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Challenges for urban transport policy after the Covid-19 pandemic: Main findings from a survey in 20 European cities

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ABSTRACT

This article explores the changes in transport and mobility patterns that were triggered by the Covid-19 pandemic, as well as citizens’ potential new expectations arising from this situation regarding public transport policy and urban planning. We conducted an extensive survey in 20 cities across 11 European countries during the second quarter of 2021, with a total of 10,000 respondents. The information that we collected covered the change in the frequency of technology-based alternatives to travel—such as teleworking and online shopping—compared to the pre-pandemic period. It also included the change in trip frequency, purpose, mode and destination. Using the survey dataset as input, we applied a classification model that explains the change in mode choice based on the respondent characteristics and preferences. Our findings suggest that the changes in mobility patterns induced by the pandemic are the result of the combination of the degree of mobility restrictions imposed in each city, the adoption of new lifestyle and work patterns, and individual choices that depend on personal risk aversion. We identify three main challenges for urban transport policy: the increasing use of car that can reinforce long-term car dependency, the avoidance of public transport that may lead to financial and operational instability, and the uncertainty as regards the future of innovation in urban transport, especially as regards emerging technologies and business models.

1. Introduction

The devastating Covid-19 pandemic could be an opportunity—a ‘silver lining’—for a change in lifestyles towards a more sustainable future. The early consensus in the field of transport policy—as expressed in the WCTRS COVID-19 Taskforce expert survey in April/May 2021—suggested that the balance of potential impacts in the long term would be positive (Zhang et al., 2021). After more than 60 months from the start of the pandemic—however—the observed trends do not justify such optimism. The results of the survey in 20 European cities presented here suggest that the role of the car in urban transport has been reinforced, to the detriment of public transport and emerging mobility options.

Transport activity is showing a gradual return to normality, with the pandemic getting under control and mobility restrictions ending, even though additional waves and variants emerge (Christidis et al., 2021). The shock for society and economy has—however—caused a number of behavioural changes that can influence the evolution of the transport sector. New remote work patterns or personal risk avoidance attitudes can lead to increased levels of car ownership and use (Lopez Soler et al., 2021). Public policy priorities in the aftermath of the pandemic would need to address the emerging challenges and adopt measures that can sustain the shift to active travel, support public transport, railways and aviation, and stimulate innovation in transport technologies and services.

The impact of the pandemic on mobility has been already monitored and analysed extensively, at least as regards the initial stages. In the Netherlands, data for the March–April 2020 period indicate a drastic decrease of mobility during the ‘intelligent lockdown’ strategy applied (de Haas et al., 2020). In Spain, the avoidance of public transport due to fear of contagion was already evident in April 2020 (Echaniz et al., 2021). In India, two different surveys (Das et al., 2021; Thombre and Agarwal, 2021) in the period March–June 2020 observed an increased car dependency and a generalized avoidance of public transport in large urban areas, across all income groups, the main reason appearing to be...
the perception of high contagion risk in mass transit. Similar trends were observed at later stages of the pandemic, as for example in the October–December 2020 period in Toronto (Wang et al., 2021). In the USA, public transport was also affected, but users with lower income changed their mobility patterns to a lesser extent (Parker et al., 2021), probably due to the lack of alternatives.

In China, where the pandemic was brought under control relatively early in 2020, a lasting impact on mobility choices was observed throughout the rest of the year. A widespread shift from public to private transport modes was accompanied by an increased willingness to purchase a car (Zhou et al., 2021). The decrease in demand for public transport was independent of the pandemic’s evolution in each Chinese city (Xin et al., 2021), indicating that the risk perception can last significantly longer than the actual health emergency. On the other hand, in Australia -where the pandemic had a slow evolution-confidence in public transport fell rapidly during March and April 2020 (Beck and Hensher, 2020). A pre-emptive change in mobility was also observed in Switzerland (Molloy et al., 2021), with cycling attracting a significant share of activity for all trip purposes.

In this work, we explore the longer term impacts of the Covid-19 pandemic on mobility and identify the main challenges for urban transport policy. We carried out an extensive user survey on the changes of personal lifestyle and mobility patterns still present after most mobility restrictions had been lifted (June 2021). In addition, we applied a classification model that explains the main reasons for change in mobility patterns and identifies the user groups that can be expected to modify their mobility choices.

2. Data and methods

We combined an extensive user survey in a representative group of European cities with a classification model that allows the identification of causal links between the respondents’ characteristics and choices. This approach allowed us to quantify the changes in lifestyles and mobility triggered by the pandemic and -subsequently- identify the main factors that influenced the observed behaviour.

2.1. Survey

We designed and carried out a survey in 20 cities across 11 Member States of the European Union addressing the impacts of the pandemic on personal mobility choices. The goal was to identify the changes in activity, lifestyles and preferences that may lead to a prolonged effect on the urban transport system, especially as regards demand and modal split. The survey explores the changes introduced by the coronavirus pandemic in transport habits, as well as citizens’ potential new expectations arising from this situation regarding public transport policy and urban planning.

The survey covered the Functional Urban Area (FUA) of each city, which includes the core urban area and its commuting zone. For each FUA, 500 respondents completed a detailed questionnaire:

- Demographic information: age, sex, level of education, income, number of household members
- Employment information: employment status, change of employment status due to pandemic, frequency of teleworking, reasons for not being able to telework
- Mobility patterns before the pandemic:
  - Frequency of use of transport avoidance options: work from home, video calls to family and friends, phone/video-conferencing for work, use of phone and video calls for health and medical services, purchase of goods online, use of home delivery services for groceries
  - Frequency of use of transport modes: walking, private bike/e-bike, shared bike/e-bike, private scooter/e-scooter, shared scooter services, private motorbike/moped, shared motorbike/moped, private car as driver, private car as passenger, shared car as driver, shared car as passenger, taxi, ride-hailing services, urban public transport (bus, tram, metro, rail, etc.)
- Frequency of use of each mode for each trip purpose: commuting, business, education, visiting relatives/friends, accompanying children to/from school, accompanying family and friends, purchasing groceries, other shopping, leisure
- Specific changes of mobility patterns due to the pandemic: use of transport avoidance options, level of comfort with using transport avoidance options, type of change in mobility patterns (number of trips, transport mode, trip schedule, destination), trip purposes affected, frequency of use of each mode, reasons for change in most frequent mode used
- User expectations as regards future mobility patterns: change in frequency of use of transport avoidance options, change in frequency of each transport mode
- Change in vehicle ownership due to the pandemic: purchase of cars (new, second-hand), bicycles, electric bicycles, motorbikes/mopeds, scooters/e-scooters
- Accessibility of public transport: distance, availability, frequency, changes due to the pandemic

We followed a combined approach of online (Computer-Assisted Web Interviews, CAWI) and telephone (Computer-Assisted Telephone Interviews, CATI) interviews. The combination of the two methods of data collection aimed at achieving a representative sample. CAWI interviews use panels of respondents with access to the internet and may under-represent specific segments of the population that may have more limited access to technology, such as lower education, lower income, or older age. In order to do so, we complemented the initial CAWI-based sample of 400 respondents in each city with 100 CATI-based interviews that targeted socio-demographic groups not covered sufficiently.

In order to achieve a representative sample, we applied quotas as regards the target number of respondents per socio-economic group. For each city, the target number of respondents matched its population profile according to five variables: age, sex, employment situation, education and urbanization (whether the respondent resides in the core of the urban area or in its periphery). The sample was constructed gradually, starting from the CAWI participants. Once the quota for one of the groups was filled, no additional respondents belonging to that group were sought. Once the 400 responses through CAWI were collected, the CATI sampling approach actively sought respondents from the under-represented groups until the shares for all four groups matched those in statistics, based on the following sources:

- sex and age at FUA level: EUROSTAT (Eurostat, 2021a)
- employment at FUA level: OECD (OECD, 2021)
- education at national level: EUROSTAT (Eurostat, 2021b)

The full questionnaire and the resulting dataset are available through the Data in Brief article (note: to be submitted in parallel, link to be added when the DiB article is accepted) linked to the present work.

2.2. Classification model

In order to explain how each user characteristic or preference influences the choice of transport mode during the pandemic, we constructed a classification model based on the gradient boosting method, a machine learning technique with numerous applications in predictive modelling (Christidis and Focas, 2019). The model was developed in R (R Core Team, 2013) and applies the ‘Xgboost’ algorithm (Chen and Guestrin, 2016) for model estimation and validation, and the ‘Shap’ forxgyboost package (Liu and Just, 2019) for the analysis and interpretation of model feature importance. Machine learning approaches --and Xgboost in particular-- allow for a higher model precision in modelling...
user choices than conventional stated preference methods, since they can account for the co-dependence between independent variables and do not require strict assumptions concerning the model structure and parameters. Moreover, in the particular case of the survey used here, gradient boosting classifiers allow for the use of categorical variables without assuming proportional odds, i.e., constant distances or monotonic relationships between their values. This capacity is especially important for the large number of survey questions that allowed responses in a 1–5 Likert scale, which include all questions regarding frequency of or comfort in using specific modes or adopting specific lifestyle and mobility patterns.

The classification model uses the full dataset of the responses to the survey as input. The dependent variable is a binary variable (0/1) indicating whether the respondent used car more frequently during the pandemic, after the confinement restrictions were lifted. As a first step, all 40 variables (questions) in the survey were used as features (independent variables) and more than 240 additional variables were constructed following standard feature engineering practices. The modelling setup followed the recommended practice of randomly splitting the dataset into training, testing, and validation sets (40%, 40%, and 20% respectively). We trained the model on the training set and evaluated its precision using the testing set. We used the validation set for the final evaluation to ensure that the model did not overfit and that it could generalize sufficiently well to previously unseen data. As an evaluation metric, we used AUC (area under the curve), the most frequently used aggregate measure of performance for classification models.

The procedure for the selection of the model variables was iterative. Initially, starting with the full set of original and engineered features, we dropped variables that the Xgboost algorithm evaluated as of low or zero importance. In subsequent iterations we tested different combinations of variables in terms of the resulting AUC for both the test and validation datasets, aiming at maximizing overall AUC and achieving comparable AUC values for test and validation. We gave preference to variables that improved the interpretability of the model and avoided others that could introduce information leak. The final model achieved an AUC of 0.715 on the test set and 0.712 on the validation set, values considered as satisfactory. The accuracy of the model—estimated through the confusion matrices of the test and validation sets—is 0.83. Judging by these evaluation metrics, the classification model explains a large part of the variance as regards the increase of car use and has good predictive capability as regards individual user probabilities. Apart from the application of the Xgboost algorithm, our methodology includes an enhanced capability for interpretation of the results. Instead of the standard Feature Importance analysis, we use the extended interpretative capabilities of SHAP values, an approach that allows the calculation of the importance of each model variable taking into account interactions.

3. Results

In order to summarize the survey results, we concentrate on the survey questions that reflect the main trends relevant to urban transport policy. On one hand, we present the results related to the behavioural changes with a potential repercussion on transport demand. The survey covered six main aspects: telework, online shopping, digital applications for personal communication, videoconferencing for business purposes, e-health and e-government, and groceries delivery. On the other hand, we explore the changes in mobility patterns in terms of trip purpose and trip mode.

3.1. Survey results

The mix of cities covered by the survey was intentionally diverse, in order to include a variety of city sizes and socio-economic profiles across Europe. This diversity is reflected in most of the behavioural changes and mobility patterns observed in the survey. The shift to teleworking was one of the main responses during the pandemic and a key disruptor for urban transport demand. The share of employed respondents who teleworked to some extent in June 2021 varied considerably, ranging from 65% in Dublin to 30% in Bacau (Fig. 1). Cities where more than 30% of the respondents fully teleworked include Dublin, Lisbon, Stockholm, Paris and Cluj-Napoca, as opposed to only 13% in Dresden and 15% in Lille. These differences are the result of several factors that include the economic profile of each city, the intensity of the pandemic at local or national level, the share of jobs that can be performed remotely, the measures put in place in each case to address the pandemic, the perceived risk by the employees, the flexibility offered by employers, technological preparedness, social and cultural norms, as well as the pre-existing frequency of telework before the pandemic.

The change in teleworking frequency as a result of the pandemic can be further explained when comparing with the levels before the pandemic (Fig. 2). Lisbon, Porto and Dublin had the highest share of respondents who increased their frequency of telework, an observation that suggests that the shift was supported by the overall measures to find the pandemic in Portugal and Ireland. In contrast, Paris, Madrid and Stockholm show a more moderate increase in frequency but still high telework levels in June 2021, a result of the already high uptake of remote work already before 2020. The average share of respondents in all 20 cities who telework much more often is 17.4% (ranging from 10% in Dresden to 27.4% in Lisbon), while that of respondents who telework at least more often is 31.4% (ranging from 22.6% in Charleroi and Dresden to 42% in Lisbon). There is also a small share of respondents who stated that they teleworked less frequently during the pandemic than they did before, but in most cases this is the result of changes in the respondents’ jobs during the period.

The other main behavioural changes brought by the pandemic—and potentially influencing transport and mobility—also appear to increase in frequency, at different degrees and a certain variation among the 20 cities (Fig. 3).

Online shopping was already quite extended in most European cities before the pandemic, but was the behavioural shift (out of the six main ones covered by the survey) that increased the most during the pandemic. On average, across the 20 cities, 31% shopped online more often and 15% much more often. In Dublin, Málaga and Lisbon the share of respondents who did so much more often was over 20%, while in Berlin, Dresden and Charleroi that share was between 8% and 9%. The change in the frequency of online shopping has a low correlation with that of teleworking (correlation coefficient = 0.14) or the other four behavioural shifts (0.14–0.24). The increased frequency is probably a large share of the population becoming accustomed to online shopping during the early stages of the pandemic—especially where lockdowns were imposed and maintaining its increased use still by June 2021. At the same time, the capacity of online retailers and conventional retailers with delivery services improved drastically during the pandemic and would now be considered as an option for a larger market segment. Especially in countries where there was limited presence of online retailers before 2020, such as Ireland and Portugal, the pandemic accelerated the introduction of new online retailers or the digitalisation of conventional brick-and-mortar businesses.

Video calls with family and friends increased at a comparable degree: 29% of respondents used them more often and 16% much more often. The variation among the 20 cities is considerable in this case too. Only 7.6% of respondents in Berlin stated that they use video calls much more often, while in Lisbon that share rises to 24% and it is only common before the pandemic, but the mobility restrictions in most cities greatly contributed in them becoming a common element of daily life. As in the case of online shopping, the familiarization with the technology during the early phases of the pandemic led to levels of adoption that can be probably sustained in the longer term. In terms of the impacts on transport demand, the question is whether video calls are a substitute for travel and mobility. Especially for long distance interactions, the increase in video calls can be attributed to the restrictions
in travel during the first phase of the pandemic and the slow recovery of both intra-national and international activity. Visiting friends and family is a main purpose for travel in Europe (about 30% of total tourism activity) and the unfulfilled demand probably increases digital interactions. At urban level, there are fewer reasons to suggest that there is a correlation between video calls to friends or family and mobility. There is probably still a certain degree of risk aversion that limits social activity, but it should be safe to assume that once the pandemic situation is completely under control video calls will be a complement—and not a substitute—of mobility related to social activity.

In contrast, technological substitutes for work and business related activity may have a more prolonged impact on urban (and long-distance) mobility. Actually, the correlation between the responses regarding the change in frequency of teleworking and those of video conferencing is particularly high (correlation coefficient = 0.58). The wide adoption of video-conferencing and remote collaboration tools during the pandemic allowed the familiarization of many employees and employers with work methods that do not require physical presence at the workplace. Better and easily accessible tools, in turn, contributed to teleworking becoming an option for a larger share of the workforce than before the pandemic. On average, 36% of respondent used videoconferences with colleagues or customers more often or much more often compared to before the pandemic. While this share is lower than the respective share for video calls with family and friends (45%), it is still remarkable considering that only a share of respondents had jobs that could be performed remotely. Similarly to the other indicators, there is a significant variation among cities, with the share of respondents increasing the frequency of work-related videoconferencing ranging from 25% (Dresden) to 50% (Lisbon).

The pandemic also stimulated an increase in the offer and use of online health and public services (e-health and e-government). Even after the initial confinement in the first half of year 2020, the share of respondents who increased their online access to such services was considerable (23% more often and 10% much more often). The variation among cities reveals certain country-level patterns. The two German cities in the sample reported the lowest increase in frequency (11% in both Berlin and Dresden), while the Spanish and Polish cities presented the highest increases (50% in Krakow, 46% in Poznan, 47% in Madrid, 49% in Málaga). There are obviously differences in the pre-existing level of e-health and e-government availability and use, as well as in the measures taken in each country during the pandemic. It is nevertheless reasonable to assume that the improved infrastructure and user uptake of online health and public services will remain in the future, at least partially. This can have an appreciable impact on transport demand. For example, 4% of total trips in Madrid are related to health services (Consorcio Transportes de Madrid, 2019).

The increase in the frequency of home delivery of groceries was remarkably less pronounced than for the other 5 technology based patterns. On average, 25% of respondents increased their frequency (17% more and 8% much more than before the pandemic), a still considerable change in daily activity. Respondents in the two cities in Germany appear to have increased frequency the least (11% in Berlin and 8% in Dresden). At the other extreme, 40% of respondents in Lisbon increased their use of home delivery for groceries.

Apart from the increased uptake of technology-based alternatives that substitute the need for physical trips, the survey results suggest that the impact on mobility patterns also remained significant in June 2021, even though mobility restrictions were not active (Fig. 4).

The majority of respondents across the 20 cities made fewer daily trips after the first phase of the pandemic compared to the pre-pandemic period. Dresden and Berlin were the outliers with the share of respondents who made fewer trips at 34% and 43% respectively. The
decrease in daily trips is-on aggregate terms-only weakly correlated with the technology-led changes in behaviour discussed above. The correlation between decreasing daily trips and teleworking frequency is 0.17, while the correlation with video-calls to friends and family is 0.18. The responses concerning the reasons for the decrease in the number of trips allow further elaboration: while 38% of respondents who decreased their daily trips commuted less, 68% decreased their trips to visit relatives and friends, and 52% decreased leisure related trips. It can be therefore deduced that a large share of the decrease in the number of trips is the results of lower levels of social activity and leisure, which were still affected by self-distancing choices or restrictions in the activity of leisure-related establishments.

Changes in modal choice were more moderate, averaging 18% across all respondents. The correlation with teleworking is even lower than in the case of making fewer trips (0.08). But similar patterns can be identified as regards the trip purpose for which the mode was changed: commuting (41% of respondents who changed mode), visiting relatives and friends (52%), leisure (64%), but also purchase of groceries and supermarket visits (40%). The latter is accompanied by a tendency of higher car use, either by respondents who already used car as their main mode, or by users of other transport modes who after the pandemic show increased preference for car use.

For most cities in the sample, the share of respondents who rescheduled their trips in order to avoid peak hours was between 20% and 25%. The trip purposes for which respondents avoided peak hours the most were groceries/supermarket shopping (62% of those avoiding peak hours) and other shopping trips (43%). For comparison, the corresponding shares of respondents who teleworked more frequently after the pandemic were 55% and 38% respectively. This difference suggests that the choice to avoid busy times in grocery and other shopping activities is driven mainly by the preference to maintain social distancing rather than the flexibility that remote working provides.

The changes in lifestyle and mobility patterns are also reflected in the frequency of use of each transport mode (Fig. 5). For all transport modes, a considerable share of respondents uses the specific mode less than before the pandemic, a direct repercussion of the decrease in the number of daily trips. There is, however, a significant modal shift, with a number of respondents using specific modes with higher frequency than before the pandemic.

The highest increase in frequency is observed for walking (34% of all respondents) and can be attributed to users avoiding public transport and other shared means of transport, such as taxis and hailing services.
The number of respondents who increased the frequency of walking is substantially higher than those who decreased it (18%), presumably because they performed fewer daily trips in general. The use of car (both as driver and as passenger) also increased for a considerable number of users (21% and 15% respectively), but was counterbalanced by a comparable share of respondents who decreased their frequency of using a car as a driver (22%) or as a passenger (28%). These shares suggest that in spite of a visible impact on car use as a result of the decreasing number of daily trips, the shift to car use from other modes dampens the net effect. In addition, the difference in the reaction of car drivers compared to car passengers implies that less carpooling takes place and the average load factor for cars decreases.

The pandemic also induced—at least judging from anecdotal evidence—an increased use of bicycles, conventional or electric, across Europe. The survey results corroborate this to a certain extent, with 14% of the respondents increasing the frequency of cycling (corresponding to 27% of the respondents who cycled before or after the pandemic). A comparable share, however, decreased the frequency (13%). The other options of two-wheeled transport, either private or shared, address different target markets in an urban context and had lower shares before the pandemic. For shared cycling, scooters, mopeds and motorcycles, conventional or electric, the number of users who decreased the frequency of use outweighs the number of those who increased it.

Demand for taxis was affected by both the falling number of daily trips and the modal shift towards modes allowing social distancing. As a consequence, 58% of taxi customers reduced their use, while only 10% of taxi users (4% of respondents) increased it, most probably shifting from public transport. The main competitor to taxis, ride hailing services such as Uber, faced a similar—though softer—market shock. Almost half of their customers (49%) decreased frequency, but 17% increased it, proportions comparable to those of car-sharing users.

The most noteworthy change in frequency of use was that for public transport. An alarming 46% of respondents, corresponding to 60% of public transport users, decreased their frequency of use of public transport. The behavioural change in this aspect is by far more profound than any other lifestyle or mobility change captured by the survey. It is obviously a consequence of users performing fewer trips as part of their daily activity, but the decline in the total demand for public transport is reinforced by a massive shift of the remaining daily trips to other modes. In fact, the survey results indicate that 35% of the respondents feel less comfortable with using public transport compared to before the pandemic, a feeling that can be attributed mainly to the contagion risk aversion.

Figs. 6 and 7 compare the changes in each city as regards trip frequency for car and public transport use, respectively, compared to that before the pandemic. The share of respondents who decreased car use is in general terms proportional to the share of respondents who also decreased their daily trips. The shares of those who increased car use, combined with the shares of those who decreased public transport use, reveal the existence of a shift from public transport to car use that is persistent in all 20 cities covered by the survey. This shift should be considered as worrying from the transport policy point of view, since it may lead to sustained or increased levels of car dependency that may continue even after the return to normal levels of total mobility demand. We further elaborate on the possible drivers of this shift in the following section.
3.2. Classification model

The survey shows a tendency of a large share of respondents to use the car more frequently after the pandemic restriction, even though their lifestyle and mobility patterns lead to a lower level of trip generation. We constructed a classification model that used car driving frequency as a dependent, binary, variable that indicates higher frequency. The independent variables included the user characteristics and preferences revealed through the survey questions. The tree-based classification algorithm ensures that collinearity and endogeneity are accounted for, a property that allows the quantification of the impact of each independent variable on the variation of the dependent variable.

The independent variables with the highest impact on the choice to increase car driving frequency, as well as the degree and direction of their impact, are visualized in Fig. 8. The most important indicator is—not surprisingly—whether the respondent used a car as a driver before the pandemic. The majority of those who were car drivers before the pandemic tend to use the car after the pandemic restrictions more frequently. This suggests that the pandemic in fact increased personal dependency on car use, regardless of other changes in lifestyle patterns. The second most important indicator is whether the use is comfortable with the use of car after the pandemic. The vast majority of respondents feel at least as comfortable with driving a car as before the pandemic (74%) and have higher odds of increasing its use.

Whether the respondent used public transport before the pandemic is high on the list of important variables and is the main explanation of why car use maintained high shares even though the total number of trips declined. The users of public transport before the pandemic have a high chance—compared to users of other modes of transport—to shift to cars after the pandemic.

In terms of lifestyle changes as a result of the pandemic, the most relevant appears to be the frequency of online purchases. Respondents who increased their frequency have a lower chance of increasing car use, an indication of the impact of online shopping on trip demand. Another behavioural change, in this case concerning mobility choices, is whether the respondent changed transport mode for commuting during the pandemic. The majority of those who did appear to have shifted to car use and to have a higher probability of continuing to use the car after the pandemic restrictions. A related indicator, lower in the ranking of importance, concerns the respondents who did not change their mobility patterns (trip frequency, mode, time or destination). They tend to drive more, while the ones who did change their behaviour—excluding the ones who changed modes and are treated separately—tend to use the car less.

Car ownership in the respondent’s household before the pandemic is relatively important and in line with expectations. However, the fact that respondents from non- or low-car households increased car use may conceal a trend of increased car purchases as a result of the pandemic. This interpretation is further supported by the next variable in terms of importance, the respondent’s age. The model suggests that the lower the age of the respondent, the higher the chances for increased car use frequency after the pandemic. This may sound counter-intuitive, but can be explained by the fact that the users of most other alternatives to cars are of lower age than car drivers, on average. The combination of the two observations can lead to the hypothesis that the pandemic accelerated car ownership or use at younger ages.

Still among the relatively important variables, the level of comfort in using public transport after the pandemic explains to a large extent the reason for the observed shift from public transport to car use. Respondents who feel less comfortable—as already mentioned, 35% of the total—have a higher chance of shifting to the car. It is also striking that—apart from the one concerning cars—the level of comfort with no other mode of transport appears in the list of the most important indicators. In addition, the availability of public transport does make a difference, whereas the availability of the other modes does not appear as important in the model. The hypothesis that can be derived is that the pandemic led to a decrease in the supply side of public transport that—subsequently—led to increase car use.

Geography plays a role in two aspects. Country specific characteristics related to the intensity of the pandemic and the measures applied to confront can explain differences in the impacts on mobility (in
addition to other economic, cultural and infrastructure availability differences). Finally, the distance to the respondent’s workplace may cause physical limitations to the available mobility options, as well as on the trip frequency.

4. Discussion

The results show significant variability at city level for most questions, since the evolution of the pandemic, the measures adopted and the population’s reaction differed considerably across the EU. In addition, the socio-economic profile of each city affected the adoption of alternatives such as teleworking or online shopping. In terms of mobility choices, while overall activity has fallen, the impact at modal level is mixed. Car use appears to have risen to levels close to those before the pandemic, at the cost of mainly public transport. Walking and cycling have increased their share, as a consequence of users maintaining social distance. Our results confirm to a large extent the findings of (Abdullah et al., 2020) that identify significant changes in trip purpose and modal choice. Even though the survey analysed here took place at a much later stage (June 2021), the shift from public transport to cars appears to be persistent. Mobility as a Service (MaaS) applications have been also negatively influenced by the fluctuations in mobility and risk aversion in the long term (Hensher, 2020).

We also corroborate the findings of (Eisenmann et al., 2021) as regards the mixed reactions of members of car-free households. While cycling in general increased its share, there is a considerable number of respondents who now find car as their preferred mode. This trend is accompanied by increased car ownership, especially by younger respondents, and reinforces car dependency in the long term. The most alarming trend revealed by the survey is the low level of comfort of users as regards the use of public transport. Combined with the overall decrease in trip demand, it may cause serious survival risks for public transport systems.

Operators and local authorities realized early-on that the decrease in demand and revenue could threaten the financial viability of public transport services. In the Netherlands, the criticality of the outlook triggered a coordinated approach between the national government and most regional and local stakeholders. The resulting actions, nevertheless, focused on the short-term provision of state aid in the form of an ‘availability fee’, without addressing the longer-term policy challenges.

Fig. 5. Change in frequency of use compared to before pandemic, all modes (for users of mode either before or during pandemic).
as regards the role of public transport (Hirschhorn, 2021). In Rome, social distancing rules in the metro system significantly reduced capacity and increased queues and waiting times. As a response, additional supply was added in order to avoid excessive travel times (Carrese et al., 2021). In Beijing, technological solutions were adopted in order to provide more customizable service for public transport, but at the same time relaxed restrictions on private car use (Zhou et al., 2021).

Such support measures provide a temporary solution to one side of the problem, maintaining the level of service even within a shrinking market. They do not address the other main challenge revealed by our results, the risk aversion that may keep users away from public transport or other modes that cannot ensure social distance. Psychological factors can play an important role on the perception of safety for passengers (Dong et al., 2021) and more should be done in order to increase the public’s confidence in public transport after the pandemic. An example is the approach followed in Japan, where an extensive information campaign involving central and local governments, experts, and medical institutes has proven successful in influencing the general perception of information reliability (Ding and Zhang, 2021). In this context, our results agree with the conclusion of (Vickerman, 2021) concerning the need to re-think the public transport model. The abrupt shock in demand and the longer-term hesitance of users to return to public transport will require significant efforts from operators and public authorities for the services to remain viable.

The behavioural changes (teleworking, video-calls, video-conferences, online shopping, e-health, e-government, home delivery of groceries) decrease demand for mobility, but the survey results suggest that the gradual return to normality is also reducing the extent to which they are adopted as an alternative to physical trips. How long can those changes stimulated by the pandemic be maintained remains an open question. Our results suggest that most of the behavioural changes were the consequence of restrictions that did not allow certain activities, rather than a deliberate choice of individuals.

As highlighted in (Marsden, G. et al., 2020), disruptive events such as the Covid-19 pandemic can change travel behaviour and can be an opportunity for policy action. The challenge for transport policy is to ensure that the favourable changes—especially the substitution of physical trips with technology based alternatives—are nourished, while the undesirable effects on modal shift are reversed. The momentum of active transport during the pandemic can be further exploited through measures that facilitate walking and cycling. For example, the extension of pedestrian zones or of cycling infrastructure can contribute to

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**Fig. 6.** Change of trip frequency as car driver after pandemic restrictions.
maintaining or increasing demand for active modes. Emerging urban planning concepts, such as the 15-min city can also influence modal split at the local scale. The establishment of low/zero emission zones can combine the objectives of achieving climate neutrality through the discouragement of conventional car traffic and the provision of alternatives for mobility. Public transport can benefit from extended networks and services that can steer demand away from passenger cars. New concepts such as mobility hubs, integrated multi-modal ticketing, micro-mobility services, and Mobility-as-a-Service applications can curb car dependency and further stimulate innovation in mobility solutions.

5. Conclusions

The survey of 10,000 residents in 20 cities across the EU provides valuable information as regards changes in lifestyle and mobility patterns as a result of the Covid-19 pandemic. The field work took place during the second quarter of 2021 and allows a snapshot of the situation after the first year of the pandemic, with most mobility restrictions already lifted, but with a still visible impact on daily activities. The pandemic initially triggered an increase in the use of technology-based alternatives that substitute the need for a physical trip, such as teleworking, online shopping or e-health and e-government applications. At the time of the survey, the use of such options was still higher than before the pandemic, even though at lower levels than those reached in the period between March and June 2020, when mobility restrictions of varying degree were in place in each city. The survey results suggest that while part of the population will eventually return to patterns of daily activity similar to those pre-pandemic, we can still expect certain practices that were adopted as a response to the pandemic to maintain at least a moderate long-term presence.

In terms of mobility patterns, the changes in daily activity have a direct repercussion on transport demand, both quantitative and qualitative. The number of daily trips is still lower than before the pandemic, mainly as a result of fewer trips related to work. Almost half of the survey respondents teleworked more frequently than before the pandemic. Limitations in public activities also led to a decrease in the number of trips for entertainment and recreation. The impact of individual preferences is also evident, mainly in relation to risk aversion that can be attributed to the pandemic evolution. Social activity -for example visits to friends and relatives-appears to still be lower than before the pandemic.

The observed risk aversion has a direct repercussion on mobility
patterns, especially as regards modal choice. We identified a clear trend in favour of car use. Even though the total number of daily trips has decreased, the increased frequency of using the car was enough to allow passenger car demand to reach levels comparable to those before the pandemic. In contrast, more than 50% of respondents decreased their use of public transport. The frequency of use of taxis, ride-hailing services or other shared modes of transport also fell considerably.

We applied a classification model that identifies the driving factors behind the shift from other modes to car use. According to the model, the respondents who used the car as their main transport mode before the pandemic are still comfortable in doing so, even though they may have reduced their trips for specific purposes such as shopping. Nevertheless, those who used public transport or other shared modes before are much less confident in continuing doing so, and tend to shift to cars. The trend is reinforced by the increased levels of car ownership -especially by younger respondents-which can signify a reversal for policies promoting public transport and other alternatives.

In conclusion, we identified three main challenges for transport policy based on the analysis of the survey results:

- Increased dependence on cars for daily urban mobility: the low perceived risk of contagion and the increasing car ownership levels contribute to maintaining high levels of private car trip demand and to attracting potential users of other, more sustainable-modes and business models.
- Risks for public transport due to the fall in demand: the -perhaps temporary-risk aversion towards shared modes of transport may cause financial problems for a large number of operators. It can be challenging to maintain the same level of service, which is necessary in order for operators not to lose additional market share.
- Impact on innovation: The fall in demand, the shift from shared to private alternatives and the overall uncertainty in terms of the evolution of economic activity may challenge the future of emerging technologies and business models such as micro-mobility or Mobility-as-a-Service (MaaS) which could potentially deliver more sustainable options for urban mobility.

**Author statement**

The views expressed are purely those of the authors and may not in
any circumstances be regarded as stating an official position of the European Commission. The territorial boundaries and names indicated in this work do not imply official endorsement or acceptance by the European Union.

Data availability

The underlying data is available as a Data in Brief article.

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