<div align="center">Research Article</div>

Main Challenges and Opportunities, Constraints and Barriers of Open Science in Transport Research

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Abstract

Over the last two decades, digital technologies are constantly developed and new working methods have been arisen. Transport research community is following the path of open science, which concerns all stages of research process and consists of different elements. The objective of this study is to identify the challenges, opportunities and barriers of Open Science in transport research. On that purpose a Delphi survey was conducted for research community, industry and public authorities. The survey was held in two rounds aiming to achieve more robust results: in the first round, a questionnaire of 30 questions was disseminated to a panel of transport experts. The responses of the first round were collected and analysed. In the second round of the survey, the experts were asked to provide their final responses, by either confirming or adjusting their answers given in the first round. Based on the results of the Delphi survey, Open Science is

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considered as a key contributor in the advancement of transport research. From the side of the research community, the most important challenges that should be considered in order to adopt a policy closer to the principles of Open Science are the various legal and ethical restrictions as well as contractual restrictions from their partners. Among the barriers that research community should overcome to adopt an open data policy, there are the lack of resources, organizational issues and conflicts concerning data ownership/IPR. As far public authorities are concerned, open data are expected to improve their operations, foster data-based decisions and increase transparency, while for the private companies the reduction of the costs, the improvement of their customer services and the accessibility to more data are among the main benefits. However, conflicts regarding ownership/IPR, protection of commercial and personal data, and access to confidential data have been assessed as the most significant barriers.

1. Introduction

As digital technologies constantly develop and new working methods arise, many sectors have begun to collaborate more and reach out the data/information and knowledge with modernized methods. Scientific community is following this path and has tried, according to OECD, "to make the primary outputs of publicly funded research results – publications and the research data – publicly accessible in digital format with no or minimal restriction" [1]. This term has been commonly agreed as "Open Science". Open Science focuses on promoting the open access of data to the whole research cycle and creating an online collaborative environment that will bring a holistic shift on the existing scientific operations. Open Science affects both individual research and research organizations scientific work and consists of different elements, which can be data-oriented (i.e. open research data, open notebooks, open infrastructure) and process-oriented (open peer review, open access, open software).

The basis of Open Science is to support knowledge sharing which brings many benefits to users in terms of economic and societal aspects. The increased use of Open Science affects several different areas such as open data, open source software, open access, open infrastructure, open methodology, open education, open notebook, open peer review and citizen science [2]. Open Science could help companies become more competitive in market as well as to speed up the development of companies, research organizations and public authorities. Collaboration among different bodies could be achieved and offer sharing of knowledge and expenses enhancing their competitiveness and encouraging the development of interoperable tools. Improved services and more opportunities for innovation could be offered as well as significant increase in scientific products could be achieved. In addition, transparency in transport research data can improve the quality of life for citizens in urban areas enhancing also their health and safety.

However, Open Science in transport research domain is not followed by all research organizations to impose proper rules and procedures to their members for adopting Open Science in their research activities. On the other hand, individual researchers may support Open Science initiatives and actions or not. Based on the latest developments in information and communication technologies, Open Science has currently been adopted in many countries and institutions even though there are concerns and barriers that limit their implementation in practice [3]. Users need to be aware and take necessary actions to mitigate. Moreover, possible negative impacts are still considered by industry stakeholders, research community and public authorities. These involve lower level of security when handling data, poor or outdated documentation of open source software, lack of roadmaps to present the strategic goals of different bodies and lack of experienced staff in Open Science.

European Commission aims to setting up a community of transport research organizations willing to work on the basis of Open Science following a commonly agreed Code of Conduct [4] that will engage transport stakeholders (and especially researchers) with the fundamental principles of research integrity. In this context, BE OPEN [5] and OSCAR [6] projects have been funded by the Horizon 2020 Work Programme 2018-2020 and they both aim to exploit the European Open Science Cloud (EOSC) [7]. The EOSC initiative could provide services that enable sharing and re-use of research data and foster big data exchange among researchers, industry community and the general public. More specifically, new technologies, data sharing and the readiness of stakeholders promote a systematic change towards Open Science in transport research that should address societal impacts and responsible innovation.

In an attempt to identify the challenges, opportunities and barriers of Open Science in transport research, this study aims to integrate and measure the opinions of research community, public and private transport companies as well as public authorities utilizing a Delphi survey in

order to facilitate a quantitative understanding of stakeholders' personal opinions focused on statistical consensus. The survey was held in two rounds aiming to achieve more robust results. After the first round, a summary of the results was provided and the experts were asked to provide their final responses in order to determine the extent to which they agree with each other and in areas where they disagree for achieving a consensus opinion. A questionnaire of 30 questions was designed to allow experts developing their opinions and identifying potential effects about utilizing and operationalizing Open Science in transport research.

The remainder of the paper is organized as follows: Section 2 describes the Delphi survey used, analyzes the steps followed and presents the different parts of the questionnaire. Then, Delphi survey results are presented in Section 3 analyzing how different stakeholders perceive Open Science in transport research. It is an attempt to determine main challenges and opportunities as well as constraints and barriers of Open Science in transport research based on experts' opinions and experiences. Finally, in Section 4 conclusions are drawn and potential societal impacts of progressing towards a more open, FAIR (findable, accessible, interoperable, and reusable) and transparent scientific environment are provided.

2. Delphi Survey

The Delphi method is a structured communication technique, originally developed as a systematic, interactive forecasting method which relies on a panel of experts. The main purpose of the Delphi method is to acquire the most reliable consensus of a group of experts' opinions by a series of intensive questionnaires combined with controlled opinion feedback [8]. Unlike other planning and forecasting methods, Delphi's goal is not only to elicit a single answer or to arrive at a consensus, but most importantly to obtain as many high-quality responses and opinions as possible on a given issue from a panel of experts to enhance decision making [9]. A drawback in using the Delphi technique is the lack of a clear theoretical framework for using

this technique. However, among the most important requirements for the use of the Delphi method are the need for experts' judgment, group consensus to achieve the results, anonymity in data collection, a complex, multidimensional problem, experienced and capable experts, dispersion of experts [8].

The starting point for the application of the Delphi survey was to identify the "problem". The aim of the present study is to identify the challenges, opportunities and barriers of Open Science in transport research. One of the most important phases of Delphi method is the selection of the most appropriate experts for the Delphi panel, since the validity of the results depends greatly on the competence and knowledge of panel members. Concerning the composition and the size of the panel of the experts, there are several points of view recorded in the literature. However, it has been recommended that the panel size may vary according to the topics covered, the nature of different viewpoints included, and the time and money available [10]. It is also recommended to use a combination of individuals with multiple specialties and heterogeneous groups [8]. Thus, the experts were selected based on their expertise in transport research, transport data and their familiarity with Open Science. The aim was to develop a panel of experts representing all transport modes and various areas of the transport sector (e.g. research, public sector, NGOs, etc.).

A total of 30 experts were invited to participate, with 18 of them accepting the invitation. Briefly, the characteristics of the Delphi panel are the following:

- 13 out of the 18 experts are males;
- half of the participants are between 35-50 years old, 28% are between 51-65 years old and 22% are older than 65 years old;

- 5 out of the 18 experts have under 20 years professional experience, 8 experts have professional experience of 20-40 years, while 5 experts have more than 40 years experience in the transport field;

- Most of experts (15 out of 18 experts) come from a European country, 2 experts are from USA, 1 expert from Canada and 1 expert from Australia;

- The main expertise of the majority of the experts participating in the Delphi survey is related to road transport (72%), the next transport modes represented are air transport and multimodal transport (both 11%) and only 6% comes from rail transport;

- About 78% of the experts of the Delphi panel come from the educational/research sector, the organisation of the 11% of the experts belongs to the group of Associations, NGOs and Federations, while another 11% of the experts come from the public sector.

A questionnaire was then developed and distributed to the Delphi panel members. The first round of the Delphi survey was conducted through an on-line platform, in which each respondent was invited to fill in a questionnaire of 30 questions. After the data collection and analysis, a second round of the survey was conducted. In the second round of the survey, each participant received the questionnaire, alongside with the results based on the panel's responses from the first round of the survey. It is noted that some questions were modified by the facilitator based on the responses or the comments of the experts in the first stage of the survey. In this round, the experts were asked to either confirm or adjust their responses by considering the answers of the panel of the experts. During both stages of the Delphi survey, the anonymity of the experts was kept. Finally, the responses of the second round were analysed and the results of the Delphi survey on the challenges, opportunities and barriers of Open Science in transport research were obtained.

The questionnaire was designed in such a manner to capture existing differences not only between the research community and transport professional sector, but also between public and private sectors. The questionnaire was comprised by four sections:

i. General: asking personal information, as well as information related to the background of the expert.

ii. Familiarity with Open Science: the experts were asked about the use of open data and open infrastructure within their organisations, in order to assess how familiar are with Open Science.

iii. Research Community: the experts were asked to assess and opt for the main challenges, opportunities and barriers of Open Science in transport research. The questions were differentiated at the following aspects: a) transport researchers and transport institutions and b) openly sharing data and using open data.

iv. Public and Private Transport Companies: the experts were asked to assess and opt for the main challenges, opportunities and barriers for transport companies/ authorities to use or share open data and services. The questions were differentiated for public and private transport companies.

3. Results

3.1 Transport Research Community

The experts were asked to assess the importance of the following challenges for research institutions to share data or publications. The most important challenges (assessed as fairly important and very important) were legal restrictions, e.g. GDPR, privacy issues, IPR etc. (80%) as well as contractual restrictions from other partners (75%), followed by the lack of skilled personnel (70%) and the potential of commercial interest for research data (65%). It

should be noted, however, that data security issues (e.g. access, cyber-security) seem to divide experts' opinions in terms of importance of this challenge.
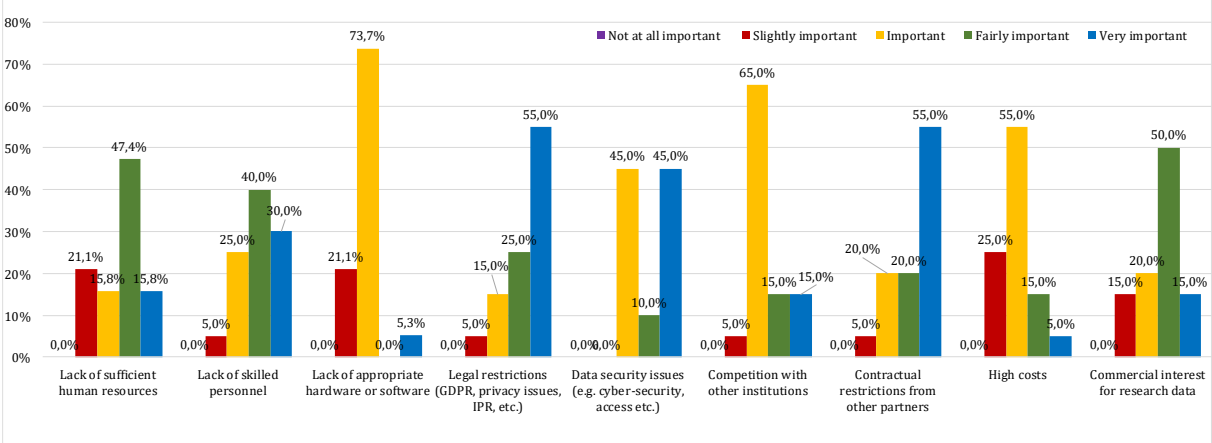

Figure 1. Assessment of importance of challenges for research institutions to share data or publications

The picture is also clear concerning the opportunities that may arise from Open Science for research institutions. The most important opportunity is considered the advance of science that could be achieved in the transport research through the Open Science (32%). Additionally, sharing data and publications is considered as a valid way to increase collaborations not only across institutional, national and disciplinary boundaries, but also between companies and research infrastructures (Figure 2a). However, two main barriers for research institutions in sharing open data were identified within this survey, i.e. data ownership issues/IPR (30%) and resources and organizational issues (25%) related to the transport research institutions (Figure 2b).
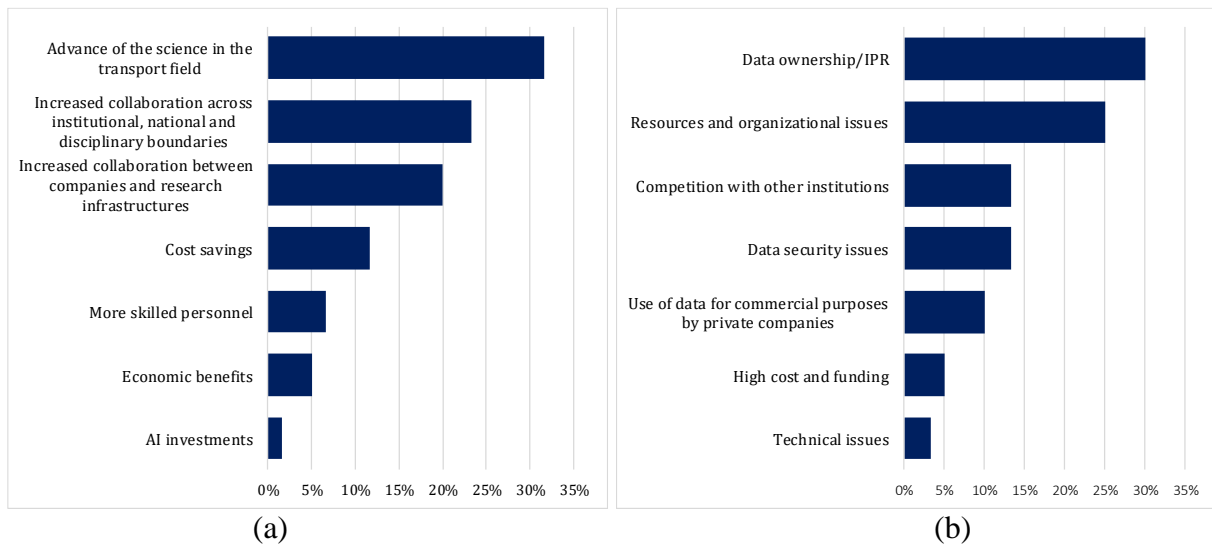
Figure 2. a) Opportunities of openly sharing data or publications for research institutions; b) Barriers of openly sharing data or publications for research institutions

As far as individual researchers are concerned, the benefits of openly sharing data and using available open data differ. The main incentives for researchers to openly share their data/ research results are the potential of gaining more co-operations/contacts (23%) and recognition in the research community (20%), as well as the opportunity of being co-author to other researchers' publications, who have used their data (20%). On the other hand, the main benefits from using available open data were considered the accessibility to more data (30%) and more cross-disciplinary co-operations (20%), while a significant part of the Delphi panel (about 17%) also believes that using open data will offer more new, original research results and products.
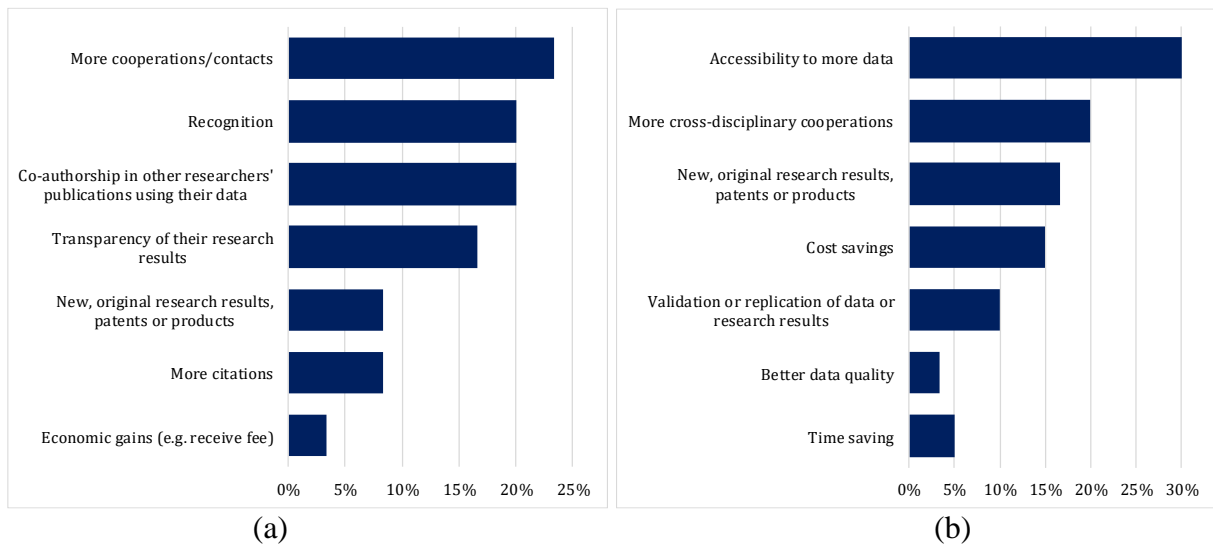
Figure 3. Benefits for individual researchers to a) share their research data and research results; b) use open research data

Regarding the barriers of openly sharing their data for individual researchers, the significant effort to produce a dataset and data protection and ethical restrictions were considered as the most significant (Figure 4a). On the other hand, the most relevant barriers preventing transport researchers from using available open data were reputed the insufficient documentation of the data (27%) as well as the not easy accessibility (23%) to such data (Figure 4b).
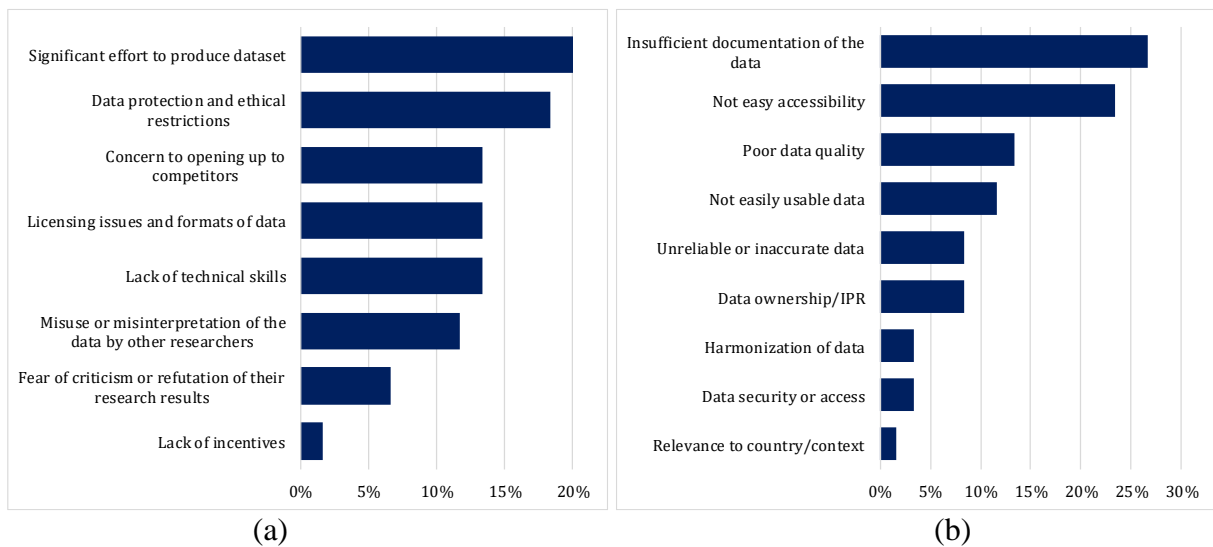

Figure 4. Barriers for individual researchers of a) sharing their research data and research results; b) using open research data

3.2 Public and Private Transport Companies and Authorities

As far as the transport companies and authorities are concerned, the most important challenges (assessed as fairly important and very important) identified were data protection, privacy and ethical issues and data ownership conflicts (94%), followed by complex socio-political interactions among authorities and transport stakeholders (89%), commercial competition (83%) and the different interests and perspectives on open data by transport stakeholders (83%). On the contrary, technical issues, data standards and formatting issues were assessed as less important than the aforementioned challenges (Figure 5).

The picture is somehow differentiated between public and private transport companies. Data ownership conflicts, data protection, privacy and ethical issues are the main challenges for both types of transport companies and authorities. However, the need for skilled personnel was highlighted as an additional challenge for public transport authorities, while the commercial competition and the different interests and perspectives on open data by transport stakeholders were also identified for the private transport companies.
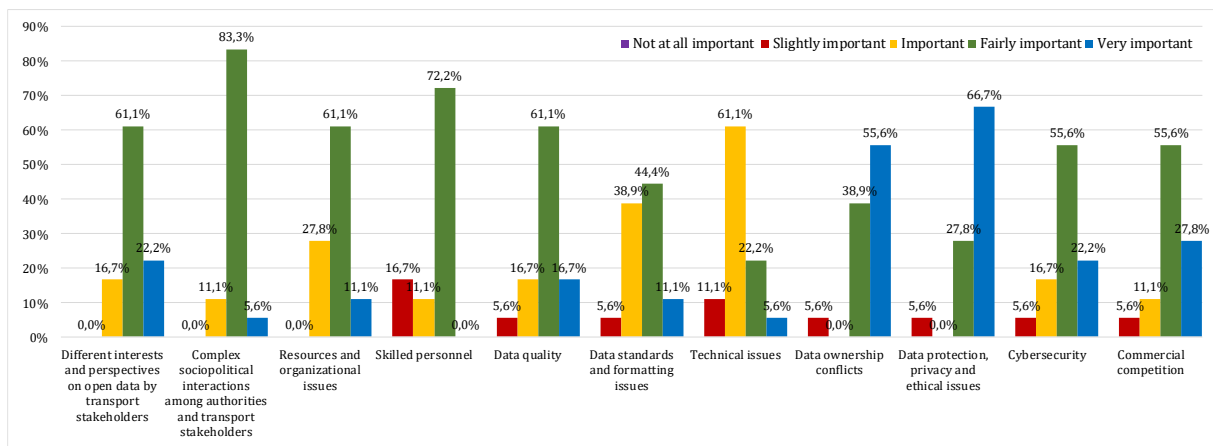

Figure 5. Assessment of importance of challenges for transport companies and authorities to share data or publications

Considering the main opportunities arising for public transport authorities from using open data services, the most relevant ones resulted to be the improvement of transport operations and

performance (26%) and fostering data based decisions (20,4%). The respective opportunities for the private transport companies were the reduction of the costs (26%), the improvement and alignment of customer needs (18,5%) and the accessibility to more data (18,5%).
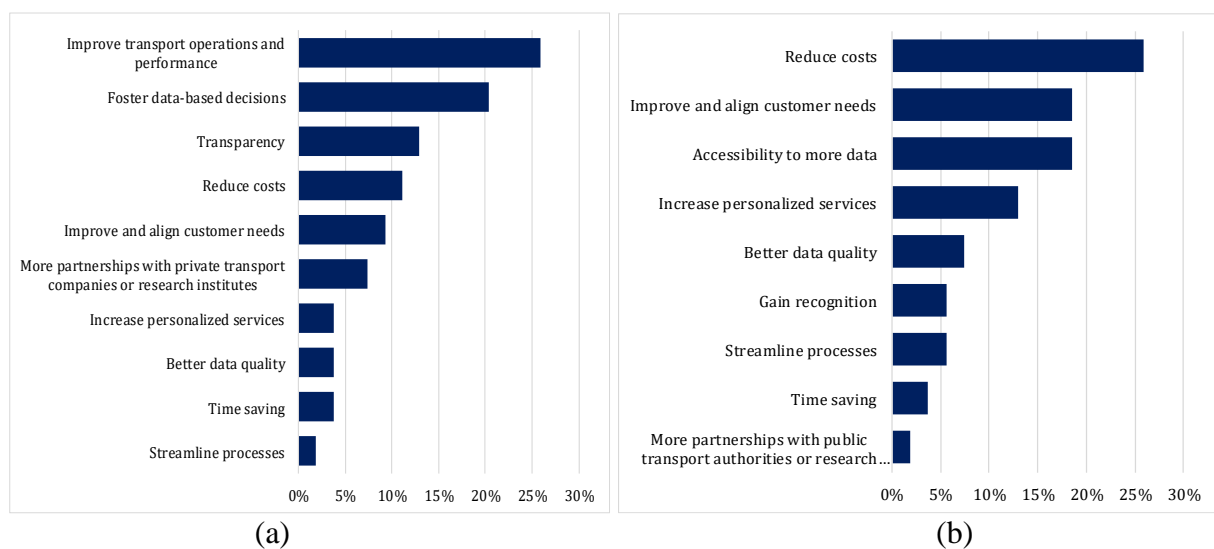

<center>(a)</center>

<center>(b)</center>

Figure 6. Opportunities of using open data services for a) public transport authorities; b) private transport companies

Regarding the barriers of sharing data for public transport authorities, the most significant barriers found from the Delphi survey were protection of commercial/confidential data (about 24%) and conflicts regarding ownership/IPR (22%), followed by the protection of personal data (17%). These three barriers were also considered as the least likely to be overcome, with the conflicts regarding data ownership and IPR being identified as the most crucial issue. It is also noted that the limited financial resources were also considered a not easy barrier to be overcome.

The same barriers in openly sharing data were identified for the private transport companies (i.e. conflicts regarding ownership/IPR (26%), protection of commercial/confidential data (26%) and protection of personal data (20%)), which were also considered as the least likely to be overcome.
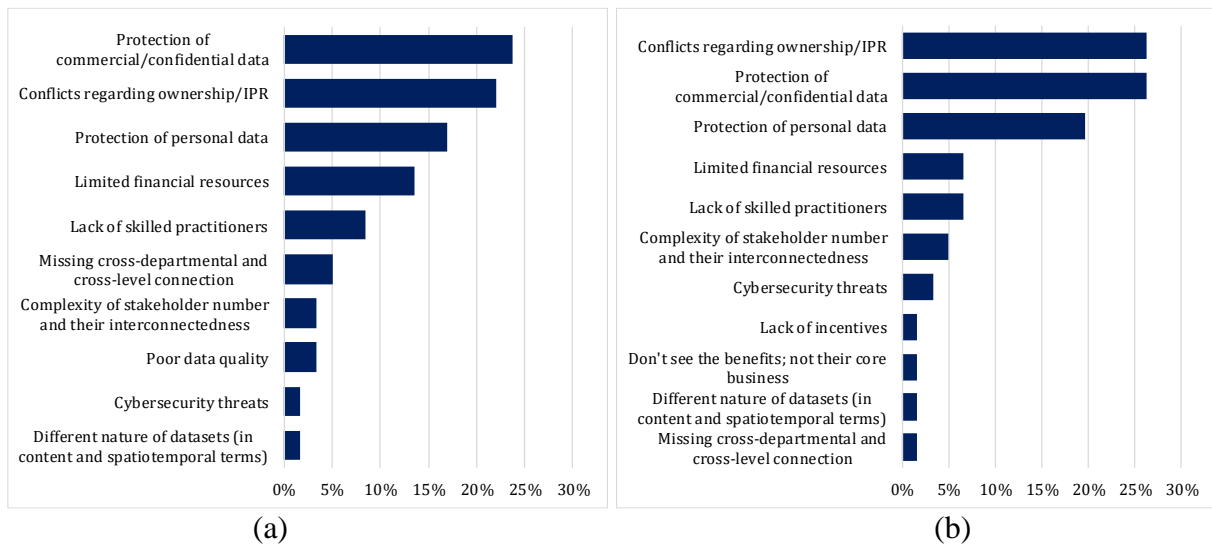
Figure 7. Barriers of sharing open data for a) public transport authorities; b) private transport companies

3.3 Discussion

Open Science is considered as a key contributor in the advancement of science, however, there is still a reluctance from the side of research institutions to adopt a policy closer to the principles of Open Science. The main challenges that they have to face are the various legal and ethical restrictions (e.g. GDPR, privacy issues, IPR, etc.) as well as contractual restrictions from their partners. The lack of skilled personnel was also highlighted as a significant challenge. More precisely the main technical skills that researchers do not dispose concern ensuring data security and privacy during the process of sharing their data, while lack of expertise in data management and computer programming were also identified by the Delphi panel. Concerning data management, issues regarding the quality of data to be opened up, as well as the complex nature of transport data and information are among the main issues arisen. Especially the last constrain is associated with the large number of stakeholders involved in the transport research, the various existing data providers and the segmentation of data ownership [11]. Within this context, it is also evident that transport researchers do not receive sufficient training in data

sharing and Open Science implementation, which requires both organisational changes within the institutions and securing the necessary financial resources as well.

Openness in transport research is expected to lead to the advance of the science in the transport field, while further co-operations with other institutions from other countries or disciplines as well as with transport companies were found among the main benefits for research institutions. Similar are the benefits of opening up for individual researchers, who could gain more co-operations and contacts as well as recognition at a wider scale within their research field. Additionally, their research could be benefited, since they will be able to access more data, by reducing the costs of collecting data and generating from scratch new datasets, which could lead faster and more easily to new, original research results and patents.

However, scientific researchers' rights and ideas should be protected, especially against commercial interests. On that purpose, a balance is needed between creating incentives for individuals or groups to exploit new scientific knowledge for financial gain and societal benefits through the products and services that are developed and the macroeconomic benefits that accrue when knowledge is broadly available and can be exploited creatively in a wide variety of ways. In this context, three different levels of data ownership and openness exist with distinct funding mechanisms, i.e. data ownership and the exercise of Intellectual Property rights, public-private partnerships and opening up commercial information in the public interest [12].

A significant barrier arisen for both research institutions and transport authorities/ companies concerns data protection and privacy. Transport research data may contain sensitive personal information, thus, special attention should be put into the protection of privacy at personal data processing, both from a legal and a technical perspective. Additionally, sharing confidential, sensitive or proprietary data poses clear challenges for protection against incidents or deliberate attacks, and requires a special effort on building architectures and develop methods and

techniques that ensure security of scientific information systems [12]. It should be stressed, however, that technology can offer some solutions to these concerns.

Open transport data, especially in the public transport sector, have been a success story for several countries, which have exploited such datasets and have created applications or other tools targeting to more efficient operation of their companies and better customer services. However, this is not always the case for the private transport sector, e.g. transport service providers, technology companies, etc., which are more reluctant to share openly or/and freely the data they create and store. Only a few major international data companies have started to differentiate their data policy over the last few years [13].

Besides the aforementioned legal and ethical issues, the lack of skilled personnel was identified for the public transport authorities, while the commercial competition was identified for the private transport companies, most of which are less eager to make their data openly available, especially when operating in highly competitive markets. Besides, there are some significant costs of producing and disseminating data for operators and these costs should be distributed under a fair context, while opening all data could cause strategic and commercial competitive disadvantages in some cases [14].

On the other side, various opportunities may arise within a complex framework. Various transport authorities in both public and private sector dispose a wealth of transport data, which develop a new framework for further co-operations and the development of various applications that can be used by the public [15, 16]. Consequently, open data are expected to improve the transport operations and performance of the public transport authorities, foster data-based decisions and increase transparency, while for the private companies the reduction of the costs, the improvement of customer services and the accessibility to more data are among the main benefits of using open data services.

4. Conclusions

The transition of transport research towards Open Science could generate new and alternatives ways for researchers to conduct and disseminate their work offering several opportunities and benefits as presented by the Delphi survey. This transition has also an impact on the interaction of the research community and the society increasing the quality of consultation processes, fostering transparency and progressing quality assessment of scientific results. In addition, industry stakeholders should promote a new culture of sharing and developing new infrastructures for dissemination in an attempt to change the current procedures and exploit potential opportunities identified by Delphi survey. The critical action is to provide adequate legal frameworks adopting EU regulations and/or modifying existing national legislations to ensure lawful use of open data, open software, etc. Last, public authorities realize that citizens are ready to participate in research that support innovation and promote integrity. Digital technologies have enabled their participation and collaboration with the rest of the transport research stakeholders.

The use of EOSC could support stakeholders in addressing the evolution of Openness in a cost-effective way and strengthen the trust in science. As such, TOPOS OBSERVATORY & FORUM [17] of the BE OPEN project could provide valuable services to transport research stakeholders and citizens. They could increase awareness of and trust in scientific research in society that result also in more effective decision making utilizing scientific tools and approaches. Strategic planning of transport research could be also improved engaging all relevant stakeholders (i.e., research community, industry and public authorities) and increase in the return on public investment in science could be achieved. Finally, scientific community could achieve improved impact dealing with societal challenges (such as COVID-19 pandemic, climate emergency) as TOPOS could support international collaboration and provide services

that allow stakeholders to work together and exchange knowledge, data, publications, software and other relevant information about transport research.

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