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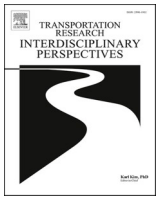

Implications of COVID-19 pandemic on the governance of passenger mobility innovations in Europe

Anastasia Tsvetkova [a,*], Ignat Kulkov [a,b], Caroline Busquet [c], Ping-Jen Kao [d], Maria Kamargianni [e]

[a] Laboratory of Industrial Management, Faculty of Science and Engineering, Åbo Akademi University, Henrikinkatu 2, 20500 Turku, Finland
[b] Cambridge Judge Business School, University of Cambridge, Cambridge, UK
[c] Absiskey Mérignac, Mérignac, France
[d] University of Sussex Business School, University of Sussex, Brighton, UK
[e] MaaSLab, Energy Institute, University College London, London, UK

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ABSTRACT

As the passenger transportation sector is disrupted by the emergence of myriad technological and business model innovations such as automated mobility, shared mobility and Mobility-as-a-Service, new and improved governance models are required. The COVID-19 pandemic can be seen as yet another disruption, stressing the need for a more proactive and inclusive governance. This article aims to juxtapose the need for collaborative, adaptive and outcome-based governance models in the mobility sector before and after the pandemic started. First, we analyse the governance needs and trends related to mobility innovations that were identified during two workshops with public and private actors in the mobility sector and through an extensive research of new governance models already applied in many European countries. Second, we analyse the impact of COVID-19 on mobility governance, focusing specifically on mobility innovations. Based on the analysis, we draw conclusions regarding the long-term trends in how the governance of mobility innovations will be affected by the ongoing pandemic.

Introduction

The ongoing COVID-19 pandemic and corresponding mobility restrictions have affected approximately 90% of the world's population, leading to the reduced mobility service provisions and increased operating challenges (Li et al., 2021; Gössling et al., 2020). It has added an additional 'unknown' into the already challenging mix of what the governance of disruptive mobility innovations needs to address and prioritise. On the one hand, rapid implementation of new mobility technologies, processes or systems proved necessary to address the challenges of the pandemic. This was the case in employing automated mobility solutions for delivery to decrease human contact or to support switching to active transport such as e-scooters or shared bikes to ensure social distancing (Hörcher et al., 2021; Hartleb et al., 2021). On the other hand, the COVID-19 pandemic has slowed down the adoption of certain passenger mobility innovations. Although Mobility-as-a-Service (MaaS) solutions make intermodal journeys more integrated and seamless (Kamargianni et al., 2016), in the face of the pandemic, they were not capable to address the changing patterns of passenger transport choices.

Even before the onset of the pandemic, European regulators and policymakers have been overwhelmed by challenges, acknowledging that existing regulatory frameworks and governance are insufficient to swiftly implement new mobility technologies, processes or systems. While innovations in mobility sector are sought for, the multitude of new mobility solutions might accentuate global challenges rather than solve them if not managed correctly (Docherty et al., 2018; Hollands, 2015; Lyons, 2018). Governance, in this case, is critical because innovations themselves are shaped by context-specific governance and institutional arrangements (Curtis et al., 2019; Moscholidou & Pangbourne, 2019).

The unprecedented challenges in governing the transport sector during the pandemic have called for new and adjusted governance processes and instruments, which will likely have implications for how the fast-changing mobility sector is governed in general. While an adaptive and resilient governance structure is considered important for

* Corresponding author.
E-mail address: anastasia.tsvetkova@abo.fi (A. Tsvetkova).

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ensuring that new, disruptive mobility solutions help solve transportation challenges and contribute to public value (Beria and Lunkar, 2021), the need to balance health, economic, social and environmental goals accentuated by the pandemic is likely to require similar governance principles. It is valuable to study how the disruption to passenger transportation brought by COVID-19 has affected the governance of passenger mobility, as its implications can be relevant for governing innovative mobility solutions. In this study, we are interested in governance responses at different jurisdiction levels: while governance related to day-to-day local mobility transportation evolution (e.g., urban planning) happens at the local level, long-term policy trends are handled at the national or international level (Irawan et al., 2021).

Our article presents the results of research focusing on the governance of disruptive mobility innovations before and after the pandemic started. The first part of this study concerns the challenges, barriers and risks that the new regulatory framework must address to deploy disruptive mobility innovations. It relies on the analysis of a database of regulations collected through desktop research and stakeholder interviews. Also, two workshops were held to collect different perspectives (public sector, private sector, and other experts such as research organizations) regarding the different governance models and principles that should be employed. In the second part of the study, a new consultation was launched to assess the impact of COVID-19 on the governance of mobility innovations and the transport sector in general. This was combined with a desktop research of different governance responses to the pandemic that were relevant for the governance of passenger mobility innovations. The geographical context of this study is Europe as this work is part of an EU-funded H2020 project, and we focus on urban passenger mobility.

Literature review

Governance of disruptive mobility innovations

Innovative technologies, digitally enabled business model innovations and a shared economy have changed value creation in the passenger mobility sector. These changes are powerful drivers in transitioning from vehicle ownership to usership, the commoditisation of private journeys, the shift from modal-centric to user-centric mobility, and changing the role of citizens in new transport systems (Docherty et al., 2018). 'Smart mobility' and 'sustainable mobility,' which rely on these shifts, generally envision individuals as being able to access a seamless system of clean, green, efficient and flexible transport to meet their needs (Lyons, 2018; Moscholidou and Pangbourne, 2019).

This paper discusses disruptive mobility innovations as they are integral to smart and sustainable mobility as well as to a future resilient transportation system needed in the post-pandemic world. Following Sprei's (2018) definition, disruptive innovations include those that can create a major change and interrupt the normal course of a system; in passenger transportation, they shift away from mobility mainly based on privately owned vehicles. Thus, we have focused on the following innovations in our study: cooperative, connected and automated mobility (CCAM), shared and on-demand mobility solutions such as ride-sharing, ride-hailing and shared micromobility solutions, and MaaS.

Disruptive mobility is associated with the application of new technologies that can change the rules of the game for the future transportation industry (Pangbourne et al., 2020). The innovations listed earlier can potentially change the attitude towards personal vehicle use because they stress the convenience of an individual journey and aim to increase the utilisation rate of transportation infrastructure. Existing trends in optimising personal car use and social changes associated with sharing consumption offer opportunities for a smooth transition in the transport industry (Kemp et al., 2012). However, whether disruptive technologies can bring about this transition to more sustainable applications is debatable (Hollands, 2015; Lyons, 2018), as whether the dominance of internal combustion engines will be undermined. Moreover, transitioning to a new mobility system may also lead to an increase in movements, which calls into question an important goal of sustainable consumption (Bardhi and Eckhardt, 2012). The many individual mobility innovations entering the mobility mix could potentially accelerate existing challenges such as congestion, inequity and environmental deterioration, which pose a need for governance intervention (see, for example, Pangbourne et al. (2020) regarding the impact of Maas and Hensher (2018) regarding the potential adverse effects of autonomous vehicles). Moreover, technological and business model innovations alone will not be enough to create a new sustainable and resilient transportation system; the successful transition needs to be supported by adequate governance (Sprei, 2018).

In this research, we adhere to the definition provided by the Organisation for Economic Co-operation and Development (OECD), where governance is "the exercise of political, economic and administrative authority necessary to manage a nation's affairs" (OECD, 2006). In the passenger mobility context, it can be seen as the process by which public institutions make and implement decisions related to transportation, conduct public affairs and manage relevant public resources. While we acknowledge the crucial role of different stakeholders, such as citizens or transportation service providers in the process of governance, in this paper, we adopt the perspective of regulators and policymakers and focus on the challenges in governing the fast-changing mobility sector. The involvement of and cooperation with these actors, however, is a natural part of 'good governance' (OECD, 2006).

When a disruptive mobility innovation enters the market, there are various social, economic and political factors that should be considered to ensure that its proliferation is beneficial to a local or global mobility system and does not risk public safety, security and well-being. Thus, the role of governance is twofold. First, there is a need to assess the potential of a new mobility solution to solve transportation problems and create benefits for society and identify what support is required to implement the solution successfully. Second, it is crucial to identify potential negative externalities of a new mobility solution and mitigate them through various governance instruments.

According to Davis (2018) and Docherty et al. (2018), the governance of disruptive mobility innovations can be orchestrated through long-term thinking with the goal of increasing social value. An incomplete set of governance measures or partial implementation in areas such as production, emission management, and sustainable consumption poses threats to the transition and successful application of disruptive mobility solutions in practice. Therefore, it is recommended that policymakers carefully select disruptive mobility solutions for implementation and develop governing rules and policies that, together, can intelligently focus on and create conditions to painlessly achieve goals (Davis, 2018). Other challenges stem from the fact that the governance of disruptive mobility innovations should address the long-term impacts of new mobility services and technologies, although they are difficult to foresee, especially when many innovations enter the market at once (Docherty et al., 2018).

According to Pankratz et al. (2019) and Eggers et al. (2018), five principles for governing emerging technologies in the mobility sector can help address at least some of the challenges described above. The ***adaptive approach*** to regulation is based on a flexible approach in terms of testing, getting quick feedback and dealing with mistakes. With rapid feedback, decision makers quickly assess innovations against standards and offer recommendations for changing standard rules. ***Regulatory sandboxes*** imply setting a specific area that allows testing an innovation, product or service without following the standard rules inherent in the industry. Regulators, together with entrepreneurs, are experimenting in an environment that encourages the formation and development of innovation. In ***outcome-based regulation***, stakeholders define how to achieve policy goals following performance indicators without constraints in the process. ***Risk-based regulation*** implies that regulatory frameworks activities and resources are allocated on evidence-based assessment risks. They are used to fulfil environmental objectives, as

well as ensuring food safety, securing financial markets and occupational health and safety, improving legal services (Black and Baldwin, 2012). Finally, ***collaborative*** (or ecosystem) regulation implies collaboration across domains and the coordination of regulation not only at the national, but also at the international levels, using the resources of an extended circle of participants. Several regulators work with businesses to shape rules and encourage innovation to protect members and users from fraud.

The emergence of disruptive mobility innovations is characterised by a mixture of business and technological solutions that are difficult to govern and require different approaches depending on the context. The lack of research on governing disruptive mobility is widely noted (Bruun, 2018; Kamargianni and Matyas, 2017; Sochor et al., 2015). Moreover, the results of some studies on mobility governance are relevant to a specific innovation and may hardly be extended to the governance of the multitude of emerging disruptive mobility innovations (Audouin and Finger, 2018). The lack of an overarching view limits objective evaluation on the impact of innovation on public value. In the face of the ongoing pandemic, which challenges the concept of mobility at its roots, navigating the multitude of potentially disruptive mobility innovations becomes overwhelming for policymakers and governors.

Impact of COVID-19 on passenger mobility and governance responses

Governments have responded to COVID-19 by implementing different restrictive measures to curb its spread, including curfews, school and workplace closures, restrictions on public transport, and stay-at-home policies, which might potentially cause a recession and financial instability (Eichenbaum et al., 2020). Indeed, millions of people have lost their jobs during this period and have waited for stimulus packages to help with their urgent circumstances (Kanda and Kivimaa, 2020; Coibion et al., 2020).

The relationship between COVID-19 and passenger transportation has been addressed in several studies, sometimes leading to rather controversial conclusions (see, for example, Sharif and Khavarian-Garmsir, 2020). On one hand, it is thought that transport infrastructure significantly contributes to the spread of infection (Connolly et al, 2021; Cartenì et al., 2020). A direct relationship was noted between the number of trips and the detection of new infections after a three-week period. Such studies have confirmed the correctness of the introduced quarantine measures to reduce the spread of the disease. However, not all researchers agree that mobility restrictions are effective enough. For example, restricting intracity and long-distance movement may have different consequences depending on the stage of spread of COVID-19 and compliance with other recommendations aimed at reducing the spread of the disease (Tian et al., 2020; An et al., 2021). Moreover, air and rail transport contribute more significantly to the spread of COVID-19 than other modes of transport.

In urban (intracity) mobility, some studies address the pandemic's impact on the transport mode shifts, including to innovative transport solutions. New mobility services, such as shared e-scooters or bicycles, have increased the number of users and the duration of travel (Teixeira and Lopes, 2020; Bucsky, 2020). Moreover, some users of the public transport infrastructure abandoned traditional public transport in favour of other types of mobility. It can be assumed that these types of mobility, primarily individualised, are more resistant to unforeseen circumstances and emergencies. However, the downside is the growing distrust of public transport, the desire to isolate from other passengers, which leads to an increase in demand for personal cars and undermines long-term strategies for the transition from owning to using a personal car (Otary et al., 2021; Procopiuck et al., 2020).

Sustainable urban planning is a response to the pandemic and to the need for changes in urban and transport infrastructure (Glaser and Krizek, 2021). The decrease in business and personal travel has reduced the strain on city streets and offered a new opportunity for change by city officials. New infrastructure design aims to account for distance, greater use of non-motorised vehicles, and pedestrian needs (Teixeira and Lopes, 2020). However, one should not draw premature conclusions about the role of the updated – often temporarily – transport infrastructure in changing the habits of transport users or overcoming the economic crisis nowadays and earlier (Glaser and Krizek, 2021; Piatkowski et al., 2015). COVID-19 has served as a reminder and a test platform for making better use of urban transport infrastructure for change for the benefit of residents. Such experiments have previously demonstrated their effectiveness and are good practice for adapting and applying new opportunities (Sengers et al., 2019) and can provide a basis for testing, tracking and generating new ideas for innovation that can be replicated if successful.

The economic and social consequences of changes brought by the pandemic affect strategies for the development of society since the usual interactions between participants require changes, including drastic ones (Beria and Lunkar, 2021; Mofijur et al., 2020). Some studies attempt to shed light on how governance and transport policy should be reconfigured following the pandemic. For example, Budd and Ison (2020) recognise the importance of individual behaviour and collective responsibility in protecting personal and public health; they propose the concept of 'responsible transport', where the environmental considerations related to transportation are combined with those of individual and community health and wellbeing. Much attention has been paid to transport governance in creating safe travel systems (Budd and Ison, 2020), and connections between the post-COVID-19 recovery and sustainable mobility transition have been noted. Therefore, our study explores the long-term impact of the pandemic on the governance of mobility innovations because we feel it is valuable to combine the learning from how the pandemic responses have affected transport governance and mobility with insights from the governance challenges related to disruptive mobility innovations. Thus, we go beyond analysing governance responses to the pandemic, i.e. the reactive measures, to studying the indications of the change in how mobility can be governed in a more adaptive, proactive manner. The design of our study, drawing from the research of governance models required for benefitting from mobility innovations that started before the pandemic, allows us to achieve these research goals.

Methodology

Research setting

The results presented here are based on an EU-funded research project aimed at developing governance frameworks for disruptive mobility innovations that would allow for a proactive rather than a reactive approach and for steering mobility innovations towards solving current and future mobility challenges. The project started in 2018 and ended in 2021. The insights presented in this paper come from evidence-based research of disruptive mobility innovations and the main trends they are built upon, as well as the extensive review of governance models and approaches that have been or could be implemented for governing them. The data for this paper were thus collected through desktop research, interviews and stakeholder consultations, including two stakeholder workshops before and during the COVID-19 as well as a survey. The data collection can be split into two distinct phases: before and after the start of the COVID-19 pandemic and its spread in Europe (see sections 3.2 and 3.3 for more details). The summary of data collection and analysis process is presented in section 3.4.

The engagement of stakeholders and respondents in the corresponding research project has been structured and systematic. The key tasks of stakeholder engagement process included, among others, getting feedback and consultations from business representatives through organizing necessary seminars and workshops, as well as interacting with the stakeholders through social media. The aim of intensive stakeholder engagement process was to ensure that the vision, views,

challenges, constraints, expectations and ideas of stakeholders are understood and can inform not only future regulations but – more importantly – the foundational principles of future regulation making processes.

The selection of interested stakeholders was carried out in the following ways: (1) targeted appeals to industry experts from a wide network of project participants; (2) direct requests from industry representatives interested in participating in the project; (3) a targeted social media campaign on LinkedIn and Twitter to raise awareness and invite participation; (4) desktop research aimed at individual selection in the presence of gaps. As a result of these activities, a database was formed including the names and expertise of stakeholders. The stakeholder database, which was collected during two years, included 187 stakeholders and was intentionally balanced by the widest array of transport modes, sectors (research, NGOs, industry, Start-ups, Regulators, local/National Authorities, lenders and funders), gender, member states, governance level (local to international) and expertise in different types of mobility innovations. From the entire database, groups of stakeholders were invited to participate in an expanded consultation process in the form of surveys, interviews, online focus groups and thematic stakeholder dialogue workshops. Surveys were normally sent to all stakeholders. When choosing workshop participants, same principles were followed to ensure gender, sector (public and private sector), and regional (Western and Eastern Europe and additionally key innovating countries in transport from the USA, China, and Singapore) balance. Online workshops were held twice on the same day so that participants from different time zones could participate.

For secondary sources of information, we relied less on academic articles on the COVID-19 pandemic, but rather searched for latest governance responses described in the media. The project was planned prior to and implemented during the pandemic, meaning there were limited sources that would aggregate the different responses to the pandemic. As part of data search, we screened latest news shared by project stakeholders in the closed LinkedIn group. In our source selection process we relied on the following criteria: the material should concern mobility innovations and governance responses to the COVID-19 pandemic. It is also worth noting that we did not look for data on the impact of the pandemic on the transport industry as a whole, but concentrated on studies in the field of governance and disruptive technologies. The Platform for Redesign 2020 portal has also become an important source of additional information, see section 3.2 for details.

Phase 1. Before the pandemic: Review of governance models and recommendations on a regulatory process for disruptive mobility innovations

In the first phase of the research, a database was created to collect regulations and governance measures related to disruptive mobility innovations, including MaaS, CCAM and shared mobility solutions. The objective was to analyse the different policy instruments and governance models used and identify the policy trends to define a new regulatory framework with characteristics of the proactive approach rather than the reactive approach, i.e., a global governance approach covering all transport modes instead of the current fragmented one. Data on the current governance of mobility innovations were collected through stakeholder consultations and interviews that include both public and private actors in the mobility sector, extensive desktop research and analysis of existing regulations and governance tools. Workshop 1 was organised in October 2019 to elicit knowledge of how disruptive mobility innovations are currently governed and how they need to be governed, the socio-economic and political factors to consider as well as the success criteria to establish cooperation models. A pre-workshop survey was sent to a wider group of stakeholders and concerned the same topics. There were 24 participants from the private (41%), public (25%), non-governmental organization (NGO) (21,5%), and research (12,5%) sides. During the two-day face-to-face workshop, the participants were split in groups based on the sector they represent or mixed groups were formed, depending on the question discussed. Four content sessions were organized during Workshop 1, which covered the following topics: (1) cooperation models between public and private parties, (2) cities' experience with new mobility, (3) how to regulate new mobility and how much, and (4) which variables play a role in the successful introduction of new mobility services.

Relevant findings from this phase of research are presented further in section 4.1.

Phase 2. During the pandemic: Governance responses to COVID-19 and the impact on the governance of disruptive mobility innovations

The impact of COVID-19 was studied by reviewing the most recent governance measures applied in the mobility sector and studying opinions and communications on the impact of this and other pandemics on future governance. First of all, consortium members searched for European news that appeared in the online and offline press, policy briefs, scientific articles devoted to governance responses to COVID-19 in passenger transportation, and any other relevant materials. We focused on such responses as changes in legislation, programmes to support public and private players in the passenger transportation sector, changes to transport infrastructure, implementation of new work standards, and increased focus on clean transportation, etc. Information about European policies related to green recovery and sustainable mobility was obtained primarily from the Platform for Redesign 2020 (2020). Additionally, we launched a stakeholder consultation through a survey regarding the impact of COVID-19 on the governance of mobility innovations in the short and long term and collected 24 answers regarding this impact and concrete governance responses that have affected the implementation of mobility innovations.

Workshop 2 was held online in May 2020 and included 41 participants (41% private, 20% public, 39% NGO and research). During the online workshop, we gathered data related to the influence of COVID-19 on various mobility innovations and to the needs for mobility innovation governance in general, without accounting for the pandemic. Similarly to Workshop 1, participants were split in groups depending on the topic discussed. For example, the first session focused on reviewing known governance models for mobility innovations, and participants were asked to validate the models and propose which factors need to be considered to create a suitable regulatory framework. Separate groups were formed to discuss different innovations, including shared mobility, MaaS, and connected and automated vehicles. Another relevant session focused on the future mobility scenarios and new regulatory responses, and the responses to COVID-19 pandemic to date were discussed.

Summary of data collection and analysis process

Data collection and analysis took place in two phases as described above. The timeline for the collection of primary and secondary data is visualised in Fig. 1.

Below we summarise how we analysed data during the two phases of this study (see.

Table 1).

Research conducted before the pandemic allowed us to understand the major shortcomings of current governance frameworks applied to mobility innovations and to define the requirements for good governance. Particularly, the data collected during Workshop 1 and Workshop 2 helped us identify the main categories related to how governance needs to change in order to accommodate mobility innovations and ensure that society benefits from them. The data were analysed using content analysis employing inductive category analysis (Mayring, 2004), which means that researchers grouped the findings into several topics that emerged from the data. Further, the analysis of more than 200 regulations and other governance tools, interviews with stakeholders and other discussions during the workshops allowed us to

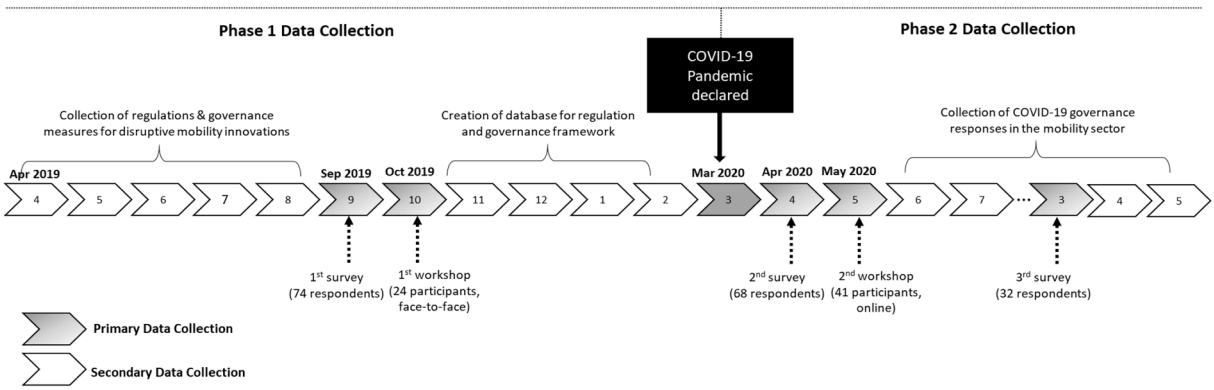

Fig. 1. Timeline for data collection (before and during the COVID-19 pandemic).

Table 1
Summary of data collection and analysis employed in the study.

Phase	Primary data: Stakeholders' interviews and workshops	Secondary data: Desktop research	Analysis focus
1. Before the pandemic	- Interviews with stakeholders (4) - Workshop 1 (24 participants): - How and how much to regulate? - Which socio-economic and political factors to consider?	Collection of regulations and governance models used for governing mobility innovations (focusing on Europe; 228 regulations and governance tools)	- Analysis of governance models used for governing mobility innovations and defining policy trends - Principles for good governance of mobility innovations
2. During the pandemic	- Workshop 2 (41 participants): Perspectives and insights on how governance can aid in creating benefits for society through mobility innovations - Survey on the impact of responses to COVID-19 on the future governance of mobility innovations (24 responses)	Desktop research of governance responses to COVID-19 related to mobility innovationsSynergies with other EU projects related to mobility	- Principles for good governance of mobility innovations - Analysis of governance models that were broadly employed during the pandemic using the analytical framework and theoretical categories generated during phase 1

understand which existing governance models and tools can help achieve the envisioned governance model and which new models could be employed. In section 4.1, we present the findings from this part of the study.

In the second phase of the study, we interpreted the results from the survey regarding the impact of responses to COVID-19 on the governance of mobility innovations by theoretically informed reading, which involved "reflecting theoretically on specific topics of interest and writing interpretations, without following any systematic method" (Weck and Ivanova, 2013). In such theoretically informed reading, we focused specifically on explaining how governance responses to COVID-19, identified in the desktop study and in survey responses, can impact the governance of disruptive mobility innovations in the future given the requirements for governance that we identified in the first phase of the study. The findings from this part of the study are presented in section 4.2.

Findings

The need for changes in governing mobility innovations – pre-pandemic

In this section, we present how governance of the transport sector should be changed in order to benefit from the myriad mobility innovations while focusing on building sustainable transport systems. We devise these findings by confronting the analysis of the current state of how these innovations are governed, which stems from the regulations and governance tools analysis, with discussions of how governance needs to be changed during the two workshops and interviews.

During Workshop 1, the expectations from the governance of mobility innovations have been discussed with the stakeholders on a general level. During Workshop 2, separate discussions were held to examine the key changes in governance required for ensuring that CCAM, MaaS and other shared solutions (such as e-scooter and bike sharing, carpooling and car sharing) are successfully implemented and contribute to creating public value. Some topics that emerged from these discussions, such as the need for more collaborative, adaptive and outcome-based governance, are in line with the principles to tackle emerging technologies outlined by Pankratz et al. (2019) and are presented in section 2.1. Other topics, including the need to harmonise governance at different levels and across sectors, were induced from these data. In Table 2, we present some key excerpts from the discussions that represent which issues were raised during the workshops. Further, we discuss the topics that emerged more generally and provide examples of how the requirements for the governance of mobility innovations have manifested themselves in the governance tools already applied or how they could be put into practice.

The need for more ***collaborative governance*** models has been brought up when discussing all types of mobility innovations mentioned earlier. It is deemed especially important for defining data policies that would clarify how data can be shared between public and private parties in order to benefit from mobility innovations. More clarity and dialogue are also expected to help mobility service providers direct their offerings towards helping municipalities meet their goals for sustainable transport.

Additionally, at the international level, private and public stakeholders can be gathered to define interoperable, technical, legal, environmental, ethical and safety standards at the EU level to ensure regulation acceptance from private stakeholders while addressing policy challenges. In the database, the Declaration of Amsterdam (2016) (related to CCAM) is a good example of collaborative governance. The recent initiative brought by several Hyperloop start-ups aimed at creating a harmonised regulatory framework for this disruptive mode of transportation, in collaboration with the European Committee for Standardization (CEN) and the European Committee for

Table 2
Topics related to the governance of mobility innovations that emerged during the workshops.

Topic	CCAM	MaaS	Shared solutions
Collaborative governance	- Strong partnerships between public and private parties are necessary - Cities must talk to companies to incentivise sustainable modes of transport - The dialogue between the private and public sectors is region-specific, but there should be some standard for this collaboration	- Cooperation between public authorities and mobility service providers is important - Data policies need to be established together since MaaS will collect data from citizens and provide them to administrations	- The private sector would like more transparent guidelines, communication and data sharing from the public side in terms of expected mobility systems - Clear guidelines on data sharing are needed, too - Public authorities must make sure collaboration is profitable and sustainable and can cover disadvantaged areas where the service is difficult to provide
Adaptive governance		- Regulatory approach is required to customise mobility packages and services relying on data analysis - - A B2G platform for exchanging data should be established to facilitate decision-making	
Outcome-based governance	- Authorities need to define a protocol to make sure that the mobility service is profitable and of good quality - Governing bodies should look at a wider picture rather just focus on subsidies – consider the societal context and create a marked-based condition for the services to flourish rather than focusing only on a single mobility service - Important to focus on the service quality – is it a good and feasible service?	- Need to "charge" the environmental impact - B2G partnership agreement (quality contract) - Local differences should be accounted for at the local level; while some general frameworks should be set, it should be left to local authorities to implement solutions that address their local problems	- Since many interconnected solutions and business models are introduced, there needs to be a discussion on how to create and share value in light of the shared economy - Why would municipalities provide spaces for business that make money? The private sector needs to prove the benefit for the municipality, e.g. by promising a certain reduction in traffic due to the use of shared cars. Such proof is also required to justify decisions to the public on using public space - A clear direction for mobility services and scenarios for the future are sought after. Policy-makers/governors must champion future mobility vision
Regulatory sandboxes		- Need to 'test' services' performances for a limited time	
Harmonised governance		- Top-down approach (not distributed responsibility) - Strong integration between regulatory frameworks is required to foster the ease of operability	- Mobility market and regulatory environment is fragmented. Different standards, regulations in different countries make it difficult for mobility solution providers to scale up
Citizens' education	- Education of people regarding alternative modes - Incentivising people to move towards more sustainable modes	- Communication with end-users showing how their choices are impacting the environment is also important as this can nudge them to adopt modes which may have better impacts on the environment but are perceived as less comfortable	

Electrotechnical Standardization (CENELEC) (Happich, 2020). Also, we could mention the Joint Undertaking (2016) put in place within the SESAR project for the deployment of urban air mobility. As another example, several memorandums of understanding were established for the deployment of shared mobility solutions over several cities, such as Lisboa, Portugal.

During the first workshop, participants mentioned that collaborative governance should be used to regulate new markets at the EU level. Gathering private and public stakeholders to collaboratively define standards at the EU level is crucial for achieving the technical compatibility, data interoperability and legal compliance necessary for many mobility innovations to succeed and create intended value. In MaaS, local collaboration is necessary for coordinating the urban infrastructure planning and fleet size management and developing solutions for the first and last mile journeys.

The need for ***adaptive governance*** has been stressed by proposing that regulatory approaches must be flexible and informed by data on mobility and related changes. This relates to the need for public–private collaboration and data sharing discussed earlier. Adaptive governance aims to check whether the performance and policy objectives are achieved at each step of deployment (Pankratz et al., 2019), as in the case of the Innovation Partnership Programme for MaaS deployment in Sweden (Holmberg and Brenden, 2018). Adaptive governance can also be employed in the Sustainable Urban Mobility Plan (SUMP) development process (Wefering et al., 2013), going step-by-step to implement a sustainable mobility framework in a city (resources, planning, implementation, impact analysis), adopting a global approach instead of a fragmented one.

Policy instruments for this governance model can be temporary authorisations, or tradeable permits, that allow for testing the solution before adopting it. For instance, in Ghent and Milan, the car-sharing permit is granted through an annual evaluation that assesses the environmental impact of carsharing with the ecoscore of each vehicle, the number of users per vehicle, etc. (Modijefsky, 2020).

Many participants in the workshop agreed that it is crucial to establish goals for sustainable local mobility systems and assess the quality of new services against them. This goes in line with the principle of ***outcome-based governance*** proposed by Pankratz et al. (2019). Thus, the focus would shift from concrete technologies or business models to encouraging innovations that solve local challenges and contribute to achieving set goals. In that respect, some existing governance instruments, such as taxing corporate cars in France, were criticised during Workshop 2 since they motivate companies to buy corporate cars for their employees to use. An alternative solution would be to provide mobility budgets for employees, which could take car sharing into use, but this requires a reformed tax benefit structure to create proper incentives.

Focusing on the environmental impact of different mobility services was mentioned in the workshops as one way of setting goals for sustainable mobility. Indeed, a successful transition to sustainable transportation systems needs to be supported by adequate governance (Sprei, 2018), and incomplete sets of governance tools that do not account for production, emission management and sustainable consumption may lead to suboptimal results (Davis, 2018; Docherty et al., 2018).

Subsidies and incentives can indeed foster innovations for sustainable mobility and encourage users to adopt this. During the first workshop, participants mentioned that these policy instruments promote positive behaviour and can apply directly to the users. For example, in the Region Ile-de-France, the authority creates financial incentives for carpoolers (Iledefrance-mobilites, 2019). However, workshop participants also mentioned a risk related to possible market distortion caused by using the policy instrument. Another tool for outcome-based governance is labelling and ecolabelling transport services and operators. Labelling schemes can encourage positive externalities, as in the case of the car-sharing labels employed in the city of Lyon (GrandLyon, 2021). Finally, soft governance as recommendations can also be used for outcome-based governance. For example, the CarSharing Toolkit (2020) developed in Italy provides guidance for deploying car-sharing in a given territory.

The need for ***regulatory sandboxes*** (Pankratz et al., 2019) was considered important for 'testing' performances of new mobility services (in this case, MaaS). Although not explicitly mentioned in the workshops, this is an important tool for implementing more technologically complex innovations such as CCAM. In this case, pilot projects and pilot zones can help develop innovations and assess the impact of autonomous vehicle performance in order to build an appropriate governance framework. Regulatory sandboxes can thus complement adaptive governance by providing information for making governance decisions.

Fragmentation was discussed by several participants in Workshop 2 and was especially stressed by the private sector, i.e. mobility service providers. They urged the ***harmonisation*** of governance frameworks for mobility innovation to improve the service quality rather than adjust to the many local requirements. Meanwhile, the public side mentioned that local differences should be accounted for. While it is beneficial to set general frameworks at the EU and national levels, local authorities must be able to set requirements for and implement solutions that help tackle their problems and achieve local development goals. In that sense, a top-down approach for setting more generic goals and standards needs to allow more flexibility locally to achieve these goals. This aligns with the principles of outcome-based governance discussed earlier.

Harmonised governance would tackle challenges related to the replicability of the implementation of different mobility innovations at the city, regional, national or international levels. This is especially relevant for innovations regarding supranational infrastructures. In this respect, EU directives, binding rules, and UNECE regulations can serve as policy instruments to achieve harmonised standards and regulatory frameworks, which are required to successfully implement many mobility innovations. Guidelines for developing SUMPs, mentioned earlier, also help overcome currently fragmented governance frameworks segmented by modes of transport and mobility services.

Authorities' role in ***educating citizens*** was also mentioned during the workshops; this can be seen as a 'soft governance' tool. Collaboration between mobility service providers and authorities is also relevant in this situation because the impacts of mobility innovations need to be measured and communicated to the end-users.

Awareness campaigns, through targeted educational programmes, workshops and roundtables show the impacts of a mobility solution and inform the public about the impacts of an innovation. For example, the MIMOSA project, a CIVITAS initiative, set up the School Mobility Manager Campaign, the Pedestrian Circulation Campaign (interactive initiative), Public Transport Campaigns and Eco driving campaigns (interactive workshops) to educate the citizens regarding sustainable mobility services (Ramazzotti et al., 2012).

We can conclude from this analysis that new, more inclusive and flexible governance models can address the challenge of the many new mobility services entering the market, as well as their complexity. They also have the potential to facilitate a harmonised regulatory approach sinstead of the current fragmented one. In this quickly evolving framework, with the current climate emergency, it is key to incentivise the deployment and adoption of sustainable mobility solutions. Choosing a progressive regulatory process, including stakeholders, step by step from the definition of standards to the operational deployment, through the experimentation of the solution will help guard against negative externalities, thanks to a continuous monitoring of the impacts of the mobility innovation.

Impact of COVID-19 on the governance of mobility innovations

We surveyed the stakeholders to ask how the pandemic will change the governance of mobility innovations in the future. While five respondents considered that there will be limited or no change to the governance of innovations in the future, 16 respondents provided their

Table 3
Survey results regarding the impact of the COVID-19 pandemic on the future governance of mobility innovations organised by key conceptual categories.

Topic	Number of mentions	Illustrative quotes
Collaborative governance		
- more collaboration between public and private sectors	5	"It has fostered greater collaboration.""In general, more collaboration. Public and private sector shouldn't get too close, obviously, but also shouldn't be afraid of one another."
Adaptive governance		
- adapting governance measures and faster decision-making	6	"It has shown the willingness of the general public to accept governing mistakes. If the government made a mistake and is quickly adapting the policy, and it is transparent about it, that is accepted.""Faster decision-making has been shown to be possible.""Hopefully faster decision-making to test mobility innovations."
- governance informed by data	3	"It will probably bring more data-centred decisions and operations within a more collaborative environment." "More data innovation and provision [is expected]."
Outcome-based regulation		
- importance of achieving sustainable transition, resilience of mobility systems	5	"Hopefully it will increase understanding that air pollution is an urgent problem and encourage further transition from private vehicles and fossil-fuel driven trucks etc. to alternatives." "Conversion of temporary measures to reallocate capacity to more sustainable mobility have been made permanent."
- focus on collective needs and questioning the mobility mix	3	"It might change the idea of fair shared public spaces (e.g. for which mobility mode they are mainly designed).""It underpins the collective needs (local quality of life) ." "Public transport is essential and worth subsidising, but not all parts of public transport are effective and worth subsidising if alternatives exist and could be combined."

view on which changes are likely to happen. We were able to identify recurring themes that concerned the governance principles discussed in the previous section.

Table 3 provides the list of changes to mobility innovation governance, categorised according to the topics that emerged in section 4.1, as well as supporting quotes from our data.

Further, we discuss the expected changes in the governance of mobility innovations and present examples of responses to COVID-19, which we identified in our desktop study, illustrating these shifts.

Collaborative governance

As noted by several survey respondents, the pandemic has fostered more collaboration between public and private parties in the transport sector. Illustrative examples of this, identified in our desktop study, concern collaborative actions towards the design of a more resilient and sustainable mobility framework. In particular, the World Economic Forum (2020) established a "Covid Mobility Works" taskforce, which initiated a coordinated action in order to share knowledge and incentivise multistakeholder collaboration to build resilient mobility systems. Then, SUMP Resilient Topic Guidelines were created at the EU level, which also reported that the Smart Ways to Antwerp Programme supported 119 companies in developing smart mobility policy.

New facets of collaborative governance can also be seen in data sharing between local authorities and mobility service providers. For example, the French city Versailles cooperatively partnered with Wever service to adapt the transport offer according to the data analysis from Wever in order to address challenges related to mobility uncertainties (Corby, 2020).

Adaptive governance

Rapid measures to address the challenges of the pandemic were taken. For example, streets were repurposed to provide more space for walking, cycling and other active mobility; in Bordeaux, France, 78 km of temporary bike lanes were opened (Union Cycliste Internationale, 2020). Some cities, like Brussels, have been adjusting traffic light timing to manage the increased flow of cyclists and pedestrians and mitigate crowding at road junctions. Such temporary measures have been rapidly deployed without heavy bureaucratic processes (ITF, 2021). Also, existing plans for sustainable mobility and public space use have been implemented at an accelerated pace, which is discussed further in this section.

Data-driven businesses have demonstrated their support to local authorities regarding decision-making through continuous reporting (International Transport Forum, 2020b), such as data sharing between the UK's Department for Transport and ITS UK (Witzel, 2020). Mobile apps provide real-time information on the public transport occupancy level and adapt the offer of the transport services (e.g., in Hamburg) (Lozzi et al., 2020). In particular, Catalonia introduced a new app to track public transport loads online in order to reduce congestion and develop individual passenger routes. City authorities quickly introduced new rules based on traffic monitoring and collected data, e.g. Paris has improved the use of cycle paths and traffic in general.

The possibility for fast decision-making and rapid, adaptive governance informed by real-time data has been demonstrated during the pandemic and might have a lasting effect on the future governance of mobility, as the survey respondents noted.

Outcome-based governance

Since personal car use has been a common type of modal shift in transportation, the importance of green, sustainable transportation was accentuated more than ever. Numerous policy incentives have been taken to accelerate the ecological transition at the national and international levels, including the New Interim Climate legislation to boost electric vehicles in Spain, sustainable recovery plans in many European countries (WSP Global Inc, 2020), and the European Green Deal (Claeys et al., 2019). These plans address social and economic challenges from the COVID-19 crisis, while accelerating the ecological transition to sustainable mobility.

To provide another example, the Department for Transport in the UK has developed a series of technological innovation and sustainable transportation programmes to foster the next generation of automotive technologies and sustainable transport systems (London Councils, 2020). These practices aim to alleviate the negative impact of COVID-19 on the transition of car ownership to usership and accelerate the electrification of passenger mobility (e.g. the development of batteries and other electric vehicle technologies, the introduction of electric vehicles and e-micromobility).

COVID-19 has become a prerequisite for accelerating the fight against the climate crisis. Most proposed measures to combat the effects of the pandemic in European countries go hand in hand with methods to combat climate change and environmental goals. In some countries, attention to climate change mitigation has been lowered due to a lack of funding or other priorities. However, the COVID-19 pandemic reminded of the need for joint action to be responsible for humanity's future.

Temporarily reallocating street lanes to increase space for cycling and walking has spurred discussion regarding the fair sharing of public spaces. Besides competition for public space between cars, public transport and lighter modes, including walking, delivery of goods has increased, thereby requiring curb space as well. Since public transportation has decreased and will remain in lower demand during the pandemic, cycling, walking and car travel are expected to increase in the post-confinement phase, urging cities to reallocate space for physically spaced walking and cycling (International Transport Forum, 2020a).

As in the case of sustainable transition, COVID-19 created the momentum for many European cities to fast-track their local mobility and urban space allocation strategies. For example, Brussels has sped up the implementation of its "Good Move" mobility plan, which was developed years before the pandemic (Salazar, 2021). Similarly, London's "Streetspace" plan and Paris' response plan to COVID-19 include goals that existed before the pandemic but also aim to enhance the cities' resilience (ITF, 2021). National governments established support for active modes through financial incentives, such as the €20 million "Coup de Pouce Vélo" plan in France and the £2 bn plan to boost cycling and walking in the UK.

Regulatory sandboxes, harmonised governance and citizen education

Although nothing specific was mentioned in the survey regarding the three topics raised in the first phase of the study, i.e. regulatory sandboxes, harmonising governance frameworks and citizen education, we have identified several indications of relevant changes in the governance during the desktop study of governance responses to COVID-19.

The different temporary measures introduced during the pandemic, such as pop-up lanes for light traffic and traffic monitoring for adjusting transportation offering in real time, could be seen as regulatory sandboxes where bureaucratic barriers could be quickly overcome to implement required solutions. Consequently, it is possible to test different solutions and discover new traffic management opportunities (Sengers et al., 2019).

The relationship between public transport and new mobility services has also been seen differently during the pandemic. Previously discussed solutions for active mobility and shared solutions have absorbed some of the demand diverted from public transportation due to the fear of crowded spaces and virus transmission. It became apparent that these solutions could even become a preferred option to public transport, raising the questions of fair access to public space and questioning the status quo of the mobility mix. For example, ride-hailing has been used to ensure transportation connections for remote areas in Finland (Yle, 2020).

Harmonisation regarding governance was not a priority when a fast reaction to the pandemic was needed at the local level. However, it remains on the policy agenda as the governance of mobility innovations and new EU standards are being developed to establish resilient transport systems (Prus and Sikora, 2021).

Regarding citizens' education on preferred modes of transport during the pandemic and, importantly, in the recovery period, the crucial task will be to educate citizens concerning the safety of shared solutions, including public transportation and shared mobility services. A few information campaigns have already been implemented, for example, in France, regarding car-pooling (Couvidat, 2020). Education is crucial for showing the benefits of shared solutions as well as proving their safety, especially after the initial uncertainty regarding the safety of shared mobility solutions (for example, the advice to avoid public transport in London).

Discussion

As the first part of our study showed, flexible, adaptive, real-time policies are mandatory for a resilient transportation framework capable of maximising the public value of mobility innovations. As big data is a crucial resource which will be part of new resource interdependencies among the growing network of actors in the passenger mobility sector (Hensher, 2018), the experience of data sharing, public–private collaboration, and frameworks for such exchange facilitated by the COVID-19 pandemic is expected to become a solid basis for future development of data-driven, adaptive policymaking and governance. This is extremely important as data exchange between participants at the city or country level can help optimise traffic flows, reduce emissions, and attract new participants to the market. Data exchange can seamlessly move from testing mobility innovations to full implementation and exploitation of their capabilities. Adaptive governance, informed by data, thus requires the harmonisation of data standards at the international level to foster an interoperable data exchange for collaborative policymaking. It is important, however, to point out the risks for this type of governance model, as privacy and security will be major challenges for both public and private parties. Lack of trust and willingness to share data could hinder the deployment of data-based innovations and governance.

During the pandemic, we also observed how adaptive governance models were progressively implemented among countries, changing policies step by step. These models were often employed together with collaborative policymaking, leading to better adoption by private parties and increasing public confidence to use the new solutions. Despite positive examples of collaborative governance presented in section 4.2, it is highly possible that due to the urgency in decision-making triggered by the pandemic and more reactive approach, certain instruments like public consultation could have been bypassed.

As discussed in section 4, numerous recovery plans and the European Green Deal published among the EU countries over the last few months aim to boost the growth of strategic environmental sectors to achieve carbon neutrality by 2050. These policies were developed before the pandemic started, but they received a boost during the pandemic. However, sustainable mobility policies will be challenging to implement as public resources will get lower due to the economic crisis issues from this pandemic and as citizens' behaviours might change back to private car use. Thus, the definition of goals to achieve not only sustainable but also resilient and safe transportation systems is becoming crucial. In this respect, collaborative governance, as in the example of the task force established by the World Economic Forum, appears to be a useful instrument for defining the future strategy for resilient transportation. Mobility innovations in achieving these goals will require further deliberation compared to pre-pandemic times.

Citizen education also has an important role. Now, besides educating passengers on innovative mobility services and their environmental impact, it is necessary to re-establish trust in the safety of shared mobility and start the discussion of how much mobility we actually need. As a recent paper by Budd and Ison (2020) highlights, developing self-assessment policies could be key for a low-carbon scenario, raising awareness about individual responsibility during transport journeys and carbon footprints, preventing unnecessary travels, working remotely when possible and travelling sustainably. In this regard, the pandemic has revealed unsustainable mobility patterns and has also demonstrated the potential of alternative mobility scenarios and mode shifts.

As society recovers from the pandemic, some measures (e.g. temporary interruptions in piloting new mobility services or pop-up infrastructure) might disappear while others might have a lasting effect on disruptive mobility and relevant governance. It is important to understand how the ongoing and somewhat ad hoc governance of the crisis in the passenger mobility sector will lead to lasting changes. For instance, the role of public–private collaboration and data sharing has become apparent for both sides now more than ever, and the individual 'goodwill gestures' of data sharing can become a common practice in the future as part of creating safe and resilient transport systems. To provide another example, the re-spacing of cities to allow for more active transport will probably be retracted after the pandemic, but it will certainly impact infrastructure planning in the long term.

In Fig. 2, we provide an overview of the different governance

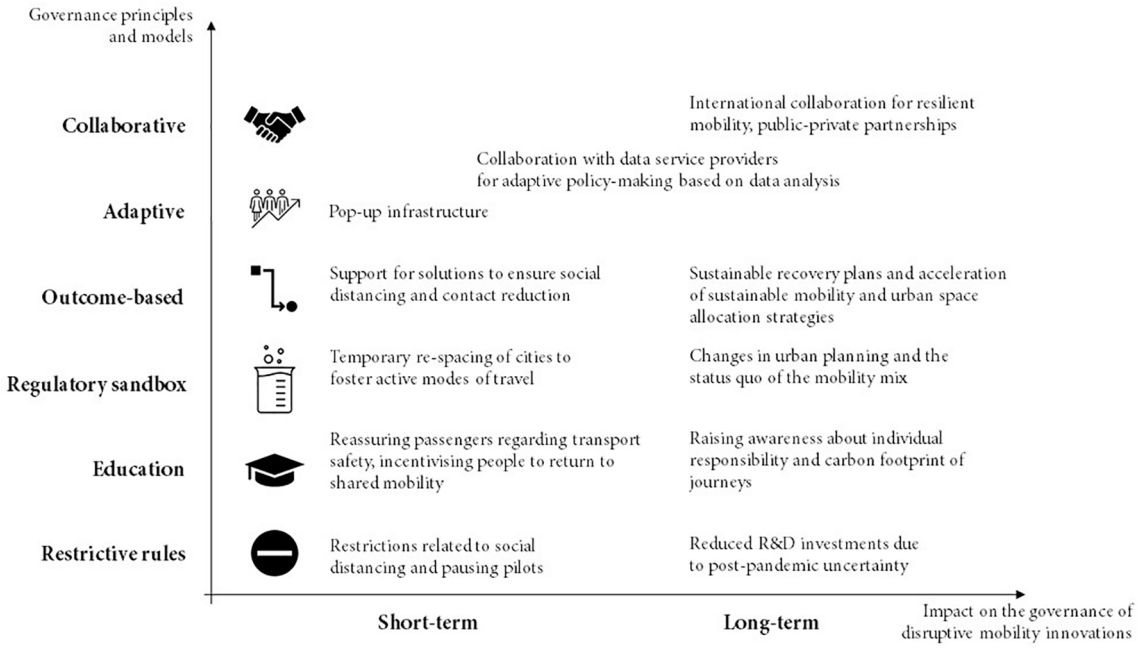

Fig. 2. The impact of governance responses to COVID-19 on the governance of disruptive mobility innovations.

responses to COVID-19 discussed earlier as to their short-term or long-term impacts on how disruptive mobility innovations will be governed. The indications on whether certain governance measures will have short-term or long-term impacts are based on the analysis of the survey responses and desktop study of the different governance responses to the pandemic that affect mobility innovations (see section 3.3).

Conclusions

COVID-19 can be considered as a disruption in the mobility landscape, for which new governance responses are needed to address challenges related to the evolution of the pandemic, adapting in almost real-time to the new conditions of virus spreading, while achieving sustainable policy goals.

This article presents results of the research that has focused on the governance of disruptive mobility innovations before and after the pandemic started. After analysing the needs and principles for governing mobility innovations in passenger transportation, we use collaborative, adaptive, outcome-based governance and several other relevant aspects as an analysis framework to illustrate how mobility governance in Europe is changing due to COVID-19.

Our findings show that inclusive and proactive regulatory approaches are mandatory in complying with a fast mobility framework, which has become even more volatile due to the COVID-19 pandemic. New governance models based on adaptive, data-informed decision-making allow a continuous impact monitoring of the mobility framework, which is crucial for managing transportation during the pandemic and beyond. These models can support the achievement of policy goals, such as carbon neutrality or social equity, thanks to 'real-time' adjustments that will prevent negative externalities. A particular policy implication is that short-term agility needs to be combined with long-term capacity to avoid future crises by anticipating and preparing for the impacts of these crises on transportation.

Another policy implication is that policy goals for sustainable mobility also require redefinition since resilience and safety become as crucial as the environmental impact of transportation in achieving a sustainable future. The challenges of the pandemic have highlighted the need for a resilient transport system and have spurred collaborative action at the international level to define requirements for resilient and sustainable transportation to update policy goals.

It is crucial to note that there are contradictions between various governance responses to the pandemic and their respective influences on new mobility solutions, which might further hinder the goals of sustainable mobility. Without a long-term and overarching perspective on the governance of new passenger mobility solutions, policymakers might unintentionally promote specific innovations and deter the development of others that are integral to medium- and long-term recovery and sustainable mobility plans. Further research into these tensions and challenges to align the goals of safe, resilient and low environmental footprint transportation is necessary. This can be combined with the redefinition of goals for sustainable mobility, as discussed earlier.

The limitations of this study include the geographical context, which allows us to draw conclusions regarding mobility governance in Europe. We propose researchers to conduct comparative studies on the impact of the pandemic on the governance of mobility innovations in other parts of the world. Since European context is rather specific due to the multi-level governance, it would be beneficial to study whether the complexity of governance structures affects the implementation of the principles for governing mobility innovations in a negative or positive manner.

The situation is rapidly changing, and it is too early to make any unambiguous conclusions about the long-term impact of the pandemic on the governance of disruptive mobility innovations in regard to the governance goals, impact and concrete efforts. Further research should also observe the actual impact on the governance because this study provides early indications of such changes based on opinions of major stakeholders in the passenger transportation sector. In addition, it is critical for future studies to investigate the potential long-term aversion of sharing public transport space as it might influence how we provide governance for mobility solutions in a significant way. Nevertheless, this paper provides insight into the direction that mobility governance has been taking in Europe.

CRediT authorship contribution statement

Anastasia Tsvetkova: Conceptualization, Methodology, Investigation, Visualization, Writing – original draft, Writing – review & editing.

Ignat Kulkov: Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing. **Caroline Busquet:** Conceptualization, Methodology, Investigation, Visualization, Writing – original draft. **Ping-Jen Kao:** Conceptualization, Methodology, Investigation, Visualization, Writing – original draft, Writing – review & editing. **Maria Kamargianni:** Methodology, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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