Shared mobility in post-COVID era: New challenges and opportunities

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ABSTRACT

This study is aimed at exploring the challenges and opportunities that the COVID-19 outbreak presents to the sustainability of shared mobility. To date, the sustainability of shared mobility has received little attention in the literature, and this study determines its central constructs that are critical to the sustainability of shared mobility. We accordingly conducted a three-phase Delphi approach composed of both qualitative and quantitative methods. Feedback was obtained from 18 international experts who are very knowledgeable regarding civil engineering and shared mobility, initially finding 18 challenges and 18 opportunities. Finally, we identified 12 key constructs as highly critical to the sustainability of shared mobility. The current work is an attempt to address gaps in exploring the challenges and opportunities that the COVID-19 outbreak has created in shared mobility, particularly when a comprehensive examination is needed. This study will serve as an inspiration and catalog for new studies within this field.

1. Introduction

In keeping with the rapid progress of digitalization, which has changed the face of society in almost all facets, shared mobility has become a major and multifaceted topic. Price stated that sharing is "the most universal form of human economic behavior" one engaged in over a span of several hundred thousand years (Price, 1975). In this context, sharing can include sequential sharing, concurrent sharing, and core services such as taxis and public transit (Shaheen et al., 2019). Innovations in internet technologies and location-based services have enabled shared mobility to expand rapidly, supporting a bright era of transportation as one of the most basic human activities linking almost all daily routines from employment and obtaining essential services to shopping and (Schiller & Kenworthy, 2017).

In recent years the terms "sustainable mobility" and "accessible transportation" have come to be used interchangeably with or substituted for the term "sustainable transportation" (Schiller & Kenworthy, 2017).In order to arrive at a better understanding of sustainable shared mobility, we first quote two definitions. Wiederkehr et al. stipulated an environmentally sustainable transport system as one where transportation does not endanger either public health or ecosystems and meets access needs consistent with (a) the use of renewable resources

below their rates of regeneration and (b) the use of non-renewable resources below the rates of development for renewable substitutes (Wiederkehr, Gilbert, Crist, & Caïd, 2004). On the other hand, Byars, Wei, and Handy argued that sustainable mobility meets the present generation of mobility needs without compromising future generations' abilities to meet their own (Byars, Wei, & Handy, 2017).

Shared mobility is an emblem of a shared economy that is linked with both sustainable travel behavior and sustainable urban infrastructure from the social, economic, and environmental perspectives (Wu & Zhi, 2016; Ye & Titheridge, 2020). Achieving sustainability in shared mobility is crucial to addressing the wider challenge of sustainable development (Walnum, Aall, & Løkke, 2014). By providing better working conditions, broadening access to services, and generating local economies (Barquet, Seidel, Seliger, & Kohl, 2016; Teles et al., 2018), it acts toward social well-being and equity that promote sustainable societal development.

Dalal-Clayton et al. have taken sustainable development to mean achieving a quality of life that can be maintained for many generations because it is:

- Socially desirable by fulfilling cultural, material, and spiritual needs inequitable ways;

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- Economically viable by paying for itself with costs not exceeding income, and;
- Ecologically sustainable by maintaining the long-term viability of supporting ecosystems (Dalal-Clayton, 1994; Dalal-Clayton, Bass, & Swingland, 2002) (Fig. 1).

Although the number of sustainability dimensions has some controversies among authors who refer to the existence of additional dimensions such as cultural, institutional, and governance (Macedo, Rodrigues, & Tavares, 2017), for the intent of this study, we refer to the commonly-agreed description using three dimensions.

The most demanding aspect of working on sustainable development is preparation for facing the prospect of fundamental problems affecting sustainability. The outbreak of a novel coronavirus (hereafter COVID-19) has cast serious doubts on the sustainability of shared mobility (Mezghani, 2020) due to lock-downs and subsequent broad impacts. The COVID-19 Community Mobility Reports provided by Google show that personal travel plans, particularly those for the categories of retail and recreation, transit stations, and workplaces, have all seen a massive fall (Google, 2021). The COVID-19 outbreak and extended lock-down measures have shown a previously unimaginable image of modern cities. The economic influences of this crisis are also becoming more obvious following the World Health Organization's declaration of the COVID-19 outbreak as a global pandemic (Cucinotta & Vanelli, 2020). Significant drops in the global gross domestic product (GDP), falls in household consumption, falling energy prices, and unprecedented stock market impact all caused by COVID-19 have made the shared mobility industry one of the first to enter a slump.

When entering into a global pandemic scenario, most countries rushed to follow the example of China: lockdowns, mobility restrictions, massive quarantine hospitals, increases in public health measures, protection of the elderly, etc. (Fernandes, 2020). The central goal of an outbreak control closure period is to prevent individuals with asymptomatic infections from spreading the disease (S. Chen, Yang, Yang, Wang, & Bärnighausen, 2020). Subsequent social distancing policies have been an effective response to the outbreak of other epidemics (Ferguson et al., 2005; Hatchett, Mecher, & Lipsitch, 2007; Markel et al., 2007; Poletti, Caprile, Ajelli, Pugliese, & Merler, 2009). The lack of population resistance to a novel disease facilitates contact with the virus and may lead to a rapid increase of severe cases over a short period as seen in Italy (Siwiak, Szczesny, & Siwiak, 2020); most countries accordingly decided to apply a home-based quarantine. Approximately one-fourth of infections occur during the use of public transit vehicles (Muller, Balmer, Neumann, & Nagel, 2020) because an infected individual potentially transmits the virus to healthy ones during close contacts within a confined space such as a shared vehicle (Yang et al., 2020). In addition to these policies, fear of spreading the virus via public transit and shared vehicles has already had a profound impact on both shared mobility services and interpersonal behaviors. As an effect of global mobility, coronaviruses will likely cause similar spreads and outbreaks of different strains in the coming years (Sahin et al., 2020). After being impacted by the COVID-19 pandemic, we are now reaching the stage where striking a balance between personal hygiene care and long-term community preferences regarding shared mobility is essential. This should not be investigated as only a temporary subject since future outbreaks may create a long-term issue that is similarly difficult to control.

The main aim of this study is to investigate probable influences of the COVID-19 outbreak and its impacts on the sustainability of shared mobility at the travel behavior and urban infrastructure levels, as well as making suggestions concerning which containment measures will be adopted in pursuit of maintaining customer retention rates.

The reason for undertaking this study considers the fact that many pre-COVID-19 forecasts regarding shared mobility are now defunct, and a priori circumstances are now subject to rapid changes. Detecting the challenges and opportunities that shared mobility will face in the future is accordingly a necessary step forward for both enterprises and authorities. This study investigates the various impacts that the COVID-19 outbreak has had on shared mobility that is not limited to any specific place and time. This study is the first to investigate the impact of the COVID-19 outbreak on the sustainability of shared mobility. We accordingly pursue the following questions:

RQ1: What are the potential opportunities and challenges that the COVID-19 outbreak presents for the sustainability of shared mobility at the travel behavior level?

RQ2: What are the potential opportunities and challenges that the COVID-19 outbreak presents for the sustainability of shared mobility at the urban infrastructure level?

The rest of the paper is structured as follows. Section 2 presents a review of the literature concerning the effects of travel restrictions and the role of shared mobility on spreading the virus; there is not yet a full review encompassing available studies and reports. Section 3 describes the research methodology and study design. Section 4 presents the findings, which are further discussed in Section 5. Section 6 concludes the paper with a summary, implications for research and practice, study limitations, and directions for further research.
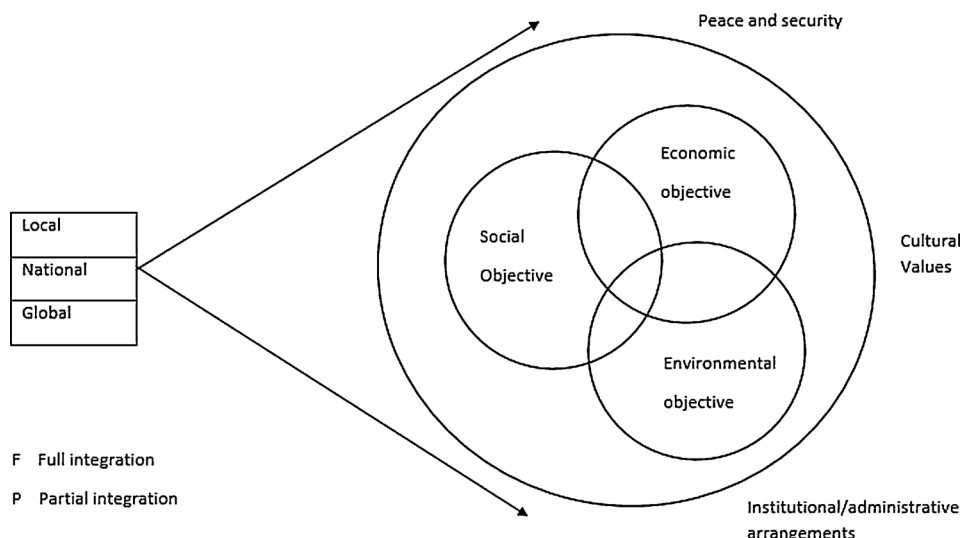

Fig. 1. Systems of sustainable development (source: Dalal-Clayton, D.B., S. Bass, and I.R. Swingland, Sustainable development strategies: a resource book).

2. Literature review

Some studies have been done aimed at anticipating the spreading of this coronavirus by using travel data (Cao et al., 2020; Lai et al., 2020; Wu, Leung, & Leung, 2020), and some studies have done to measure the impact of travel bans (Aleta, Hu, Ye, Ji, & Moreno, 2020; Anzai et al., 2020; Brynildsrud & Eldholm, 2020; Costantino, Heslop, & MacIntyre, 2020), even though the impact of travel restrictions on human mobility, a necessary first step in the causal chain to outbreak containment, is difficult to measure (Peak et al., 2020). Aleta, A. et al. propose that travel restrictions have a positive impact on the temporal evolution of the disease in so far, the reduction in the flow of individuals delays the spreading of the disease to the rest of mainland China (Aleta et al., 2020). Some studies are focusing on modeling the spreading of the virus. The spread of COVID-19 in China was driven by human mobility early on and mitigated substantially by drastic control measures implemented since the end of January (Kraemer et al., 2020). Du, Z. et al. estimated the probability of transportation of infectious COVID-19 cases from Wuhan to cities throughout China before January 23 by using a simple model of exponential growth coupled with a stochastic model of human mobility among 369 cities in China (Du et al., 2020). A particularly large outbreak occurred among the passengers and crew of the Diamond Princess cruise ship, where more than 700 infections are reported (Del Rio & Malani, 2020). An Initial Investigation of Transmission of COVID-19 Among Crew Members During Quarantine of a Cruise Ship underscores the need for swift epidemiologic investigation as soon as a COVID-19 case is detected in an area or group where a large number of persons gather in a closed or crowded setting (Kakimoto et al., 2020). One of the first studies assessing the transmission potential of the COVID-19 outbreak was a study of unfolded outbreak aboard the Diamond Princess Ship, January-February 2020 in which indicates that the passenger-to-passenger transmission type dominated the transmission dynamics aboard the Diamond Princess Ship. Thus, a high proportion of the symptomatic cases after the quarantine gradually shifted from largely passenger cases to crew cases. Indeed, despite their potential risk of acquiring the infection, crews had to continue to work to deliver services to isolated passengers (Mizumoto & Chowell, 2020). Wang, Y., Z. Fang and W. Gao propose that the epidemic only transforms the centralized transportation of passengers into decentralized transportation, rather than stagnating at a low level (Wang, Fang, & Gao, 2020). Muller, S.A. et al. show that especially home, leisure, work, and public transit activities have a strong influence on the epidemic spreading (Muller et al., 2020). Zheng, R. et al. indicated that imported cases via public transportation played an important role in the spread of COVID-19 (Zheng, Xu, Wang, Ning, & Bi, 2020). This is more important in areas of a dense population like Beijing as newly infected patients have shifted from the imported to local gradually (Tian et al., 2020). Yang, X. et al. suggests densely populated cities like Paris, Tokyo, and Singapore with advanced public transportation and plenty of popular public places are particularly vulnerable to the viral transmission while the general population in US cities like Los Angles who commute via family cars significantly reduce the risk of virus transmission (Yang et al., 2020). Chen, S. et al. propose that governments should use the closure period of outbreak-control for community screening active contact tracing too (Chen et al., 2020). Oliver, N. et al. in their paper propound that individual mobility and contact data in the early recognition phase, monitoring mobility during the acceleration phase, and near real-time data on mobility and hotspots is essential and this kind of information also contributes to the building of more accurate epidemiological models that can explain and anticipate the spread of the disease (Oliver et al., 2020). Some papers are investigating the Impact of COVID-19 on Transport Demand and choices. Michael S. Warren, Samuel W. Skillman used anonymized and/or de-identified mobile device locations to measure mobility, a statistic representing the distance a typical member of a given population moves in a day (Warren & Skillman, 2020). In a paper with analysis based on ticket validations, sales, and passenger counts data proposed that public transport ridership in Sweden has been hit particularly severely compared with other transport modes (Jenelius & Cebecauer, 2020). "Public transport and COVID-19, how to transition from response to recovery" is a white paper focused on the transition stage that considers the supply-side implications for public transport provision, rather than an assessment of returning demand for travel (Short, Gouge, & Mills, 2020). Axhausen, Kay W. has presented The impact of COVID19 on Swiss Travel at TU Delft Webinar, July 2020 (Axhausen, 2020a). Giacomo Fallchetta and Michel Noussan investigated the Impact of COVID-19 on Transport demand, Modal Choices, and Sectoral Energy Consumption in Europe, and their key conclusion is that passenger transport demand will remain lower than a counterfactual case of no-COVID19 beyond the year 2020 (Falchetta & Noussan, 2021). João Filipe Teixeira & Miguel Lopes have done a great work focuses on the impact of COVID-19 on the transport system of New York City, which determined the existence of a statistically significant increase in the average duration of City Bike's trips, which was positively correlated with the number of daily new COVID-19 cases (Teixeira & Lopes, 2020). Yeabsira Mehari has investigated The Role of Social Trust in Citizen Mobility During COVID-19(Mehari, 2020). International Centre for Trade Union Rights has also published a paper written by Alana Dave, an Urban Transport Director with the ITF in London, which concentrates on Keeping public transport workers safe from Covid-19(Dave, 2020). Austan Goolsbee & Chad Syverson examined the drivers of the collapse using cellular phone records data on customer visits to more than 2.25 million individual businesses across 110 different industries and realized that while overall consumer traffic fell by 60 percentage points, legal restrictions explain only 7 of that. They argue that individual choices were far more important and seem tied to fears of infection (Goolsbee & Syverson, 2020). European Rail Research Network of Excellence has published an essay titled "COVID-19 IMPACT IN TRANSPORT, AN ESSAY FROM THE RAILWAYS' SYSTEMS RESEARCH PERSPECTIVE" and introduces the concept of 5 "R" as the necessary steps the rail sector needs to undertake to play a significant role in tomorrow's mobility. These steps are Resilience, Return, Reimagination, Reform, and Research (Tardivo, Sánchez Martín, & Carrillo Zanuy, 2020). In investigating changes in travel behavior Shamshiripour, Ali, et al. designed as a longitudinal analysis with multiple survey waves to monitor the activity-travel dynamics and they categorized Attitudinal and behavioral changes caused by the COVID-19 pandemic into four sections; Working from home, In-store and online shopping, Airplane travels, and Risk perceptions (Shamshiripour, Rahimi, Shabanpour, & Mohammadian, 2020). Molloy, Joseph, et al. with great effort in a study called "The MOBIS-COVID tracking study" showed that participants in their study which are inherited in German and French speaking part of Switzerland anticipated the "lock down" by starting to reduce travel two weeks in advance of March 16th 2020 and the number of trips fell by 40 % (Molloy et al., 2020).In India, a study was carried out in urban cities of India using a web-based questionnaire to capture travel choices in different stages (Thombre & Agarwal, 2020). Jonas De Vos has investigated The effect of COVID-19 and subsequent social distancing on travel behavior (De Vos, 2020). For assessing the impacts of lock-downs a study by de Haas, Mathijs, Roel Faber, and Marije Hamersma is a quintessential region-focused study in which presents the first insights in current and potential future effects of the virus and the Dutch government's 'intelligent lockdown' on people's activities and travel behavior (de Haas, Faber, & Hamersma, 2020). On the other hand, some only focused on opportunities and challenges. Wisdom Kanda & Paula Kivimaa explore the ramifications for sustainability transition research on electricity and mobility, drawing from selected examples in Finland and Sweden and introduce some long-term consequences (Kanda & Kivimaa, 2020). Megahed, Naglaa A., and Ehab M. have added "Fewer cars, more cycling, and walking" as one of "Urban Approaches" and a lesson we can learn from the COVID-19 pandemic (Megahed & Ghoneim, 2020). Other study is called "The Impact of COVID-19 on Public Space A Review of the

Emerging Questions" that is a work presented by twelve researchers and faculty members from all around the world and shared mobility and public transit are the two of questions they tried to find an answer for them (Honey-Roses et al., 2020).

The most significant contribution and results of the afore-mentioned studies in the literature review on shared mobility could be categorized as two groups – transmission and spreading the disease, covid-19 impacts on shared mobility- which are listed as below:

1- Transmission and spreading of the disease

- Spreading the virus from an infected person to others are dominating the transmission dynamics in confined spaces such as shared mobility (Del Rio & Malani, 2020; Kakimoto et al., 2020; Mizumoto & Chowell, 2020)
- Public transit activities have a strong influence on the epidemic spreading (Muller et al., 2020; Zheng et al., 2020)
- Densely populated cities are particularly vulnerable to viral transmission (Tian et al., 2020; Yang et al., 2020)
- Travel restrictions have a positive impact on the temporal evolution of the disease (Aleta et al., 2020; Peak et al., 2020)
- The importance of contact data, individual mobility, and real-time data to modeling the spreading of the virus (Cao et al., 2020; Lai et al., 2020; Wu et al., 2020)
- Governments should use the closure period of outbreak-control for community screening and active contact tracing (S. Chen et al., 2020)

2- Covid-19 impacts on shared mobility

- The epidemic only transforms the centralized transportation of passengers into decentralized transportation, rather than stagnating at a low level (Y. Wang et al., 2020)
- Public transport ridership has been hit particularly severely compared with other transport modes (Axhausen, 2020a,2020b; Jenelius & Cebecauer, 2020)
- Significant increase in the average duration of bike trips and walking in large cities (Butler, 2020a; Goldbaum, 2020c; Teixeira & Lopes, 2020)
- Passenger transport demand will remain lower than a counterfactual case of no-COVID19 beyond the year 2020 (Falchetta & Noussan, 2021)
- Individual choices were far more important and seem tied to fears of infection (Goolsbee & Syverson, 2020)

While many studies have analyzed the current situations of transportation systems in cities in the COVID-19 age, detecting the obstacles that shared mobility can and will experience in the future, and the opportunities that it would capture is a crucial move forward for both businesses and policymakers. This research explores all sorts of impacts that the epidemic of COVID-19 has had on the sustainability of shared mobility and is not limited to any particular location and period.

3. Research method and study design

Thorough knowledge is needed in the extraction and assessment of constructs relevant to opportunities and challenges in Shared Mobility in the Post-COVID era; therefore, feedbacks from experts should have been received and analyzed systematically (Bao et al., 2020; Turoff & Linstone, 2002). The classic Delphi approach was considered to be suitable for collecting evidence from tech-savvy experts about the future opportunities and challenges that the COVID-19 outbreak presents at both travel behavior and urban infrastructure levels (Nguyen, Chen, Du, & Shi, 2019; Okoli & Pawlowski, 2004). Delphi survey in several studies used to predict the impact of new technologies on social and economic facets of businesses which shows this method is helpful in predicting (Jiang, Kleer, & Piller, 2017) as well as reaching consensus (de Jesus,

Antunes, Santos, & Mendonça, 2019). There is no consistent and definitive formula on how to use the Delphi method (de Jesus et al., 2019). Many scholars have proposed that the classic Delphi approach is capable of adapting and it could be tailored to particular situations to be as consistent as possible with the case. (de Jesus et al., 2019; Gnatzy, Warth, von der Gracht, & Darkow, 2011; Turoff & Linstone, 2002). Most studies have not found any certain discrepancies in their findings and results after contrasting conventional paper-based approaches with e-mail-based methods. In addition, the process of implementing the Delphi method via mail or online was more solid and speedier than conventional pilots. (Belton, MacDonald, Wright, & Hamlin, 2019; Fritschy & Spinler, 2019; Manias-Muñoz, Jin, & Reber, 2019). The online pool enables the researcher to obtain feedbacks in spite of distances. Since the strength of this strategy is contingent on the way in which it is carried out (Bolger & Wright, 2011), the intensive focus was taken in executing each step. The input of all experts was reported at each point of the process and the adjustments were noted in a standardized manner to ensure the validity and reliability of the outcomes.

3.1. Selection and classification of experts

The engagement of experts in the Delphi analysis is always challenging (Belton et al., 2019; Hasson, Keeney, & McKenna, 2000), but the strong network and connection between authors and foreign researchers and scholars facilitated the recruitment of 22 international shared mobility and civil engineering experts with years of experience. The number of the expert panel was considered to be a sufficient sample size based on the recommendations of Okoli and Pawlowski (2004) and Belton et al. (2019). The specialists come from diverse countries and backgrounds. This approach adds heterogeneity to the expert team. (Belton et al., 2019) (Table 1). Following the recommendation of Rowe, Wright, and Bolger, 1991, p. 241), the panel was split into two categories based on their education and experience: the first group consisted of 10 experts specialized in shared mobility and the second group consisted of 11 experts specialized in civil engineering. Experts have been assigned to multiple groups to guarantee accurate answers and to prove internal validity (Bao et al., 2020). Participants with more than 20 years of experience have been classified as Level 4 experts, those with experience between 15 and 20 years have been characterized as Level 3

Table 1
The expert panel classification and composition.

Questions	Sub-questions	UN Sustainable supply chain dimensions	Number of answer items per sub-question	Number of Extracted constructs that are affected by COVID-19
What are the probable influences of the COVID-19 outbreak on the sustainability of shared mobility on the travel behavior level?	What are the potential opportunities?	Social	23	4
		Economic	16	3
		Environmental	12	2
	What are the potential challenges?	Social	30	5
		Economic	17	3
		Environmental	20	2
What are the probable influences of the COVID-19 outbreak on the sustainability of shared mobility on the urban infrastructure level?	What are the potential opportunities?	Social	17	3
		Economic	5	1
		Environmental	21	4
	What are the potential challenges?	Social	8	2
		Economic	24	3
		Environmental	23	3
Summation			216	35

experts, with expertise between 10 and 15 years of Level 2 expertise, and experts with experience less than 10 years of experience have been classified as Level 1.

The bulk of the pool members were academics and researchers focused on civil engineering, sustainable transportation, and shared mobility. The composition of the panel based on qualifications, expertise, gender, nationality, and seniority can be seen in Table 1.

3.2. Research design

A three-phase pool was set up to accumulate expert comments and provide stable and reliable results. (Belton et al., 2019; de Jesus et al., 2019; Hsu & Sandford, 2007). The survey was undertaken to specify cut-off and independent parameters in such a way that no external parameters could be developed, and no change in the accuracy of responses and measurements could be obtained by any additional Delphi pool (Kauko & Palmroos, 2014). There is no best number of phases of the survey (Manias-Muñoz et al., 2019; Melander, Dubois, Hedvall, & Lind, 2019); however, the latest scholarly articles on the classical Delphi system were based on two or three pools, not more thoughts. It was necessary to restrict the number of pools to have experts wishing to engage in a survey and, thus, not to minimize the response rate. (de Jesus et al., 2019; Manias-Muñoz et al., 2019; Melander et al., 2019). The Panel was promised that all comments would be kept private and confidential. (Miller et al., 2020). Before giving the questionnaire in each process to the experts, the instruments were pre-tested and were carefully reviewed for consistency by two-panel experts. (Belton et al., 2019; Heiko & Darkow, 2010). The pre-tests indicated that the questionnaires were wide-ranging, accurate, and suitable for this research. The procedure of adopting the Delphi method in this study could be seen in Table 3.

3.3. Question formulation and data collection

A fair degree of autonomy in response was important considering the purpose of this project to address future opportunities and challenges associated with the sustainability of shared mobility after the COVID-19 pandemic and to explore potential ideas and suggestions from experts. As a result, the questions presented in the first phase of the survey were not constrained in terms of the specificity of the items. Three open-ended questions were submitted to the participants (Belton et al., 2019; de Jesus et al., 2019; Kache & Seuring, 2017; Manias-Muñoz et al., 2019; von Briel, 2018); however, opportunities and challenges were divided as sub-questions to ensure that the answers were as precise as possible. The expert panel was supposed to give three to five opportunities and challenges for each question (Belton et al., 2019; de Jesus et al., 2019; Rowe et al., 1991). As Table 2 projects, the open-ended questions are as follows:

RQ 1: What are the probable influences of the COVID-19 outbreak on the sustainability of shared mobility on the travel behavior level?

RQ 2: What are the probable influences of the COVID-19 outbreak on the sustainability of shared mobility on the urban infrastructure level?

Data were obtained between April 2020 and July 2020. Experts were required to send their responses and feedback within two weeks of receiving the questionnaire. In situations where no response has been received, the researchers have sent several reminder email messages. If expert input was not obtained or their viewpoints were inaccurate and unusable, the expert was removed from the analysis. Despite the authors' commitment to elicit expert feedback and nearly three months of daily updates and follow-up, three experts from the initial sample were removed, limiting us to only 18 experts, whose feedback were considered usable (85 % response rate in Phase 1 and 100 % in Phases 2 and 3).

Table 2
The open-ended questions and number of constructs.

	Phase 1	Phase 2	Phase 3
Summary	The experts were asked to share their opinions about opportunities and challenges relevant to the impacts of the COVID-19 outbreak on the dimensions of sustainability of shared mobility at travel behavior and urban infrastructure levels.	As all items required prioritization and ranking in order of importance and impact a quantitative assessment was carried out. The importance and patterns of result distribution were statistically measured by using a five-point Likert scale.	The third phase involved the modification and finalization of the rankings performed in the previous phases to considerably improve the quality of the responses.
Response rate	18 out of 21 (85.71 %)	18 out of 18 (100 %)	18 out of 18 (100 %)
Outcomes	By coding the responses, 36 independent constructs were elicited through the sub-questions, that were categorized within three dimensions of sustainability.	Constructs whose mean group value was 4.5 or above were considered the most important items identified by the expert panel.	Of the 18 participants, four slightly modified their scoring, whereas the rest verified their previous ratings. As a result, "A boom in online shopping" and "Handling crowds" were could not hold their ranks, but no new construct was added to the list.

Table 3

Delphi phases.

The original text item	Sample code 1	Sample code 2
Crowded trains and buses is less popular	Avoiding crowded transportation	Lack of trust among passengers
People will want less crowded transportation	People are not willing to take public transport	
Because of the social distancing compliance, revenue will decline	Companies lose their income	People spend less money on transportation
GDP per capita will fall	Individual income falls	
Companies will lose their income	Companies lose their income	
People use their bikes again	people tend to use bikes	
More commuting by bicycle where is possible	people tend to use bikes	Spike in using green mobility
Cycling and walking will rise	people tend to use bikes	
Diesel and gasoline should be replaced by hydrogen fuels	Eco-friendly vehicles use increases	

3.4. Data analysis

The individual responses accumulated in step 1 have been carefully analyzed. All responses have also been coded to evoke the main concepts and the central idea. Different papers have addressed the coding method in several ways that are consistent with their research. As for this study, the inductive grounded coding technique has been used since it is a method of reasoning that yields evidence for the truth of the conclusion, and codes are categorized and evaluated from verifiable data (Hasson et al., 2000; Merfeld, Wilhelms, Henkel, & Kreutzer, 2019; Roßmann, Canzaniello, von der Gracht, & Hartmann, 2018; von Briel, 2018). The coding processes bracketed with "Lack of trust among passengers," "People spend less money on transportation," and "spike in using green mobility" from the original answers given by the expert panel in the first

Table 4

The illustration of the coding process.

Identified opportunities	Level of applicability	
	Travel Behavior	Urban Infrastructure
Social		
Increasing social equity in having access to transportation	–	Y
Feel-good factor rises because of less congestion	Y	–
Improving mental health because of using bikes	Y	–
Participate people in decision making in designing and planning	–	Y
Social and cultural factors play a more important role	Y	–
Family trips increases and its good impacts	Y	–
Considering people needs over cars' in planning urban infrastructure	–	Y
Economic		
Riders save more money by telecommuting	Y	–
A boom in online shopping and delivery services	Y	–
Commercial increase for digitalization increase	–	Y
Unjustified rides decline	Y	–
Environmental		
People walk more	Y	–
Freeing-up roads	–	Y
Rethinking of urban planning to protect the environment	–	Y
The convenience of empty streets for road repairing	–	Y
Shifting street space from cars for bikers and pedestrians	–	Y
Spike in using green mobility	Y	–

pool has been shown in Table 4.

Constructions that are influenced by the Covid-19 outbreak at the travel behavior and urban infrastructure levels and future challenges have also been identified. Researchers have taken an open-coding step to determine the in-vivo codes (i.e., the words and phrases used by the experts) and have concentrated on phrases and evaluated the concept of each answer. To classify acceptable codes, the research investigated the discrepancies between codes to ensure inter-coder reliability (Fritschy & Spinler, 2019; von Briel, 2018). Researchers have used sub-codes to ensure that all codes are evaluated systematically. Also, each expert was given a number code to avoid the emerging personal identity and privacy (Manias-Muñoz et al., 2019; Melander et al., 2019; Turoff & Linstone, 2002).

In the second phase of the Delphi analysis, experts were asked to rate and prioritize the constructs in order of importance and the degree to which each factor is impacted by the outbreak of COVID-19 outbreak and its impacts (de Jesus et al., 2019; Nguyen et al., 2019; Okoli & Pawlowski, 2004). In Phases 2 and 3, experts were advised to evaluate the constructs separately by using a "Five-point Likert Scale" varying from 1 ("very low") to 5 ("very high"). A rating of 0 was included to imply non-applicability. The frequency distribution, the mean, and the standard deviation of each construct were shown in Tables 8–11; the results were suitable enough to allow for the detection of a distinction between the constructs (Belton et al., 2019; de Jesus et al., 2019; Egfjord & Sund, 2020; Kache & Seuring, 2017; Miller et al., 2020). In phase 3, the researchers sent the cumulative quantitative rankings and primary prioritization levels to the experts to allow them to compare their initial scores with the overall group average and to make adjustments when appropriate (Grisham, 2009). In the final process, a few small modifications were made by the experts. Since the Delphi analysis was very robust, the data collection was completed successfully. The researchers used version 26 of SPSS software to perform the data analysis in this study.

3.5. Validity, reliability, stability, and replicability

The composition of the expert panel (i.e., competent managers with several years of experience and highly educated experts in mobility and civil engineering) and the iterative manner in which the study was carried out affirm the internal validity of the survey, render the Delphi method a robust approach in the production of accurate data (Bao et al., 2020; Belton et al., 2019; Gupta & Clarke, 1996). External validity is the degree to which the results of the analysis can be applied in larger populations (Davis, 2008) that were not at issue in this work since participants were from different countries and working on different sectors of shared mobility. This way, the study avoided prejudices in the answers given and banished the "opinion leaders' domination" concerns; experts were not discouraged from completing the questionnaires and were free to think freely and give their opinions unchanged (Bolger & Wright, 2011; Goodman, 1987). From the point of view of many scholars, quality is more critical than quantity, information, experience, and knowledge, since having unqualified experts ends in distorted results (Akins, Tolson, & Cole, 2005; Alyami et al., 2014; Nguyen & Wang, 2018; Nguyen et al., 2019; Rae & Alexander, 2017; Wang & Nguyen, 2017). In addition, the size of the expert pool should not be too large to make it unworkable (low response rates and time constraints) and not too small to affirm its representativeness (de Jesus et al., 2019; Gerrish & Lacey, 2010; Hsu & Sandford, 2007). In this research, against this false presumption, there are no guidelines laid down in Delphi surveys for the minimum number of participants, the minimum number of rounds, or any other favored procedures and tools. (Manias-Muñoz et al., 2019). The number of experts was examined to be adequate for both qualitative and quantitative analysis. (de Jesus et al., 2019; Kache & Seuring, 2017; von Briel, 2018). Since the shared mobility market is heavily regulated in all countries around the world. Researchers have tested for possible non-response bias by dividing the panel of experts into early and late

respondents. The Mann-Whitney test was carried out to contrast the responses from both classes, which did not reveal any major variations. As a result, the lack of response bias was not a concern in this study (Armstrong & Overton, 1977; Roßmann, Canzaniello, Gracht, & Hartmann, 2018; von Briel, 2018). As stated earlier, a pilot survey analysis was performed to ensure the validity of the contents (Manias-Muñoz et al., 2019). This analysis also includes reliability, which is the degree to which identical outcomes are produced each time the test is replicated (von Briel, 2018).

As experts were asked to change their responses with regards to feedback from other participants in each phase (Fritschy & Spinler, 2019; Merfeld et al., 2019; von Briel, 2018), the authors were in charge of controlling stability. In the end, a three-phase Delphi research involving qualitative and quantitative methods led to a significant stable conclusion. The researchers, by ensuring that all measures and conclusions were as clear as possible, checked the repeatability of the results. This clarity was achieved by implementing the Delphi analysis in three phases and recording the Delphi process, including the design of the study, the collection of experts, and the procedures for collecting data.

4. Results

4.1. Phase 1 results

Experts were invited to express their views on opportunities and challenges that the Covid-19 outbreak has had on the sustainability of shared mobility in social, economic, and environmental domains. The experts offered 216 responses, which were carefully analyzed and aggregated. We stuck to the guild lines (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003; von Briel, 2018). In the first stage, 81 elements were listed as critical items. After aggregation and incorporation by axial coding, this is the method of linking and comparing subcategories to categories (von Briel, 2018) 35 constructs (Taking into account all the opportunities and challenges encountered at the travel behavior and urban infrastructure levels) were derived via the sub-questions. Among the seven social opportunities, four are at the travel behavior level, and three are at the urban infrastructure level. Among the four economic opportunities, three are at the travel behavior level, and one is at the urban infrastructure level. And Among the six environmental opportunities, two are at the travel behavior level, and four are at the urban infrastructure level. In challenges, among the challenges associated with the travel behavior level, five are social, three are economical, and two are environmental. Whereas among the challenges associated with the urban infrastructure level, two are social, three are economical, and three are environmental (Tables 5 and 6).

4.2. Phase 2 results

In this phase, constructs with a mean group rating of 4.5 or higher were deemed to be the most significant objects found by the expert team. Among the opportunities relevant to the social dimension of sustainability, "Social and cultural factors play a more important role" received the third rank (AVE = 4.55) across the travel behavior level, and "Considering people needs over cars' in planning urban infrastructure" has gained the second place (AVE = 4.72) across the urban infrastructure level. In the dimension of economic, "Unjustified rides decline" attained the second rank (AVE = 4.61) at the travel behavior level, and "Commercial increase for digitalization increase" reached the first place (AVE = 4.77). Across the environmental dimension of sustainability, "spike in using green mobility" received the highest rank (AVE = 4.72) of all other constructs associated with opportunities at travel behavior, whereas "Rethinking of urban planning to protect the environment" has only reached the second place (AVE = 4.61) at the urban infrastructure level. Among the challenges linked to the social dimension of sustainability, "Lack of trust among passengers" received the highest rank (AVE = 4.83) across the travel behavior level, and "Scarcity of urban

Table 5

Identified opportunities on travel behavior and urban infrastructure levels.

Identified challenges	Level of applicability	
	Travel Behavior	Urban Infrastructure
Social		
Traveling abroad nosedive	Y	–
Health care systems Asserting not to share vehicles	Y	–
Lack of trust among passengers	Y	–
Scarcity of urban infrastructures for imposing social distancing policy	–	Y
Handling crowds in transport infrastructures	–	Y
Increasing racism and discrimination	Y	–
The difficulty of changing the travel routines	Y	–
Economic		
Urban freight distributions lag in the pandemic	–	Y
Riders spend less money on transportation	Y	–
Essential workers need to be on work in any situation	Y	–
Reduction in investment in mobility infrastructures	–	Y
Taxis and hailing rides are much more expensive	Y	–
High-tech infrastructures are not sufficient	–	Y
Environmental		
Most cities don't have enough bike lanes	–	Y
Environment issues in urban areas rise	–	Y
Using private cars increases	Y	–
Trivialize environmental issues	Y	–
Roads are not capable to bear a large number of cars	–	Y

Table 6

Identified challenges in travel behavior and urban infrastructure levels (Z = Standard score; P = P-value (0.05)).

	AVE	SD	Number of experts with rating					
Opportunity constructs on travel behavior level			5	4	3	2	1	0
Social								
Social and cultural factors play a more important role	4.55	0.61	11	6	1	0	0	0
Feel-good factor rises because of less congestion	4.05	0.87	6	8	3	1	0	0
Improving mental health because of using bikes	3.83	1.09	6	6	3	3	0	0
Family trips increases and its good impacts	3.00	1.28	3	3	5	5	1	1
Economic								
Unjustified rides decline	4.61	0.70	12	5	1	0	0	0
A boom in online shopping and delivery services	4.11	1.18	9	5	2	1	1	0
Riders save more money by telecommuting	4.00	1.02	7	6	3	2	0	0
Environmental								
Spike in using green mobility	4.76	0.43	13	5	0	0	0	0
People walk more	4.00	1.53	10	4	1	1	1	1

infrastructures for imposing social distancing policy" has gained the first place (AVE = 4.72) across the urban infrastructure level. In the dimension of economic, "Riders spend less money on transportation" attained the second rank (AVE = 4.66) at the travel behavior level, and "Reduction in investment in mobility infrastructures" reached the first place (AVE = 4.61). Across the environmental dimension of sustainability, "Trivialize environmental issues" received the third of ranks (AVE = 4.55) of all other constructs associated with challenges at travel behavior, and "Environment issues in urban areas rise" reached third place (AVE = 4.55) at the urban infrastructure level.

4.3. Phase 3 results

The third phase includes adjustment and finalization of the previous phase rankings to boost the quality of the answers. Of the 18 participants, three adjusted their score slightly, while the others confirmed their prior scores. As a result, the ranking order was the same as it had been previously, and no additional construct would have to be added to the list, and so the stability, replicability, and reliability of the findings have been verified.

4.4. Overview of aggregated final results

The opportunities and challenges associated with the effect of the outbreak of COVID-19 on the sustainability of shared mobility have been determined based on the results of the Delphi method to address research questions. The researchers, by evaluating the constructs, arranged them in a series of different clusters to classify well-defined constructs.

4.4.1. Opportunities at the travel behavior level
The experts stated that at the travel behavior level, the COVID-19 outbreak affects the sustainability of shared mobility in all the dimensions. In the social dimension, "Social and cultural factors play a more role" is highly affected. In the economic dimension, "Unjustified rides decline". In the dimension of environmental, "Spike in using green mobility "is affected by the COVID-19 outbreak (Table 7).

4.4.2. Opportunities at the urban infrastructure level
Regarding the experts rating, at the urban infrastructure level, the COVID-19 outbreak has considerable effects on the sustainability of shared mobility in all the dimensions. In the social dimension, "Considering people needs over cars' in planning urban infrastructure", whereas in the environmental dimension, "Rethinking of urban planning to protect the environment", and as for new economic dimension, "Commercial increase for digitalization increase" is affected (Table 8).

4.4.3. Challenges at the travel behavior levels
At the travel behavior level, shared mobility confronts with serious problems and several issues requiring utter focus. Specifically, the major challenges identified by the experts are "Lack of trust among passengers," "Riders spend less money on transportation ", and "Trivialize environmental issues" (Table 9).

Table 7
Ranking of opportunity constructs on travel behavior.

	AVE	SD	Number of experts with rating					
Opportunity constructs on the urban infrastructure level			5	4	3	2	1	0
Social								
Considering people needs over cars' in planning urban infrastructure	4.72	0.46	13	5	0	0	0	0
Participate people in decision making in designing and planning	4.05	0.99	7	7	2	2	0	0
Increasing social equity in having access to transportation	3.38	1.46	5	4	5	2	1	1
Economic								
Commercial increase for digitalization increase	4.77	0.42	14	4	0	0	0	0
The convenience of empty streets for road repairing	3.11	1.40	4	3	5	3	3	0
Environmental								
Rethinking of urban planning to protect the environment	4.61	0.50	11	7	0	0	0	0
Shifting street space from cars for bikers and pedestrians	4.33	0.84	10	4	4	0	0	0
Freeing-up roads	4.05	0.99	7	7	2	2	0	0

Table 8
Ranking of opportunity constructs on the urban infrastructure level.

	AVE	SD	Number of experts with rating					
Opportunity constructs on the urban infrastructure level			5	4	3	2	1	0
Social								
Considering people needs over cars' in planning urban infrastructure	4.72	0.46	13	5	0	0	0	0
Participate people in decision making in designing and planning	4.05	0.99	7	7	2	2	0	0
Increasing social equity in having access to transportation	3.38	1.46	5	4	5	2	1	1
Economic								
Commercial increase for digitalization increase	4.77	0.42	14	4	0	0	0	0
The convenience of empty streets for road repairing	3.11	1.40	4	3	5	3	3	0
Environmental								
Rethinking of urban planning to protect the environment	4.61	0.50	11	7	0	0	0	0
Shifting street space from cars for bikers and pedestrians	4.33	0.84	10	4	4	0	0	0
Freeing-up roads	4.05	0.99	7	7	2	2	0	0

Table 9
Ranking of challenges constructs on travel behavior.

	AVE	SD	Number of experts with rating					
Challenges on travel behavior level			5	4	3	2	1	0
Social								
Lack of trust among passengers	4.81	0.40	15	3	0	0	0	0
Health care systems Asserting not to share vehicles	4.50	0.70	11	5	2	0	0	0
Increasing racism and discrimination	4.27	0.82	9	5	4	0	0	0
The difficulty of changing the travel routines	4.27	0.82	8	8	1	1	0	0
Traveling abroad nosedive	3.61	1.14	5	5	4	4	0	0
Economic								
Riders spend less money on transportation	4.66	0.59	13	4	1	0	0	0
Essential workers need to be at work in any situation	3.66	1.53	7	5	2	2	1	1
Taxis and hailing rides are much more expensive	3.22	1.66	5	4	4	2	1	2
Environmental								
Trivialize environmental issues	4.55	0.78	12	5	0	1	0	0
using private cars increases	4.33	0.76	9	6	3	0	0	0

4.4.4. Challenges at the travel urban infrastructure levels
Shared mobility is confronted by serious problems at the urban infrastructure level due to the COVID-19 outbreak. These are "Scarcity of urban infrastructures for imposing social distancing policy ", "Reduction in investment in mobility infrastructures", "and Environment issues in urban areas rise" (Table 10).

4.4.5. Determining key opportunities/challenges at the travel behavior and urban infrastructure levels
The ranking of opportunities and challenges at the travel behavior and urban infrastructure levels reveals that such constructions are strongly impacted by the outbreak of COVID-19, which, in turn, may have a direct effect on the sustainability of shared mobility. These constructs are also known to be the main dimensions since they have been awarded an overall score of 4.5 or higher. Accordingly, six such constructs are the key opportunities and challenges (Table 11). Figs. 2 and 3 demonstrate these challenges and opportunities.

Table 10
Ranking of challenge constructs on the urban infrastructure level.

|	AVE	SD	Number of experts with rating					
			5	4	3	2	1	0
Challenges on the urban infrastructure level								
Social								
Scarcity of urban infrastructures for imposing social distancing policy	4.72	0.46	13	5	0	0	0	0
Handling crowds in transport infrastructures	4.44	0.61	9	8	1	0	0	0
Economic								
Reduction in investment in mobility infrastructures	4.61	0.60	12	5	1	0	0	0
High-tech infrastructures are not sufficient	3.94	1.25	8	5	2	2	1	0
Urban freight distributions lag in the pandemic	3.38	1.50	5	5	3	3	1	1
Environmental								
Environment issues in urban areas rise	4.55	0.70	12	4	2	0	0	0
Roads are not capable to bear a large number of cars	4.11	1.07	9	4	3	2	0	0
Most cities don't have enough bike lanes	3.33	1.32	4	4	6	3	0	1

5. Discussion

5.1. Social attitudes and cultural factors are more important

Shared mobility marks an important milestone in the provision of sustainable development in striking a balance between ecological, economic, and social interests, so it is not just a subgroup of the sharing economy with few economic impacts to mention. The first part we are discussing we believe is of paramount importance because bringing existing appeals of shared mobility closer to the perception of a system in which technology and community needs meet requires complementing a study that seems quite apt in the disciplines of social science and human science. As well as being told, cars and humans have separate and intertwined biographies (Dowling, Maalsen, & Kent, 2018). The onset of the COVID-19 outbreak has shown us all that everyone's health is intertwined (Manjoo, 2020); on the other hand, pandemics can be stressful so as CDC states it may worsen mental health conditions, and people like frontline workers and essential workers may respond more strongly to the stress of a crisis (Centers for Disease Control & Prevention Public Agency., 2020); therefore social attitudes and human factors must receive serious consideration. As an attempt to bridge the before-mentioned research gap, it must be ascertained that in shared mobility, stakeholders do not affect a cavalier attitude to societal and human life factors. From this perspective, this opportunity could further investigation of a multi-attribute attitude towards capturing human flourishing for all the status-seeking individuals. The gaps and contradictions between morals and practice, words, and actions keep alive the necessity of continuity of raising knowledge about what initiatives are working and why. Social attitudes such as perceptions about the role of human and machine interface, longstanding notions around

vehicle ownership and usage (Corwin, Vitale, Kelly, & Cathles, 2015) could change in and/or impacts the adoptions of new technologies, and socio-demographic trends affect travel demand through a combination of the lifecycle, period, and cohort effects (Circella, Tiedeman, Handy, Alemi, & Mokhtarian, 2016). Covid-19 outbreak (with its dramatic period effects (Circella et al., 2016)) affects travel demand that coping with them highly depends on human factors and socio-demographic patterns. Macedo et al. in their proposed system of indicators for urban mobility has proposed a more homogenous distribution as of social is being 34 % and cultural stands for 12 % compared to environmental with 40 % and economic with 13 % in the system which results in a more efficient sustainability assessment system (Macedo et al., 2017).
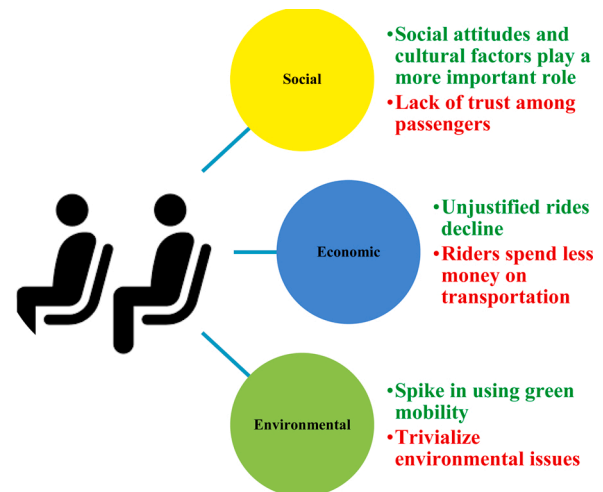
Fig. 2. The key opportunities and challenges at the travel behavior level.
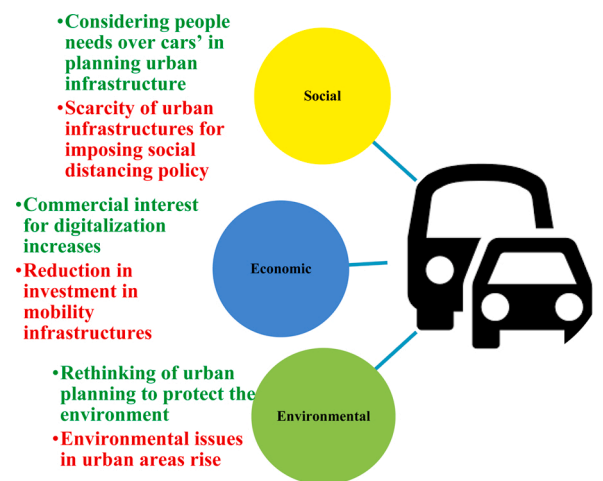
Fig. 3. The key opportunities and challenges at the urban infrastructure level.

Table 11
The key opportunities and challenges on travel behavior and urban infrastructure level.

Level	Opportunities	Challenges
Travel Behavior		1 Lack of trust among passengers
	1 Social attitudes and cultural factors play a more important role	2 Riders spend less money on transportation
	2 Unjustified rides decline	3 Trivialize environmental issues
	3 Spike in using green mobility	
Urban Infrastructure		1 Scarcity of urban infrastructures for imposing social distancing policy
	1 Considering people needs over cars' in planning urban infrastructure	2 Reduction in investment in mobility infrastructures
	2 Commercial interest for digitalization increases	3 Environment issues in urban areas rise
	3 Rethinking of urban planning to protect the environment	

The pandemic has shown the difference between societies, their individuals' economic, social and cultural differences, and any response to the consequences of the pandemic on the sharing economy must consider the Solidarity situation- mechanical solidarity and Organic Solidarity- in each community. In a vicious circle of health crises and economic recession, the corporated methods that have just been adopted by managers in imitation of other companies are not necessarily going to have the same results if the cultural differences were overlooked. In the districts that are not being faced with an overflow in their Intercity public transit and there is a mixture of shared mobility services available, the cultural differences and the degree to which people take COVID-19 seriously is a decisive factor that must be considered. Also, implementing policies such as social distancing and quarantine highly depends on cultural factors and individual habits (Huynh, 2020; Rahmani & Mirmahaleh, 2020).

To have a better justification, the distillation of the essence of social science and human science and the concept of rights-based ethics must be deployed. Within a community, essential characteristics have to be recognized. One of these characteristics, according to Park, is that its individual units living in a relationship of mutual interdependence that is symbiotic rather than societal, but as Neal argues, both human ecology and the ecological metaphor agree that interdependence implies that people come to depend on one another to meet their needs, and thus that a functioning society requires different people performing different functions(Neal, 2020).

5.2. The inherited crowded public transit and social distancing dilemma

Amid concerns about the possibility of transmission coronavirus in public transit (see introduction), a lack of trust among passengers has become the major challenge (Christina Goldbaum, 2020a). Thierry Mallet, CEO of Transdev, which operates transit systems in 18 countries and has 82,000 employees, said many riders would shift to personal cars (McFarland, 2020). These concerns are not just among passengers and riders, although among drivers and operators. Unions for transportation workers have been demanding mandatory mask policies for riders since the death of Detroit bus driver Jason Hargrove on April 1(George, 2020). Mayor Bill de Blasio in March said, "The subway is not the issue, the train is not the issue, the issue [with the coronavirus] is prolonged, consistent contact."(Sosa & Sheehy, 2020). These concerns have recently found another serious basis, in a paper titled "It Is Time to Address Airborne Transmission of Covid-19," it is expected that SARS-CoV-2 behaves similarly, and that transmission via airborne micro-droplets is an important pathway, and they recommend Avoiding overcrowding, particularly in public transport and public buildings (Morawska & Milton, 2020). In the discussion about the future of the sharing economy, trust seems to be generally recognized as the most important driver (Ter Huurne, Ronteltap, Corten, & Buskens, 2017) and in a recently published study, Mehari found that low social trust is positively associated with reduced citizen mobility (Mehari, 2020). In May, nearly half of New Yorkers said they would avoid public transportation when the city comes back to life, according to a survey conducted by Elucd (Goldbaum, 2020a). Trust concerns were so serious from the early stages of the pandemic, and after a few months, as countries are trying to get back to normal, trust concerns seem not going to be eliminated as easily as they have been developed. The Centers for Disease Control and Prevention public agency suggests that drivers must avoid providing pooled rides or picking up multiple passengers who would not otherwise be riding together on the same route to limit contact (Centers for Disease Control & Prevention, 2020) and the World Health Organization in a published document recommends that If you have to use a taxi, avoid sharing it with other passengers, as physical distancing would not be possible (World Health Organization, 2020b). First, we need to know what trust is. Trust is a peculiar belief predicated not on evidence but on the lack of contrary evidence – a feature that makes it vulnerable to deliberate destruction (Gambetta, 2000). Ter

Huurne, M., et al. subdivided trust in the sharing economy into trusting beliefs towards the seller, the buyer, the platform, and the community (Ter Huurne et al., 2017). So to bolster public trust in shared mobility, one should focus on the lack of contrary evidence and ultimately rebuilding trust beliefs. In this section, we list some of the useful and requisite steps that experts have mentioned. These steps must be taken while imposing other measures in other parts of this study to end the cliff-hanging situation that has plummeted public transit use to a level that seems to be an all-time low for quite a time:

● Stagger working hours
● Wear a protective mask
● Disinfection
● limit contact
● Provide Occupancy level monitoring
● Help to get essential workers
● Support drivers and front-line workers

According to the CDC, Social distancing, also called "physical distancing," means keeping space between yourself and other people outside of your home (Centers for Disease Control & Prevention Public agency, 2020). The social distancing policy has been an effective response to the outbreak of other epidemics (Ferguson et al., 2005; Hatchett et al., 2007; Markel et al., 2007; Poletti et al., 2009) and for COVID-19 increasing social distance can significantly reduce the infection rate (20–40 %) during the first 30 min (Sun & Zhai, 2020). Although CDC advises that Limiting face-to-face contact with others is the best way to reduce the spread of coronavirus disease 2019 (COVID-19) (Centers for Disease Control & Prevention Public agency, 2020), in shared mobility, it is a catch-22 situation – you can't expect to reopen the economy and get back to normal without having an overflow in your public transit. WHO warns where people come together in crowds, you are more likely to come into close contact with someone that has COIVD-19, and it is more difficult to maintain a physical distance of 1 m (3 feet) (Organization, 2014; World Health Organization, 2020a); however, studies demonstrate that 1 m is not enough for infection controlling and 2−6 m is the safe distance (Sun & Zhai, 2020). The dependence on crowded public transit in large metro areas is now a real challenge for authorities and health care systems if they want their figures to keep receding. Buses, trains, and shared vehicles are the top contact points and therefore difficult to impose social distancing regulations and it decays positive social influences of shared mobility on urban sustainability including safety and effectiveness (X. Wu & Zhi, 2016). In the central business district of Sydney, where 65 percent of workers commute by public transport, distancing rules will mean that only about 10–12 percent will be able to take that option (Currie, 2020). There seems to be no other choice for many except to use shared mobility services. These concerns about urban anomalies go beyond shared mobility and lie between urban planning and controlling crowd behavior. The Social Distancing Circles at Domino Park, Brooklyn is an example of how cities try to ensure that people follow social distancing in almost every situation (Young, 2020). We recommend these steps:

● Urban anomaly detection
● Crowd manipulation
● Monitoring social distancing

5.3. A temporary backslide or the worst slump

The effects of the COVID-19 outbreak and the policy responses resulted in more than 1100 daily stock market moves (up or down) greater than 2.5 percent from 1900 to 2019 (Baker et al., 2020). This made the president of the United States say on 11 March 2020 that "This is not a financial crisis. This is just a temporary moment that we will overcome together as a nation…" when more than 1000 cases of COVID-19 have hit the U.S. As of writing this article there are more than

seven million U.S confirmed cases and the U.S economy that had entered recession in February after the end of the longest expansion in history has seen a 32 percent negative economic growth for the second quarter. But China, the second-biggest economy in the world in which the Virus came from there, surprisingly has a low number of cases and has seen a rise in economic growth in the second quarter. This big recession had its negative impacts on shared mobility derailed it from its unvarying routines. Thomas A. Egan, CEO of MV Transportation, Inc. In an article titled "The Future of Public Transportation," published in a book with the same title has named constrained budgets, regulatory requirements, record unemployment, and rising costs of running service as the factors affecting how agencies deliver transit. It seems like this disruptive pandemic has made these constructs stronger and perilous. The pandemic transformed the way people spend, and transportation is one of the very first places that had felt the changes. The worst-case scenarios are that public transit systems bankrupt, they will get little public money support in the near future (Honey-Roses et al., 2020). With companies having their income evaporated, the costs of running services are rising sharply. Air travel is the quintessential industry, particularly hard-hit during the pandemic. The air travel industry was the first one but not the last one. It happened right, left, and center. Micro-mobility services and MaaS companies had to lay off their employees during this pandemic to meet their thin, constrained budgets, and it seems there is no cliffhanger to this nightmare. Big MaaS companies like Uber and micro-mobility companies like Bird had to lay off their employees during this pandemic, and Lime has merged into Uber. Seeking a balance in ride-hailing is now more important than ever; an unbalanced ride-hailing network may reduce the satisfaction of riders in using Uber services and in turn reduce ride-sourcing market share (Shokoohyar, Sobhani, & Ramezanpour Nargesi, 2020). On the other hand, drivers suffer from insufficient compensation of the operating costs, poor job security, experiencing bad behavior of the riders, and poor customer service (Shokoohyar, 2018). On the urban infrastructure level, reduction in investment in urban infrastructures is the consequence of this situation, and the transportation industry needs urgent financial support and fiscal facilities granted to small and medium-sized companies. UITP Europe has brought together more than 80 CEOs and city representatives to call for the urban public transport sector to be included in the EU's COVID-19 recovery plan. Walnum et al. in their paper, after stating that companies have no reason to reduce profits by reducing the scale of their business or volume of products; they want to sell more and gain market share, argue that one reason policymakers hesitate to curb mobility is because of its strong coupling to economic growth, but the rebound effects of that will be evident as long as the economy keeps growing (Walnum et al., 2014).

5.4. The environment is ingénue in this story

As Tedros Adhanom in a COVID-19 Virtual Press Conference on 27, May 2020 said, "the pandemic has given us a glimpse of what our world could look like if we took the bold steps that are needed to curb climate change and air pollution. Our air and water can be cleaner, our streets can be quieter and safer, and many of us have found new ways to work while spending more time with our families."(Tedros Adhanom., 2020).

The first guideline of the ES project for moving towards environmentally sustainable transport is developing a long-term vision of a desirable transport future that is sustainable for the environment and health and provides the benefits of mobility and access (Wiederkehr et al., 2004). The Paris Agreement, adopted in 2015, aims at keeping global temperature compared to that of the preindustrial climate, "well below 2 °C" (Rogelj et al., 2016; The ECONOMIST, 2020a). The EU has binding climate targets for 2020 and 2030, which apply to transport, and by signing the Paris Agreement, the EU also implicitly accepted 2050 targets (European Federation for Transport & Environment, 2020). In the United States, Joe Biden unveiled a new climate plan indicating that it will Ensure the U.S. achieves a 100 % clean energy economy and

reaches net-zero emissions no later than 2050 and Rally the rest of the world to meet the threat of climate change (Joe Biden's website, 2020). On the other hand, the school strike for climate change or Fridays for the future movement was an emblem of the awareness and the degree to which people and particularly the young generation care about climate change and protecting the environment, but the pandemic has derailed many of these plans. Climate change is no longer the top priority of the commission, which has an economic and political crisis to fight (The ECONOMIST, 2020a), and the Sustainable Development Scenario in the IEA's World Energy Outlook 2018 that presents a 6% decrease of energy consumption in transport for 2040(Noussan, Hafner, & Tagliapietra, 2020) may be jeopardized. The impacts of the COVID-19 outbreak on the energy sector include increased residential energy demand due to a reduction in mobility and a change in the nature of work (Mofijur et al., 2020). This situation is in contrast with Human ecology from an eco-ethical perspective; "Eco-ethics viewed from a human ecology perspective must be governed by the principles of the inseparability of human health and the social and physical-natural environment"(Alvim, de Oliveira, & Castellanos, 2020). By calling for a so-called green recovery plan in transportation, we can take steps towards low carbon production and a more sustainable, environmentally benign mobility. Michel Noussan et al. categorized the different policies that may be adapted to foster effective decarbonization of the transport sector on passenger or freight transport. The problem now is that COVID-19 has impeded movements towards some of them, like promoting the Increase in the Average Occupancy of Vehicles with Carpooling or promoting a shift from private cars to public transport and clean car sharing (Noussan et al., 2020).

Italy is an example to discuss more because Italy was the country that showed the seriousness of the coronavirus (Beria & Lunkar, 2020; McCann, Popovich, & Wu, 2020; Mofijur et al., 2020)and the first country that implemented a mass quarantine in which the share of people moving and the range of movement fell dramatically to a nearly physiological level (Beria & Lunkar, 2020), so the outcomes are of much greater importance from the perspective of social and environmental matters. Italy has also been a world leader in its reductions of greenhouse gases in recent years and planned to become the first country to make it mandatory for school children to learn about climate change and sustainable development (Mooney, Muyskens, Dennis, & Freedman, 2020). Fig. 4 shows that after easing lockdown and lifting the regulations, transit and driving are making their way back to the place where they had been before the crisis or even higher.

On the other hand, people may trivialize environmental issues during this turbulent time. The sharp plunge in oil prices in the first quarter of 2020, reduced carbon tax, the differences in which communities are more vulnerable to catch the virus and the immunity that some people assume they have over others from pollution and congestion negative impacts make them feel reluctant to fight against climate change hereafter. It certainly leads to more use of private cars and less interest in green vehicles which results in heavy traffic on the streets and therefore more pollution. It is also happening that COVID-19 daily death numbers may result in forgetting the numbers for past calamities of nature, such as an estimated 15,000 died in France in 2003 as a result of scorching August temperatures (The ECONOMIST, 2020c). Not all memories are equally welcome in awareness, and People to limit the time they spend thinking about unpleasant experiences. It is called Motivated Forgetting (Anderson & Hanslmayr, 2014).

5.5. Somehow, it had to be done!

In an article titled" Can the pandemic end the great innovation slowdown?" published in FT Weekend Magazine, the author, Tim Harford argued that the 2010−19 decade of productivity growth in the UK was the lowest for the past couple of centuries and hopes for a change after the pandemic (Harford, 2020). The covid-19 outbreak and its impact have increased commercial interest in digitalization and
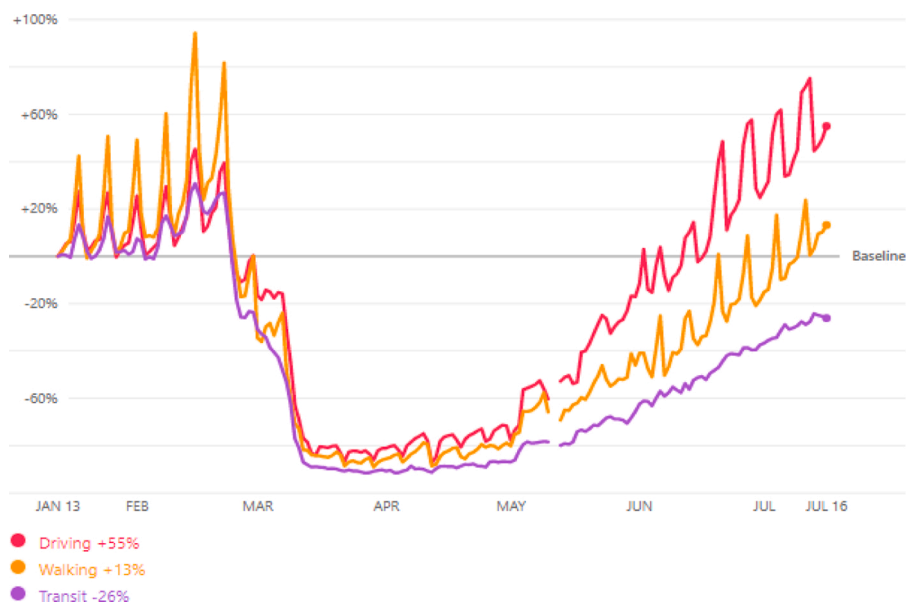
Fig. 4. Changes in transit and driving in Italy (Source: covid19.apple.com/mobility).

developing new technologies. Digitalization is a key enabler of sustainable development of cities' socio-economic dynamics with the potential to foster climate-friendly urban environments and societies (Balogun et al., 2020). In the shared mobility industry, many novel technologies have been introduced, and some could be endorsed during this pandemic to mitigate the negative impacts like Drone delivery, Robot delivery, AVs, Reservation Apps, and Truck platooning. Remote working is another reason to focus on using new technologies and digitalization in shared mobility services. More than one-third of the labor force between February and May 2020 switched to remote work, resulting in about half of American workers now working from home (Brynjolfsson et al., 2020). These technologies could lead to the concept of virtual cities; however, it takes time for an innovation to be communicated among the participants. In the Diffusion of Innovation (DOI) Theory, developed by E.M. Rogers in 1962, Rogers argues that diffusion is the process by which an innovation is communicated over time among the participants in a social system. Innovators are the people who are eager to use these new technologies, and they represent only 2.5 % of the population, followed by Early Adopters (13.5 %), Early majority (34 %), Late Majority (34 %), and Laggards (16 %) (Rogers, 2002). The Diffusion of Innovation theory and adaptation curve is a staple in marketing, and using this theory, in this case, helps us better understand the process of penetration of these new technologies. A promising future study is to investigate the impacts of hourly lockdown or weekend curfews on the behavior of drivers and the amount of accidents; even before the pandemic a slight difference could be seen as a study on the ride-sourcing mode in Philadelphia city showed traffic is slightly lighter during weekends when compared to weekdays and therefore drivers are able to drive faster (Shokoohyar, Sobhani, Sobhani et al., 2020). In addition, a surge in Delivery services provided by ride-sourcing networks requires rigorous approaches to adapt with the new circumstances and help those who are influenced by these new restrictions. Using machine learning techniques help companies like Uber in travel-time prediction and decision support (Shokoohyar, Sobhani, Malhotra, & Liang, 2020).

5.6. A sustainable, human-centered mobility

"No specific drugs or vaccines are available, and health systems are overburdened everywhere. We have to rely on targeted, non-coercive, community interventions with sufficient transparency and public

engagement and trust, and implement them urgently (Ebrahim, Ahmed, Gozzer, Schlagenhauf, & Memish, 2020)."

The reason why our modern way of life has been beset by coronavirus outbreak is simply put out in a title of an article in the New York Times as it says, "Public spaces weren't designed for pandemics" (Hu & Haag, 2020). It is probably true because there are other large cities like New York that suffered more from coronavirus. In fact, the pandemic first struck in major metropolises, and then it found its way to rural areas (Thebault, 2020). Hence the urban planning is an important consideration if we do not want dense cities to lose their appeal, and Seoul is the oft-quoted example in handling the coronavirus outbreak with a much smaller fraction of deaths than large western cities like New York (Putzier, 2020; The ECONOMIST, 2020b). We all might have had hopes of getting back to normal soon or at least have thought about it, but is a normal life good enough?! Now that countries have reopened, is a normal city, a normal society going to be the ultimate reward? What is the right direction for a better-planned city, and how shared mobility comes under this new vision? The current pandemic threatens to profoundly change our relationship with these spaces, especially when other people are present (Honey-Roses et al., 2020). This pandemic gave a second wind to green mobility services and caused a global awareness that prompted a lot of people to use such services and vehicles for the first time. A chance to have clean and clear air in our cities and a new form of streets, free of cars, was a desire that had been fulfilled during the lockdown. New York's transportation commissioner, Polly Trottenberg, said that the de Blasio administration is committed to examining how the city can capitalize on the recent shift toward bikes and other forms of "micro-mobility." (Goldbaum, 2020a). Shared mobility operators have suffered but will rebound quickly on the back of food delivery, logistics, and micro-mobility services (Henze, 2020). A global surge in using bikes (Butler, 2020b; Chen, 2020; Christina Goldbaum, 2020b) and shared micro-mobility like bike-share and e-scooter share fleets (D'Agostino, Circella, & Sperling, 2020; Wilson, 2020) after lockdown besides the fact that many people avoid doing some unnecessary trips or have had been spending much less which occurs to using cheaper fleets (Wilson, 2020) has brought a marvelous opportunity to get people to use eco-mobility services in the future. The EcoMobility Alliance which is a network of ambitious cities, committed to building a sustainable mobility future that is efficient, people-centered, low emission and environmentally friendly is an example of these efforts that have been started years ago and now 68 percent of the Alliance Cities residents

Walk, cycle and use public transportation. A sustainable transportation (ST) in comparison to business as usual (BAU) Emphasizes accessibility, quality, the plurality (multi-modality), interconnections (inter--modality), and integrated planning combining transportation with other relevant areas (Schiller & Kenworthy, 2017). But integrated urban planning needs to be people-centered too. As of lifting regulations and easing lock-down, a lot of cities are having second thoughts like Sadiq Khan, Mayor of London, says the city needs to be repurposed for people as it emerges from coronavirus restrictions (Taylor, 2020). The differences in sustainability of major cities result from diverse government and industrial policies, economic bases, cultures, community norms, and lifestyles (Sassen, 2018). In addition, a sustainable economic development additionally argues that 'real' improvements cannot occur unless the strategies which are being formulated and implemented are ecologically sustainable over the long term, are consistent with social values and institutions, and encourage 'grassroots' participation in the development process (Barbier, 1987). Ruffalo, M. and Ghirmatzion, R. In a column for TIME, wrote down that "this pandemic opened a new window to trust the locals because responses without community leadership tend to make matters worse. When communities have resources to build on local strengths and buy-in, they come up with effective, durable, and creative solutions to address short-term crises and long-term inequities." (Ruffalo & Ghirmatzion, 2020). Cities also need more autonomy in this time as ECONOMIST writes that New York's mayor, Bill de Blasio, has been a poor advertisement for muscular local government, but Seoul's world-beating coronavirus response has been organized largely by the metropolitan government and by local officials (The ECONOMIST, 2020b). Maintaining the trust of citizens at a time of crisis like the current one is a priority that includes respecting the requirements for maintaining fundamental respect for human rights, ethical principles, and existing legislation (Nanni et al., 2020). The pandemic has opened our eyes to novel ways of living and working in which we can assure economic growth not in a way that harms the nature, but in a way that brings sustainability. It is the right time for shared mobility to take the first step and make changes. Martin, C.J. Argues that If the sharing economy follows this pathway of corporate co-option it appears unlikely to drive a transition to sustainability (Martin, 2016). It is a very ghoulish vision to want to have both, but it seems not unlikely.

6. Conclusion

The shared mobility industry has seen many changes in this decade more through digitalization, and currently, some of the biggest companies in the world are in the shared mobility industry. This astonishing growth has had some big barriers and opponents. It seems that the COVID-19 outbreak would be its arch-enemy by far. This study, by looking through the impacts of the COVID-19 outbreak on shared mobility, had tried to explain opportunities and challenges that this pandemic has brought. In this regard, contemplating different opinions and having a comprehensive attitude in a study was crucial, which has made the Delphi method a perfect setting for this purpose. By assessing social, economic, and environmental together, we realized that all of them have had almost equal importance if we wanted to mitigate the negative impacts of the COVID-19 outbreak on shared mobility. If any recovery plan for shared mobility does not consider social and environmental factors as important as economic constructs, it might result in some more serious problems with perilous impacts on the whole industry.

In this study, the authors focused on the sustainability of shared mobility from the perspective of social, economic, and environmental, and the novelty of this study is to categorize the impacts on travel behavior level and urban infrastructure level. We believe this classification was necessary to better realize different constructs of opportunities and challenges, and only in this way a full perception could be gained. This study is the first comprehensive research with an international relevance on the subject.

As a work limitation, we highlight the difficulty of working on the most challenging and rapidly changing subject that has had its impacts on both macro-level and micro-level, which made it so hard for the team to not lose its focus on the latest news and reports and not let this affect the whole process of carrying out the research.

As a recommendation for future work, we suggest further studies on each of the constructs presented in the results and the recommendations made in each part of the discussion. Future studies will have different results in various countries more through the differences in the economic situation and social and cultural factors that we have discussed before.

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.

Appendix A

	Gender of the final respondents	Countries of the final respondents	Number and background of invited experts			
Level of expertise	F = Female M = Male	The US (US)- Canda (Ca) Germany (Ger)- India (In) England (En) – Iran (Ir) China (Ch) – Italy (It)	Years of expertise in different levels	Background on Shared mobility (final number of participants)	Background on Civil engineering (final number of participants)	Final number of study participants
Level 4	2(M), 1 (F)	3 (US)	20 or more	2(2)	2(1)	4(3)
Level 3	5 (M)	3 (Us) – 1 (Ch)- 1 (It)	15−10	3(2)	3(3)	6(5)
Level 2	6(M),2(F)	3 (En)– 2 (Ger) – 3 (Ca)	10−15	4(4)	5(4)	9(8)
Level 1	1(M), 1 (F)	2 (In)	Below 10	1(1)	1(1)	2(2)
Summation				10(9)	11(9)	21(18)

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