD, with transport research finding a huge challenge due to the nature of transport data (e.g., different sources, types of transports, infrastructures, vehicles, geographic data). The problems can be found in the interoperability of data and systems, and data storage, among other issues. The use of standards is indispensable for the success of OFD sources for any research data, including the transport sector. Privacy and GDPR problems are also expected to be found in transport data, due to the personal and safety threats that can surge from incorrect transport data management (e.g., sharing data that it is not meant to be shared). With the Transport Research Cloud (TRC) being related to the European Open Science Cloud it is expected that some norms and standards will need to be taken into account to allow transport research data to be catalogued and accessible from these sources.

Most transport institutes (approximately 60 %) do not conduct much of their research based on open and FAIR data (between 0-25 %). The main challenges are reliability of the material. However, the majority (72 %) of transport research organizations produce a lot of open/FAIR data themselves which has generated new administrative positions in general IT, data management and data protection. There is a higher percentage of institutes that conduct more than 50 % of their research based on open or/and fair data when the institute is in the field of transport planning (35 %) or technological research (22 %) than other key areas (9 %).

In addition to survey results for Open and FAIR data usage, a review on Open Source Software (OSS) was conducted. During the review, the pertinent literature of open software in European research and the existing sources in Transport Research were identified and examined. As a starting point, international and European OSS initiatives/projects were listed and described briefly. These projects were separated in two groups, which are initiatives for embedding software in the research process and OSS infrastructure sources, and individually presented. Following, the review process targeted to map existing sources in Transport Research sector through a desk research using the European integrated open repository OpenAIRE. As an outcome, current OSS projects in Transport research covered mostly the technological and the transport planning competence areas with the majority of programmes covering road or multimodal transportation sectors.

In comparison with the review outcomes, survey results showed that most transport research organizations allow use of open source software, but only 7 % of the organizations that allow the use of open source software use it more than half of their time using computer software. Most institutes encourage use of open source software due to flexibility and low cost. Low security, non-existing relevant software and lack of knowledge is mentioned as main reasons for not encouraging use of open source software. Attitudes towards open source has become more positive in recent years. For open software there is less diversion between the different key research areas, where the percentage varies between 6-9 % for the institutes that use open software more than 50 % of their time using software.

Resources and services provided by the Research Infrastructures are very important for research communities since it conducts research and fosters innovation. For effective implementation of European

research programs and projects, the European Research Infrastructure Consortium (ERIC) was established in order to establish and operate new or existing Research Infrastructures on a non-economic basis. In addition, e-Infrastructures are key in future development of research infrastructures, as activities go increasingly "online" and produce vast amounts of data. e-Infrastructures address the needs of European researchers for digital services in terms of networking, computing and data management.

According to the survey results, shared infrastructure seems quite important in transport research as 57 % of the organizations share their infrastructure with other organizations and 74 % of all organizations use infrastructure from other organizations. The ones that does not share mention competitiveness as the most important reason, closely followed by GDPR and cost/time. There is a higher percentage of institutes in the transport planning sector (85 %) and other sectors (82 %) that use other institutes infrastructure regularly or ad hoc than in technological transport research (73 %).

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14. https://fsfe.org/campaigns/swpat/swpat.en.html
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7. ANNEX – BEOPEN Survey

BeOpen survey eng

Preview of version 6.0

ID: Intro

Information

Survey about Open Data, Open Software and Open Research Infrastructure

We would like to invite you to take part in the BE OPEN project by completing this survey on Open Science in transport research. Some of you have received a former survey form BE OPEN about general attitudes and knowledge about open data/science/software and questions about innovation. This questionnaire is a follow up of the last one, but this time we focus on company's strategies/policies and more details around use/non-use. You can answer this questionnaire without having answered the previous one.

The BE OPEN project is a coordination and support action (CSA) sponsored by the European Commission in the Horizon 2020 research and innovation programme under the grant agreement No 824323. To read more about the project take a look at our webpage: https://beopen-project.eu/. BE OPEN aims to create a common understanding of the practical implementation of Open Science in transport research and to develop a code of conduct for the entire research family. The objective of this survey is to identify use of, barrier, policies, strategies in relation to Open and Fair data, Software/source and Open Science Infrastructure.

Open Data – Research data that can be freely used, reused and redistributed by anyone – subject only, at most, to the requirement to attribute and share alike.

FAIR Data – meets standards of findability, accessibility, interoperability and reusability. FAIR data is

Information
accessible by a defined group of people. Open Software – Software that can be freely downloaded and used for analysis etc. Open Infrastructure – Large scale laboratories (hard infrastructure) that can be used collaboratively as well as libraries, databases (soft infrastructure). This survey contains X questions and takes about 10 min to complete. If you have any questions, please contact Anja Fleten Nielsen afn@toi.no or Silvia Olsen sjo@toi.no We look forward to receiving your feedback by the 30th of June.

Organization	Please state the name of your organization:
	Open

Activity	Please state the main research activity(ies) of your organization (maximum 2)	
range:#1:2		
Legal/regulatory		1
Technological		2
Transport planning		3
Business modelling		4
Socio-economic		5
Environmental		6

ID:Open_and_fair_data

Information
Questions about Open and FAIR data Open data should be available to everyone to access, use, and share, without licenses, copyright, or patents. FAIR data is data which meets standards of findability, accessibility, interoperability, and reusability. FAIR data is accessible by a defined group of people.

strategy	**Has your organization established a strategy for the use and provision of open and FAIR data?**	
range:*		
Yes		1
No		2

Information
filter:\strategy.a=1 Has your organization established a strategy for the use and provision of open and FAIR data? Please send us the policy document per e-mail if possible:

research	**How much of the research conducted at your organization is based on open and/or FAIR data?**	
range:*		
0-25%		1
26-50%		2

research	How much of the research conducted at your organization is based on open and/or FAIR data?	
51-75%		3
76-100%		4

arguments	What are your organizations main arguments for using open and/or FAIR data?	
range:*		
Time savings		1
Low cost		2
Accessibility		3
Possibilities of conducting time-series analyses		4
Other, please specify		Open

challenges	What are the main challenges of using open and/or FAIR data?	
range:*		
Reliability of the material		1
Relevance of the material		2
Accessibility		3
Other, please specify		Open

production	Does your organization produce open and/or FAIR data?	
range:*		
No		1

production	Does your organization produce open and/or FAIR data?	
On ad hoc basis		2
Yes, as part of the organization strategy		3

Research areas	In what research areas?
filter:\production.a=2|\production.a=3 **range:***	Open

Plan budget	Do research projects at your organization normally include a data management plan, and a budget for the provision of open and/or fair data for non-EU projects?	
filter:\production.a=2|\production.a=3 **range:***		
No		1
On ad hoc basis		2
Only certain types of projects		3
Only a data management plan		4
Only if funds are set aside		5
Always		6

admpos	What new administrative positions has been established at your organization in order to provide open and/or FAIR data?
filter:\production.a=2|\production.a=3 **range:***	

admpos	What new administrative positions has been established at your organization in order to provide open and/or FAIR data?	
None		1
General IT staff		2
Data protection		3
Database management expertise		4
Other, please specify		Open

barriers	What are the main barriers for producing open and/or FAIR data?	
range:*		
Cost/time		1
GDPR/privacy restrictions		2
Competitiveness of the organization		3
Other, please specify		Open

ID:Open_software_source

Information
Questions about Open software/source Open source software is a type of computer software in which users are granted the rights to study, change, and distribute the software to anyone and for any purpose.

opensource	**Does your organization allow the installation and use of open source software?**	
range:*		
Yes		1
No		2

Opensource_yesa	**What percentage of time spent on computer software would you consider being on open source?**	
filter:\opensource.a=1		
range:*		
0-25%		1
26-50%		2
51-75%		3
76-100%		4

Open source use	**Does your organization encourage the installation and use of open source software?**
filter:\opensource.a=1	

Open source use	Does your organization encourage the installation and use of open source software?	
range:*		
Yes		1
No		2

opensourceuse_yes	Why?	
filter:\opensourceuse.a=1		
range:*		
Low cost		1
High security		2
Quality		3
Transparency		4
Stability		5
Interoperability		6
Flexibility		7
Other, please specify		Open

opensourceuse_no	Why?	
filter:\opensourceuse.a=2		
range:*		
Low security		1

opensourceuse_no	Why?	
Low quality		2
Lack of knowledge		3
Lack of documented efficiency		4
No open source software significantly relevant for my institution exist		5
Other, please specify		Open

attitude	Has your organization's attitude towards open source software changed since it first became available?	
filter:\opensource.a=1 **range:***		
No		1
More positive towards it in the past 1-2 years		2
More positive towards it in the past 3-5 years		3
More negative towards it in the past 1-2 years		4
More negative towards it in the past 3-5 years		5

licenses	Please check off what open-source licenses are being used at your organization	
range:*		
Word processing software		1
Transport modeling software		2
GIS software		3

licenses	Please check off what open-source licenses are being used at your organization	
Communications software	☐	4
Survey software	☐	5
Data processing software	☐	6
Coding software	☐	7
Other, please specify		Open

ID:Open_research_infrastructure

Say
Questions about Open research infrastructure This section deals with the availability and use of research infrastructure in your organization. By research infrastructure, we mean large scale laboratories (hard infrastructure) that can be used collaboratively, as well as libraries and databases (soft infrastructure).

infrastructure	What kind of open research infrastructure does your organization have?	
range:*		
Laboratories (hard infrastructure)	1	
Computing systems /models	2	
Databases	3	
Models	4	
None	5	
Other research infrastructure, please specify	Open	

shareinfra	Do you share this infrastructure with other research organizations?	
range:*		
Yes	1	
No	2	

shareinfra_yes	On what basis is this done?

shareinfra_yes	On what basis is this done?
filter:\shareinfra.a=1 **range:***	
Specific projects	1
Networking around research infrastructure	2
Sharing between different partners/countries	3
Other, please specify	Open

shareinfra_yes_2	What principle do you use for the pricing of these infrastructures?
filter:\shareinfra.a=1 **range:***	
No charge	1
Marginal cost pricing	2
Average cost pricing	3
Two-part tariff	4
Other, please specify	Open

shareinfra_no	What are the main barriers for sharing research infrastructure?
filter:\shareinfra.a=2 **range:***	
Cost/time	1
GDPR/privacy restrictions	2

shareinfra_no	What are the main barriers for sharing research infrastructure?	
Competitiveness of the organization		3
Other, please specify		Open

shareinfra_otherorg	Does your organization use infrastructure from other organizations?	
range:*		
Yes, regularly		1
From time to time		2
No		3

ID:slutt

Information

 exit:yes

 redirect:https://beopen-project.eu/

 status:COMPLETE

Thank you for your participation!

Your answers are now saved.