Case Studies on Transport Policy 12 (2023) 101010

Contents lists available at ScienceDirect

Case Studies on Transport Policy

journal homepage: www.elsevier.com/locate/cstp

Telework and MaaS adoption in a post-pandemic scenario. Evidence from municipal employees of Padua, Italy

Andrea Baldassa [a,b,*], Federico Orsini [a,b], Riccardo Ceccato [a]

[a] Department of Civil, Architectural and Environmental Engineering, University of Padua, 35131, Italy
[b] Mobility and Behavior Research Center – MoBe, University of Padua, 35131 Padua, Italy

ARTICLE INFO

Keywords:
MaaS
Work from home
COVID-19
Urban mobility
Discrete choice model

ABSTRACT

In recent years, the adoption of teleworking has witnessed a significant surge, partly driven by the COVID-19 pandemic. The existing literature suggests that its implementation has elicited mixed reactions from workers; while some workers have expressed satisfaction with its introduction, others prefer to work in a traditional, on-site setting. Concurrently, there has been a growing interest in Mobility-as-a-Service (MaaS) and an increase in the number of companies offering such services. However, there is limited research exploring the relationship between teleworking and the utilization of MaaS. This paper aims to fill this gap, by analyzing (1) which factors influence users to adopt teleworking in a post-pandemic scenario and (2) the relationship between willingness to telework and the propensity to join a MaaS system. An ordered logit model and a mixed logit model were developed to achieve the two goals, respectively. These models were calibrated and validated using data collected from questionnaires administered to Padua Municipality employees between October 2020 and January 2021. As expected, the employees most inclined toward teleworking are those who seek more flexibility and are unable to commute by private means. In addition, results show that employees who expressed the preference to telework more in the future are less likely to adopt MaaS, suggesting that the increased popularity of teleworking due to the pandemic may have a negative effect on the uptake of MaaS. These findings were utilized to formulate several policy recommendations.

1. Introduction

Mobility-as-a-Service (MaaS) is a topical subject in both the transportation industry and research. Several recent studies reviewed its features, its barriers/risks, and its future perspectives (Arias-Molinares and García-Palomares, 2020; Butler et al., 2021; Mulley, 2017). However, COVID-19 pandemic significantly affected the entire transportation sector, with long-term effects still to be properly assessed (Zhang et al., 2021a,b; Zhang and Zhang, 2021), and with much speculation being made on what mobility could look like in the post-pandemic era. In particular, as Hensher (2020) outlined, two alternative scenarios are realistically expected: the first is a return to the pre-pandemic situation; the second is a "new normal" situation, in which the changes in mobility patterns due to COVID-19 become permanent.

In this context, it is believed that MaaS may face both opportunities and challenges (Paiva and Mourao, 2021). On the one hand, there has been an impulse toward sustainable mobility and digital transition (Megahed and Ghoneim, 2020); in particular, a survey on user attitude toward MaaS conducted in several European countries during the pandemic showed that personal opinion on environmental friendliness, potentially emphasized by the ongoing pandemic, had a significant influence on the willingness to use MaaS (Matowicki et al., 2022). On the other hand, the short- and long-term COVID-related reduction in the use of public transportation (Ecke et al., 2022; Khursheed and Ahmad Kidwai, 2022; Shemer et al., 2022; Tirachini and Cats, 2020), which is considered the "backbone" on MaaS (Arias-Molinares and García-Palomares, 2020; Matyas and Kamargianni, 2019) is likely to have negative consequences on MaaS adoption.

Early findings from works directly investigating why and how COVID-19 is affecting/will affect MaaS adoption and acceptance are somewhat inconsistent. A study carried out in Australia found that the likelihood of changing post-Covid transportation preference plays a key role in predicting MaaS use for different trip purposes, although most participants indicated they will maintain their pre-Covid transportation preferences, which suggests that temporary disruptions are unlikely to establish habits (Duan et al., 2022). In another work investigating

* Corresponding author at: Department of Civil, Architectural and Environmental Engineering, University of Padua, 35131, Italy.
E-mail address: andrea.baldassa@dicea.unipd.it (A. Baldassa).

https://doi.org/10.1016/j.cstp.2023.101010
Received 27 October 2022; Received in revised form 10 February 2023; Accepted 25 April 2023
Available online 27 April 2023

feasibility of MaaS in Italy, it was observed that the effect of COVID-19 on mobility varied across the three cities analyzed, with the majority (58.6%) of Rome respondents declaring changes in travel habits, contrary to those based in Turin and Genoa (40.0% and 42.6% respectively), highlighting that location-specific characteristics of transportation systems and mobility demand may play a relevant role (Caballini et al., 2022). Findings from a survey administered in 20 European cities indicated that the reduced demand for mobility, the preference for personal transportation over shared services, and the unpredictable nature of the economy could all impede the progress of new technologies and business models, including MaaS (Christidis et al., 2022). However, in general, as highlighted by Baldassa et al. (2022), there is a lack of studies investigating the long-lasting effects and implications of COVID-19 pandemic on MaaS, and therefore more research is needed, and more case studies should be analyzed.

Telework is one of the countermeasures implemented by authorities during the pandemic, in order to prevent contact among people while maintaining productivity of several activities (Barbour et al., 2021; Mouratidis and Papagiannakis, 2021). Although it is not a recent practice and has been studied for several years as a travel demand strategy to reduce traffic-related emissions and congestion (de Abreu e Silva and Melo, 2018), its sudden widespread adoption, which was generally well received by workers, could make it a permanent phenomenon (Hensher et al., 2022). A study based on survey data from the state of Washington (Kong et al., 2022) confirmed that having teleworked during COVID-19 pandemic positively influences the choice of teleworking in the future, although a significant share of users was not comfortable with it and is likely to discontinue it. Beck and Hensher (2022) underlined how the benefits of telework will also be shared with those who cannot work from home thanks to a reduction in traffic congestion, and this may favor future policies aimed at its promotion; however, the author also pointed out that the telework rates observed during COVID-19 pandemic are bound to decrease.

Telework has potential environmental benefits (Zhang and Zhang, 2021), but also the risk of rebounding effects (e.g., a shift from public transportation to less environmentally friendly means) (Andreev et al., 2010; Hensher et al., 2021b). Even more, some studies have disputed the claim that teleworking reduces travels; using pre-pandemic data from the English National Travel Survey, Caldarola and Sorrell (2022) found that, despite making fewer trips, the majority of teleworkers travel farther than non-teleworkers, due to a combination of greater distance from the workplace and non-work-related travel. Recently, the work of Ceccato et al. (2022) provided a comprehensive view of the problem, by investigating factors affecting the decision of teleworking and by quantifying traffic-related emissions, confirming the risk of a rebound effect reversing the positive impacts of working from home and, therefore, underlining the need to combine telework with other measures fostering sustainable travel habits.

In essence, it is plausible to envisage a long-term change in travel behavior due to the pandemic-induced rise of telework, but this does not necessarily imply a reduction in people's mobility. How this may influence the acceptance of MaaS systems and how MaaS could contribute to improving the efficiency and sustainability of transportation systems in this new scenario is still far from being properly understood. Therefore, analyzing the potential long-term impacts of COVID-19 and, in particular, of telework on MaaS adoption represents a current and pressing challenge.

In this sense, the objective of this work is to understand (1) which factors influence users to adopt teleworking in a post-pandemic scenario and (2) the relationship between willingness to telework and the propensity to join any MaaS system. In both cases, aspects related to COVID-19 were also taken into account (e.g., the perception of health risk and the belonging to a group with particular health risks).

The analyses presented in this paper are based on a revealed- and stated-preference questionnaire, administered to employees of the Municipality of Padua, Italy, in the period between October 2020 and January 2021. Italy was one of the most severely affected countries in the early stages of the pandemic and several strict limitations on people's movements were implemented. This, coupled with a traditionally low share of telework prior to the pandemic, led to a 1000% increase in the number of people adopting telework in 2020 compared to the previous year, which only decreased by 7% in 2021 (ISFORT, 2021). This suggests that the widespread pandemic-fueled telework in Italy could have long-lasting effects on people's travel choice with potential implications on MaaS adoption and makes the investigation of an Italian case study particularly attractive. In addition, the performed research focusing on MaaS adoption in a medium-sized city like Padua is also relevant, as most of previous works considered large-city or even nationwide case studies (Baldassa et al., 2022).

2. Methodology

The considered study area is the municipality of Padua (Italy), which has a population of about 200,000 people. The area includes Padua, which is a densely populated (2,300 inhabitants per square kilometer) medium-sized city, and the surrounding urban zones. The city has several main routes that connect it to neighboring territories and it has good connections with local networks. Currently, many transportation services are operating in the city, including public transportation (urban and suburban bus, and tram) and vehicle sharing services (bike, e-scooter, and car sharing).

Input data were obtained from a mobility survey administered to employees of the Municipality of Padua in 2020 and 2021, with the aim to collect information about travel habits and propensity towards telework and a new potential MaaS system. A synthesis of its contents is reported hereinafter.

The survey consisted of four main sections.

In the first one, respondents were asked to report information about their travel habits and specific details about their commuting trips prior to the virus outbreak.

In the second section, questions about activities (including telework), trip characteristics, and contagion risk during different phases of the pandemic were asked. Within this work, as reported by the Italian Ministry of Health (Ministero della Salute, 2022), the period from March 2020 to June 2020 is indicated with "phase 1″; instead, "phase 3″ indicates the period from October 2020 to January 2021 (consistently at the end of the administration of the questionnaires). Information was collected for both phase 1 and phase 3: in the first case telework was mandatory for all employees who could carry out their tasks from home; during phase 3, however, only a portion of the employees were required to telework and, usually, with limited weekly frequency.

In the third part, interviewees had to face panel-structured Stated-Preferences (SP) experiments focusing on MaaS bundle choice and willingness to use the service as an alternative to their travel modes adopted before the SARS-CoV-2 outbreak; in addition, they had to declare their desired future weekly frequency of telework. All bundles were offered in the form of a subscription; in fact, no pay-as-you-go solution was provided. In order to stage realistic SP experiment, all bundles' attributes were built considering data from mobility operators in the area (train, urban bus, suburban bus, night bus, car sharing, bike sharing, e-scooter sharing, Park&Ride). Values of attributes were pivoted on the travel characteristics reported in the Revealed-Preferences (RP) part; TABLE 1 shows the levels that each attribute could assume and the related costs. Each respondent faced four choice exercises and in each of them they were asked to choose between the selected bundle and the usual transportation means declared in the RP part; a D-optimal design procedure was used to select 16 possible choice scenarios (grouped in blocks) and each respondent faced four different choice tasks.

In the last section, questions about socioeconomic characteristics of respondents and their households were presented.

The aim of this research paper is to understand whether the future

Table 1
MaaS package components.

Attributes	Levels	Standard Cost [€/month]
Bike sharing	Unlimited, not included	10, 0
E-Scooter sharing	Unlimited, not included	25, 0
Carsharing	5 h included, Pay-As-You-Go, not included	50, 1, 0
Local Public Transport	Unlimited, unlimited rides for 10 days, not included	39, 20, 0
Train/Suburban bus	Unlimited, not included	As stated in RP, 0
Park & Ride	Subscription, not included	10, 0
Night bus	10 rides, 5 rides, not included	15, 7.5, 0
Cost	0.8, 1, 1.2 * standard cost	

diffusion of telework fostered by the pandemic could affect MaaS adoption. For this reason, data collected were used to calibrate two models. First, an ordered logit was implemented to understand factors that influence the willingness to telework after the pandemic. Secondly, a mixed logit model was developed to analyze factors influencing the potential adoption of a proposed MaaS system, also considering the propensity of telework.

2.1. Modeling future willingness to telework

In order to analyze factors affecting the choice to telework after the pandemic, a model was calibrated using information collected from survey answers. As already mentioned, travel habits were investigated in Revealed-Preferences part, and the propensity to telework after the pandemic was investigated in the SP part, where respondents had to indicate their desired future weekly telework frequency. Since the outcome variable (TELE_FUTURE) ranged from 0 days ("Never") to 5 days ("All week") and was ordered by definition, an ordinal logit model was adopted (Hensher et al., 2021a). The model was calibrated using R statistical software (R Core Team, 2020).

TABLE 2 shows the final list of exogenous variables used for model specification, which was obtained from an automated (backward and forward) stepwise selection. In this phase, aspects related to MaaS (e.g., bundle composition) were not taken into consideration.

2.2. Modeling MaaS adoption

Mixed logit is a fully general model used to overcome the three limitations of the standard logit model: it allows for random taste variations between respondents, unrestricted substitution patterns between choices, and correlation in unobserved factors over time. In this work, the model was used to investigate the probability of adopting MaaS, paying specific attention to its relationship with the willingness to telework after the pandemic. Moreover, the model takes into account the panel structure of collected data, as each of the respondents faced four different choice exercises where they declared the acceptance (or nonacceptance) of the proposed bundle.

The outcome variable (ACCEPTANCE) was equal to 1 if the subject stated that he/she was willing to use the proposed MaaS bundle rather than the transportation means adopted before the pandemic, and 0, otherwise.

Significant variables were selected manually using a backward stepwise selection. The model was calibrated using Biogeme software (Bierlaire, 2020). Table 3 shows the list of exogenous variables used in the final version. To consider preference heterogeneity, different distributions were evaluated for the exogenous variables, including normal, lognormal, and triangular distributions for continuous factors, and uniform distributions for dummy variables. The best ones were selected by analyzing the corresponding values and significance of the estimated mean and standard deviations. In the final version of the model, three explanatory variables were included as random parameters. In particular, the factor related to the presence of car sharing in the package with a pay-as-you-go fare and that related to the inclusion of unlimited Park & Ride, as well as household income were modelled with a normal distribution. Moreover, 1000 intelligent Halton draws were adopted.

Table 2
Description of exogenous variables from the telework frequency prediction model.

Name	Description	Type	Level
CAR_AVAIL	Car availability in the household	Dummy	Household
DEPARTURE_7	Departure to commute before 7am	Dummy	Trip
DEPARTURE_7_8	Departure to commute between 7am and 8am	Dummy	Trip
F_ASSISTANCE	Frequency of trips to look after relatives [times/week]	Metric	Individual
F_P1_BUS	Frequency of urban bus/tram use in phase 1* [times/week]	Metric	Individual
F_P1_PASS	Frequency of car use as passenger in phase 1* [times/week]	Metric	Individual
F_P3_CHILD	Frequency of trips to carry children in phase 3** [times/week]	Metric	Individual
F_P3_TRAIN	Frequency of train use in phase 3** [times/week]	Metric	Individual
F_SUB	Frequency of suburban bus use [times/week]	Metric	Individual
F_TRAIN	Frequency of train use [times/week]	Metric	Individual
INCOME	Household income [1000€]	Metric	Household
RETURN_14	Return from work before 2 pm	Dummy	Trip
RETURN_14_15	Return from work between 2 pm and 3 pm	Dummy	Trip
RP_CAR	Car as primary transportation means used to commute before COVID-19 pandemic	Dummy	Trip
RP2_CAR	Car as second transportation means mainly used before COVID-19 pandemic	Dummy	Trip
SAFE_BS_	Perceived level of health risk on bike sharing [from 1 "Not at all safe", to 5 "Totally safe"]	Dummy	Individual
SAFE_CS_	Perceived level of health risk on car sharing [from 1 "Not at all safe", to 5 "Totally safe"]	Dummy	Individual
SAFE_MOTO_	Perceived level of health risk on motorbike [from 1 "Not at all safe", to 5 "Totally safe"]	Dummy	Individual
SAFE_TAXI_	Perceived level of health risk on taxi [from 1 "Not at all safe", to 5 "Totally safe"]	Dummy	Individual
SAT_	Level of satisfaction using the declared travel mode to commute [from 1 "Not at all satisfied", to 5 "Very satisfied"]	Dummy	Individual

*phase 1: March to June 2020.
**phase 3: October 2020 to January 2021.

3. Results and discussion

In total, 255 respondents completed the questionnaire. A total number of 1,650 employees worked for Padua's Municipality at that time, therefore the sampling rate was approximately 16%; the sample size was considered appropriate for a margin of error of 10% at a 95% confidence level (Hensher et al., 2005).

Most respondents lived in households with less than five members and had at least one available car in the household; 66% of respondents were women and about half of the sample lived within the municipality of Padua. Respondents were all between 26 and 66 years old and the 55–64 age group was the largest (45%).

Almost half of the respondents (47%) said they used the private car to commute before the pandemic. Almost a quarter of respondents (24%) declared they used to travel to work by bike. About 25% used to commute by public transportation and only 4% by walk. A small

Table 3
Description of exogenous variables used in the MaaS adoption model.

Name	Description	Type	Level
COST	Cost of MaaS bundle	Metric	MaaS
CS_HOUR	Car sharing service (5 h included) in MaaS package	Dummy	MaaS
DIST	Travelled distance to commute [km]	Metric	Trip
F_CHILD	Frequency of trips to carry children [times/week]	Metric	Individual
F_HOBBY	Frequency of trips for personal activities [times/week]	Metric	Individual
F_P1_PB	Frequency of private bike use in phase 1* [times/week]	Metric	Individual
F_P3_CHILD	Frequency of trips to carry children in phase 3** [times/week]	Metric	Individual
F_TELE_FUTURE	Stated frequency of teleworking after the pandemic [number of days/week]	Metric	Individual
F_TRAIN	Frequency of train use [times/week]	Metric	Individual
INCOME	Household income [1000€]	Metric	Household
NB	Nightbus service in MaaS package	Dummy	MaaS
PARK	Park&Ride service in MaaS package	Dummy	MaaS
RISK_GROUP	Belonging to a group with health conditions	Dummy	Individual
RP_BUS	Local public transport as primary transportation means used to commute before COVID-19 pandemic	Dummy	Trip
RP_CAR	Private car as primary transportation means used to commute before COVID-19 pandemic	Dummy	Trip
RP_MOTO	Motorbike as primary transportation means used to commute before COVID-19 pandemic	Dummy	Trip
RP_PB	Private bike as primary transportation means used to commute before COVID-19 pandemic	Dummy	Trip
RP2_FOOT	Walk as secondary transportation means used to commute before COVID-19 pandemic	Dummy	Trip
SAFE_CS_	Perceived level of health risk on car sharing [from 1 “Not at all safe”, to 5 “Totally safe”]	Dummy	Individual
SAFE_SC_	Perceived level of health risk on scooter sharing [from 1 “Not at all safe”, to 5 “Totally safe”]	Dummy	Individual
SAFE_SUB_	Perceived level of health risk on suburban bus [from 1 “Not at all safe”, to 5 “Totally safe”]	Dummy	Individual
SUB	Suburban (train/bus) public service (unlimited) in MaaS package	Dummy	MaaS

*phase 1: March to June 2020.
**phase 3: October 2020 to January 2021.

proportion of respondents (10%) said they used to commute by motorcycles. Half of the respondents changed travel habits after the pandemic outbreak; 40% of respondents reported further variations in “phase 3”. Travel habits and socioeconomic information of the sample are reported in Table 4.

In order to obtain a more detailed view of respondents’ telework habits, the distribution of the declared weekly frequency of teleworking during “phase 1”, compared to “phase 3” frequency and to desired frequencies at the end of the pandemic, is reported in Fig. 1.

A sharp decline in the frequency of telework can be observed between “phase 1” and “phase 3” of the pandemic: this is due to the fact that during “phase 1”, telework was mandatory for all those who could perform their duties remotely, whereas during “phase 3” the practice of telework was partially optional, or performed by a percentage of employees on a rotating basis. Furthermore, the desired frequencies of telework once the pandemic is over were quite similar to those found for “phase 3”, suggesting that telework activities prompted by COVID-19 diffusion could be maintained in the future. It should be noted that among the respondents there were employees (about 30%) who had to necessarily carry out their activities in presence, such as policemen and kindergarten teachers.

Table 4
Travel habits and socioeconomic information of the sample.

Totals	255	100%
Household members		
1	53	21%
2	56	22%
3	64	25%
4	65	25%
More than 4	17	7%
Car available to commute		
Yes	189	74%
No	66	26%
Living in Padua		
Yes	142	56%
No	113	44%
Travel habits change (phase 1)		
Yes	125	49%
No	130	51%
Travel habits change (phase 3)		
Yes	102	40%
No	153	60%
Gender		
Female	168	66%
Male	87	34%
Age		
18–24	0	0%
25–29	1	0%
30–34	5	2%
35–44	40	16%
45–54	89	35%
55–64	116	45%
More than 65	4	2%
Household income [€/month]		
Less than 1000	6	2%
1000–1500	70	27%
1500–2000	31	12%
2000–3000	85	33%
3000–4000	46	18%
4000–6000	11	4%
6000–10000	2	1%
More than 10,000	4	2%

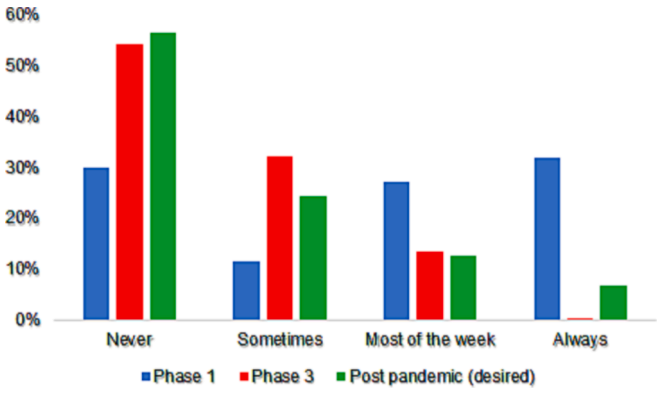

Fig. 1. Telework weekly frequency declared by respondents for different periods.

As regards MaaS adoption, 37% of municipality employees stated that they would be willing to give up the usual means and accepted at least one of the proposed bundles, indicating that the proposed MaaS

solutions were rather attractive for a significant share of the respondents.

3.1. Future willingness to telework – Model estimation

Results from the calibration phase of the ordered logit model predicting the frequency of telework are reported in Table 5. To verify parallel regression assumption, a Brant test was performed through R statistical software (R Core Team, 2020). The results of the test are reported in Table 6. Since the "probability" value is greater than 0.05 for each of the specified variables, as well as for the overall model, the ordered logit model can be adopted (Brant, 1990).

Travel habits factors were considered in different scenarios: before the COVID-19 pandemic, during the first phase of the pandemic, and during the third phase of the pandemic. As regards the aspects related to the pre-pandemic scenario, employees that declared to start their commuting trip before 7 am were less interested in teleworking (DEPARTURE_7), probably because it is incompatible with the type of work performed (e.g., shift work); the same goes for those who started their trip between 7 am and 8 am. Those who returned from work between 2 pm or between 2 and 3 pm were more inclined to telework (RETURN_14, RETURN_14_15): these people were likely to be part-time workers needing flexibility for their daily activities. The same reason applies to respondents who often performed escort trips (the coefficient of F_ASSISTANCE is positive). Car users (both as primary means, RP_CAR, and as secondary, RP2_CAR) declared less willingness to telework once the pandemic is over; several studies reported a positive correlation between private car usage and desire to telework (e.g., (Zhu and Mason, 2014) but it could be because they had been conducted before the pandemic spread. On the contrary, frequent bus or train users were found to have a high propensity toward telework (F_SUB, F_TRAIN); this result is similar to what found by (Ton et al., 2022) Specifically, this different trend could be caused by the greater flexibility of private car compared with that ensured by public transportation; in this sense, public transportation travelers could benefit more from the flexibility provided by telework.

Regarding the scenarios of coexistence with the virus, as weekly bus use increases during "phase 1", interest in teleworking decreases (F_P1_BUS); this is probably because those traveling by bus during "phase 1" required on-site presence, hence the lack of interest in

Table 5
Telework frequency prediction – estimated parameters and model statistics.

Variable name	Coefficient	SE	t-Value
Trip			
DEPARTURE_7	−1.628	0.547	−2.974*
DEPARTURE_7_8	−0.304	0.364	−0.833
RETURN_14	1.273	0.466	2.734*
RETURN_14_15	0.905	0.343	2.638*
RP_CAR	−0.821	0.368	−2.234*
RP2_CAR	−0.951	0.385	−2.472*
SAT_1	1.350	0.630	2.142*
SAT_2	1.016	0.444	2.288*
SAT_3	1.121	0.552	2.031*
SAT_4	0.436	0.369	1.182
Travel habits			
F_ASSISTANCE	0.273	0.108	2.519*
F_P1_BUS	−0.938	0.532	−1.765
F_P1_PASS	0.552	0.312	1.766
F_P3_CHILD	0.367	0.147	2.494*
F_P3_TRAIN	−0.488	0.267	−1.829
F_SUB	0.262	0.149	1.755
F_TRAIN	0.575	0.141	4.069*
COVID-19 related			
SAFE_BS_1	−0.087	0.761	−0.115
SAFE_BS_2	0.880	0.590	1.492
SAFE_BS_4	0.945	0.530	1.784
SAFE_BS_5	−0.023	0.561	−0.040*
SAFE_CS_1	0.279	0.573	0.488
SAFE_CS_2	−1.036	0.493	−2.101*
SAFE_CS_4	−0.737	0.550	−1.340
SAFE_CS_5	−0.216	0.661	−0.327
SAFE_MOTO_2	−1.815	1.060	−1.712
SAFE_MOTO_4	−1.181	0.624	−1.892
SAFE_MOTO_5	−0.276	0.492	−0.560
SAFE_TAXI_1	−0.331	0.562	−0.589
SAFE_TAXI_2	0.381	0.423	0.900
SAFE_TAXI_4	−0.340	0.541	−0.628
Sociodemographic			
CAR_AVAIL	0.995	0.365	2.729*
INCOME	0.217	0.082	2.654*
Intercepts			
TELE_FUTURE_1	1.978	0.744	2.658*
TELE_FUTURE_2	2.179	0.747	2.919*
TELE_FUTURE_3	3.626	0.774	4.684*
TELE_FUTURE_4	5.164	0.823	6.277*
*Significance codes: * t-value > |1.96|*			
Statistics			
N. of observation	255		
Null log likelihood	−259.04		
Final log likelihood	−308.10		
Cragg and Uhler's rho-squared	0.35		

Table 6
Ordered Logit - Brant test.

VARIABLE	χ^2	Degrees of freedom	Probability
Trip			
DEPARTURE_7	3.78	3	0.29*
DEPARTURE_7_8	6.22	3	0.10*
RETURN_14	2.84	3	0.42*
RETURN_14_15	0.42	3	0.94*
RP_CAR	3.44	3	0.33*
RP2_CAR	0.52	3	0.91*
SAT_1	4.24	3	0.24*
SAT_2	3.31	3	0.35*
SAT_3	7.77	3	0.05*
SAT_4	3.42	3	0.33*
Travel habits			
F_ASSISTANCE	0.38	3	0.94*
F_P1_AUPASS	4.78	3	0.19*
F_P1_BUS	2.89	3	0.41*
F_P3_CHILD	−3.98	3	1.00*
F_P3_TRAIN	5.96	3	0.11*
F_SUB	2.35	3	0.50*
F_TRAIN	0.70	3	0.87*
COVID-19 related			
SAFE_BS_1	2.47	3	0.48*
SAFE_BS_2	1.49	3	0.68*
SAFE_BS_4	0.55	3	0.91*
SAFE_BS_5	2.39	3	0.49*
SAFE_CS_1	1.52	3	0.68*
SAFE_CS_2	2.82	3	0.42*
SAFE_CS_4	4.31	3	0.23*
SAFE_CS_5	0.20	3	0.98*
SAFE_MOTO_2	0.05	3	1.00*
SAFE_MOTO_4	6.62	3	0.09*
SAFE_MOTO_5	5.73	3	0.13*
SAFE_TAXI_1	3.42	3	0.33*
SAFE_TAXI_2	5.59	3	0.13*
SAFE_TAXI_4	4.34	3	0.23*
Sociodemographic			
CAR_AVAIL	5.77	3	0.12*
INCOME	5.22	3	0.16*
OMNIBUS	95.50	99	0.58*
*significance codes: * probability ≥ 0.05*			

teleworking. In contrast, those who traveled by car as passengers during "phase 1" were more interested in teleworking (F_P1_PASS). Those who frequently traveled during "phase 3" to drive their children to various activities were more likely to telework in the future, likely to have more flexibility and freedom in their activities (F_P3_CHILD).

Regarding health safety perception, users who considered bike sharing as a very safe service were less interested in teleworking (SAFE_BS_4), consistently with what (Rotaris et al., 2022) reported. Safety perceptions of car sharing, motorbike and taxi were found to have a non-significant impact on the propensity to telework in the future (SAFE_CS_, SAFE_MOTO_, SAFE_TAXI_).

People with a high household income were more interested in teleworking in the future (INCOME), probably because, as the salary increases, the users seek greater flexibility in carrying out their working activities (greater variety of commitments associated with greater uncertainty in work scheduling) this result is in line with what is reported by de Abreu e Silva and Melo (2018) and by Astroza et al. (2020). The same applies for those who would have a car available for commuting (CAR_AVAIL). This result seems to contradict the negative signs of RP_CAR and RP2_CAR. It is worth noting that a significant share of people reporting a high propensity toward telework, despite having available cars, tended to use other transportation modes to commute. This suggests that future potential teleworkers are car owners but not car commuters.

Lastly, regarding the satisfaction in the use of declared transportation means in RP part (SAT_), "very high satisfaction" was the references level chosen for dummy modeling structure of this variable. As expected, the lower was the declared level of satisfaction, the greater was the interest on teleworking (SAT_1, SAT_2, SAT_3). This suggests that users' experience on past travels can play a non-negligible role on the decision to work from home, which could be affected by the willingness to avoid potential low-quality travels.

The model was validated applying a 5-fold cross-validation method. The procedure was performed using R statistical software. Table 7 shows confusion matrix resulted from the 5-fold validation; its accuracy is 60%.

3.2. MaaS adoption – Model estimation

The calibration of the mixed logit parameters and the model statistics are reported in Table 8. The model was calibrated using answers from the third part of the survey, where respondents were asked to state whether they were willing to adopt the selected mobility package in the future or keep the transport mode they used to commute before the pandemic. Specifically, answers to the second type of questions were used and, consequently, the model predicts the probability of adopting the chosen MaaS plan as an alternative to the travel modes reported in the previous sections of the survey.

As regards general bundle composition, the coefficient of cost of the mobility service (B_COST) is negative, as expected. The analysis of mean and spread of B_CS_HOUR and B_PARK pointed out that their effect can vary among individuals. Specifically, the presence of car sharing in the bundle positively affects the adoption of MaaS for 75% of the respondents, indicating that the inclusion of such a service could be a

Table 8
MaaS adoption – estimated parameters and model statistics.

Variable name	Coefficient	SE	t-Value	p-Value
ASC_B	6.200	1.810	3.420	<0.001***
ASC_B_S	−4.140	0.773	−5.350	<0.001***
Bundles composition				
B_COST	−0.012	0.006	−2.030	0.042*
B_CS_HOUR mean	2.550	1.170	2.170	0.030*
B_CS_HOUR *std. dev*	−5.200	2.520	−2.060	0.039*
B_NB	−0.040	0.036	−1.100	0.269
B_PARK *mean*	−5.040	2.270	−2.220	0.026*
B_PARK *std. dev*	9.940	3.650	2.720	0.007**
B_SUB	11.300	2.810	4.030	<0.001***
Trip				
B_DIST	0.078	0.035	2.190	0.028*
B_RP_BUS	1.330	1.280	1.040	0.300
B_RP_CAR	0.124	0.992	0.125	0.901
B_RP_MOTO	0.532	1.190	0.445	0.656
B_RP_PB	−1.690	1.000	−1.680	0.092†
B_RP2_FOOT	−1.330	0.688	−1.930	0.053†
Travel habits				
B_F_CHILD	−0.428	0.264	−1.620	0.106
B_F_HOBBY	0.767	0.317	2.420	0.016*
B_F_TRAIN	−1.000	0.354	−2.830	0.005**
B_F_P1_PB	−0.490	0.262	−1.870	0.062†
B_F_P3_CHILD	1.150	0.433	2.650	0.008**
COVID−19 related				
B_RISK_GROUP	2.140	0.764	2.810	0.005**
B_SAFE_CS_1	2.030	1.260	1.620	0.106
B_SAFE_CS_2	1.160	1.100	1.050	0.292
B_SAFE_CS_4	0.619	1.350	0.458	0.647
B_SAFE_CS_5	4.170	1.610	2.580	0.01**
B_SAFE_SC_1	−2.590	1.560	−1.660	0.098†
B_SAFE_SC_2	0.731	2.070	0.354	0.724
B_SAFE_SC_4	−0.982	1.300	−0.755	0.450
B_SAFE_SC_5	0.052	1.040	0.050	0.960
B_SAFE_SUB_1	−5.090	2.310	−2.200	0.028*
B_SAFE_SUB_2	−4.740	2.250	−2.110	0.035*
B_SAFE_SUB_4	−0.499	2.630	−0.190	0.850
Sociodemographic				
B_INCOME *mean*	0.309	0.151	2.040	0.041*
B_INCOME *std. dev*	−0.319	0.101	−3.140	0.002**
Desired post−pandemic telework				
B_F_TELE_FUTURE	−0.480	0.219	−2.190	0.028*
*significance codes: *** p-value <0.001; ** p-value <0.01; * p-value <0.05; † p-value <0.10*				
Statistics				
N. of observation	255(1020)			
N. of draws	1000			
Null log likelihood	−1015.12			
Final log likelihood	−328.07			
r2	0.64			

Table 7
Telework frequency confusion matrix – Results of the 5-fold cross-validation.

	Predicted Never	Predicted Once a week	Predicted Sometimes	Predicted Most of the week	Predicted Always	Total
Observed Never	131	0	12	1	0	144
Observed Once a week	8	0	1	0	0	9
Observed Sometimes	38	0	12	1	2	53
Observed Most of the week	13	0	7	7	5	32
Observed Always	7	0	4	3	3	17
Total	197	0	36	12	10	255

factor fostering its future use. On the contrary, the impact of a package with Park & Ride is quite limited, as positive effects were observed only for 25% of the individuals. Concerning this variable, it is worth mentioning that the potential interaction with factors related to private car (such as the number of cars in the household, the adoption of private car to commute, the frequency of car use) was tested, without any significant results; this suggests that the attractiveness of Park & Ride service could be independent from car-related factors. The presence of suburban bus could increase the attractiveness of MaaS (B_SUB); however, this may be hindered by the perceived risk of contagion associated with using these modes of transport (the coefficients of B_SAFE_SUB_1 and B_SAFE_SUB _2 are both negative and significant). As observed by previous authors (Baldassa et al., 2022; Beck and Hensher, 2020; Hensher et al., 2021c; Tirachini and Cats, 2020), biosecurity concerns can play a non-negligible role on the adoption of public transport, that directly affect the uptake of MaaS bundles that include it.

The length of the performed commuting trip (B_DIST) was found to positively impact the adoption of MaaS, this indicates that longer trips are more likely to be carried out with mobility solutions offered by such service. As underlined by (Matowicki et al., 2022) this results is widely confirmed in literature. Variables related to the use of private bike and walking (B_F_P1_PB, B_RP2_FOOT, B_RP_PB, respectively frequency of use of private bike during the first national lockdown, private bike commuting, or walking trips before the pandemic) were observed to have a negative effect on the MaaS adoption. This is consistent with the positive impact of trip length, suggesting that short trips on bike or walking are less likely to be performed with mobility solutions included in the MaaS bundles. This can be considered a positive result, since these travel modes are those with the least environmental impacts and should not be replaced with other potentially less sustainable mobility services. However, this impact may be partially attributed to site-specific factors, particularly the significant proportion of commuting trips made via biking and walking (approximately 26% of all commuting trips) in the area (Baldassa et al., 2022). The frequency of use of train was found to have a negative impact on MaaS adoption (B_F_TRAIN). This could seem in contrast to the positive effect of trip length, since long trips are often taken by train. However, the analysis of these two variables could suggest that long trips that are likely to be replaced by the MaaS solution are not those that are performed by train; this is because the most of commuters traveling by train work less than 500 m from the station.

Results show that those who often traveled for recreational activities were more interested in MaaS (B_F_HOBBY); the same was true for those who often accompanied their children during “phase 3” (B_F_P3_CHILD). Household income (B_INCOME) was found to positively affect MaaS adoption for the majority of individuals (approximately 83%); as reported in (Utriainen and Pöllänen, 2018), high-income groups were estimated to have a more positive attitude towards new technology. However, in some studies, such as in (Vij et al., 2020), a greater interest in MaaS was found in families with a low monthly income compared to those with a high income.

As pointed out in previous works (e.g., (Baldassa et al., 2022)), it is appropriate to include variables related to COVID-19 pandemic among the factors influencing users’ choices. The perceived level of health safety regarding the use of different means of transportation can have a correlation with the propensity to adopt MaaS: it has already been underlined that those who are afraid of the risk of contagion on the suburban bus are less inclined to join MaaS; similarly, those who perceive travelling on scooter sharing as high risk are less willing to use it (B_SAFE_SC_1). On the contrary, users who consider very safe to use car sharing were more likely to adopt the service (B_SAFE_CS_5). Lastly, belonging to a category of people with pathologies did not preclude the possibility of accepting MaaS (B_RISK_GROUP).

Finally, considering the more relevant factor with respect to the aim of the present work, i.e. the correlation between the propensity to telework and the propensity to join MaaS, for employees who declared a high interest in working from home, the probability of joining offered services in the bundles was lower (B_F_TELE_FUTURE). This indicates that the diffusion of telework induced by the pandemic can impact the choice to adopt MaaS. Specifically, telework and MaaS are negatively related, since individuals showing a low willingness to telework in the future are likely to commute a lot; therefore, their likelihood to subscribe MaaS for its use is higher than for teleworkers, who tend to travel less frequently than the formers. Furthermore, this suggests that MaaS could be adopted by employees for their daily work trips, pointing out its potential diffusion as a primary mobility service.

The model was validated adopting a 5-fold cross-validation method. The procedure was performed using Biogeme software. To estimate percentages of people accepting and non accepting MaaS, 1000 samples were taken. Table 9 shows confusion matrix resulted from the 5-fold validation; its accuracy is 81%.

4. Conclusions and recommendations

The pandemic has radically changed our habits, including the way people move. Due to COVID-19, unnecessary travel was banned for a period and, also to minimize social contacts, the practice of teleworking spread rapidly and profoundly. In Italy, employees of companies whose presence was not required were forced to telework for the entire “phase 1” (March–June 2020). In the period between October 2020 and January 2021 (therefore during “phase 3”), mobility surveys were administered to the employees of the municipality of Padua, also investigating their interest in a hypothetical MaaS that could be activated in the territory. Various additional types of information were collected, including telecommuting frequencies per week during the different phases of the pandemic and the desired one for the future. Two models, an ordered logit, and a mixed logit respectively, were constructed to understand (1) which factors influence users to adopt teleworking in a post-pandemic scenario and (2) the relationship between willingness to telework and the propensity to join a MaaS system. The factors mentioned concern both the mobility habits of the subject and the socioeconomic information of the family they belong to, including the perception of the risk linked to the pandemic spread and the use of different modes of transportation.

The results obtained from the model predicting teleworking frequency show that respondents who want greater freedom and those with greater financial resources are interested in teleworking more frequently. The same is true for those who consider the used transportation means less safe from the point of view of the contagion risk.

As regards the probability of acceptance of the proposed MaaS bundles, the interviewees declared a lack of interest in some services offered within the packages, probably due to the general characteristics of the population of respondents (e.g., car sharing is not a useful service for municipal employees probably because most of them, according to reports, own a car). The general perception of the pandemic situation does not have an influence on the probability of joining MaaS; however, the perception of the health risk linked to the use of some means (e.g., car passengers), has an impact on the choice. Finally, and most importantly, as the desired weekly telecommuting frequency increases, the probability of accepting MaaS decreases; in other words, the diffusion of telework induced by the pandemic can negatively impact the choice to adopt MaaS. This could be due to the structure of the bundles themselves, since the services were offered as subscriptions and not as pay-as-

Table 9
MaaS adoption confusion matrix – validation model prediction.

	Predicted Acceptance	Predicted Non acceptance	Total
Observed Acceptance	47	155	202
Observed Non acceptance	37	781	818
Total	84	936	1020

you-go; moreover, teleworkers tend to travel less than commuters and their interest in mobility services (e.g., MaaS) is lower.

Useful policy recommendations can be derived from the present work:

- Although the analysis showed that a good portion of commuters would be willing to adopt MaaS, it is underlined that the services, as proposed in the survey, may not integrate with the practice of teleworking, especially at high weekly frequencies and short trip lengths. For this reason, preliminary studies about the potential diffusion of MaaS should take into account the number of people working from home in a specific area. In addition, in a long-term perspective, mobility services and telework policies should be jointly managed and planned in order to maximize the benefits for the society.
- Furthermore, results pointed out that some services may be considered superfluous by specific categories of users (e.g., car sharing for municipal employees). This highlights the need for a proper design of MaaS composition, that should be tailored to characteristics of end users, thereby increasing its attractiveness.
- However, in order to maximize potential positive impacts of sustainable travel habits induced by MaaS adoption, modal shifts of users that already travel by zero emission means (e.g., by bicycle or on foot) toward non-zero emission travel modes should be avoided. Results of the analysis indicated that these switches are not likely to occur, due to travel habits of users in the area. This highlights the importance of the planning of a flexible MaaS system which should be designed according to site-specific factors.
- Another aspect to be aware of is the development of the pandemic and the consequent changes in perception and user priorities: users are more inclined to use means of transport that they consider safe also from a health point of view.

Starting from considerations above, future studies could investigate the MaaS bundle compositions that best integrate with the practice of telework, in particular for contexts of different dimensions and characteristics, without neglecting aspects related to health safety.

CRediT authorship contribution statement

Andrea Baldassa: Conceptualization, Data curation, Formal analysis, Methodology, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. **Federico Orsini:** Conceptualization, Methodology, Supervision, Writing – original draft, Writing – review & editing. **Riccardo Ceccato:** Conceptualization, Formal analysis, Methodology, Software, Supervision, Validation, Writing – review & editing.

Declaration of Competing Interest

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

Acknowledgments

The authors thank the Municipality of Padua for providing support in survey administration and Andrea Colovini for his contribution in survey design.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

Andreev, P., Salomon, I., Pliskin, N., 2010. Review: State of teleactivities. Transp. Res. Part C Emerg. Technol. 18, 3–20. https://doi.org/10.1016/J.TRC.2009.04.017.

Arias-Molinares, D., García-Palomares, J.C., 2020. The Ws of MaaS: Understanding mobility as a service fromaliterature review. IATSS Res. 44, 253–263. https://doi.org/10.1016/J.IATSSR.2020.02.001.

Astroza, S., Tirachini, A., Hurtubia, R., Carrasco, J.A., Guevara, A., Munizaga, M., Figueroa, M., Torres, V., 2020. Mobility Changes, Teleworking, and Remote Communication during the COVID-19 Pandemic in Chile. Findings 1, 1–8. doi: 10.32866/001c.13489.

Baldassa, A., Ceccato, R., Orsini, F., Rossi, R., Gastaldi, M., Severino, A., 2022. MaaS bundling and acceptance in the pandemic era: evidence from padua. Italy. J. Adv. Transp. 2022, 1–10.

Barbour, N., Menon, N., Mannering, F., 2021. A statistical assessment of work-from-home participation during different stages of the COVID-19 pandemic. Transp. Res. Interdiscip. Perspect. 11, 100441 https://doi.org/10.1016/J.TRIP.2021.100441.

Beck, M.J., Hensher, D.A., 2020. Insights into the impact of COVID-19 on household travel and activities in Australia – The early days of easing restrictions. Transp. Policy 99, 95–119. https://doi.org/10.1016/j.tranpol.2020.08.004.

Beck, M.J., Hensher, D.A., 2022. Australia 6 months after COVID-19 restrictions part 2: The impact of working from home. Transp. Policy 128, 274–285. https://doi.org/10.1016/j.tranpol.2021.06.005.

Bierlaire, M., 2020. A short introduction to PandasBiogeme. Technical report TRANSP-OR 200605. Transport and Mobility Laboratory.

Brant, R., 1990. Assessing proportionality in the proportional odds model for ordinal logistic regression. Biometrics 46, 1171. https://doi.org/10.2307/2532457.

Butler, L., Yigitcanlar, T., Paz, A., 2021. Barriers and risks of mobility-as-a-service (MaaS) adoption in cities: a systematic review of the literature. Cities 109, 103036. https://doi.org/10.1016/J.CITIES.2020.103036.

Caballini, C., Corazza, M.V., Costa, V., Delponte, I., Olivari, E., 2022. Assessing the feasibility of MaaS: a contribution from three italian case studies. Sustain 14, 1–15. https://doi.org/10.3390/su142416743.

Caldarola, B., Sorrell, S., 2022. Do teleworkers travel less? Evidence from the English national travel survey. Transp. Res. Part A Policy Pract. 159, 282–303. https://doi.org/10.1016/j.tra.2022.03.026.

Ceccato, R., Baldassa, A., Rossi, R., Gastaldi, M., 2022. Potential long-term effects of Covid-19 on telecommuting and environment: an Italian case-study. Transp. Res. Part D Transp. Environ. 109, 103401 https://doi.org/10.1016/J.TRD.2022.103401.

Christidis, P., Navajas Cawood, E., Fiorello, D., 2022. Challenges for urban transport policy after the Covid-19 pandemic: Main findings from a survey in 20 European cities. Transp. Policy 129, 105–116. https://doi.org/10.1016/j.tranpol.2022.10.007.

de Abreu e Silva, J., Melo, P.C., 2018. Home telework, travel behavior, and land-use patterns: A path analysis of British single-worker households. J. Transp. Land Use 11, 419–441. doi: 10.5198/JTLU.2018.1134.

Duan, S.X., Tay, R., Molla, A., Deng, H., 2022. Predicting mobility as a service (MaaS) use for different trip categories: an artificial neural network analysis. Transp. Res. Part A Policy Pract. 166, 135–149. https://doi.org/10.1016/j.tra.2022.10.014.

Ecke, L., Magdolen, M., Chlond, B., Vortisch, P., 2022. How the COVID-19 pandemic changes daily commuting routines – Insights from the German Mobility Panel. Case Stud. Transp. Policy 10, 2175–2182. https://doi.org/10.1016/j.cstp.2022.10.001.

Hensher, D.A., 2020. What might Covid-19 mean for mobility as a service (MaaS)? Transport Rev. 40 (5), 551–556.

Hensher, D.A., Rose, J.M., Greene, W.H., 2005. Applied choice analysis: a primer. Appl. Choice Anal. A Prim. 1–717 https://doi.org/10.1017/CBO9780511610356.

Hensher, D.A., Beck, M.J., Wei, E., 2021a. Working from home and its implications for strategic transport modelling based on the early days of the COVID-19 pandemic. Transp. Res. Part A Policy Pract. 148, 64–78. https://doi.org/10.1016/j.tra.2021.03.027.

Hensher, D.A., Ho, C.Q., Reck, D.J., 2021b. Mobility as a service and private car use: evidence from the Sydney MaaS trial. Transp. Res. Part A Policy Pract. 145, 17–33. https://doi.org/10.1016/j.tra.2020.12.015.

Hensher, D.A., Wei, E., Beck, M.J., Balbontin, C., 2021c. The impact of COVID-19 on cost outlays for car and public transport commuting – the case of the Greater Sydney Metropolitan Area after three months of restrictions. Transp. Policy 101, 71–80. https://doi.org/10.1016/j.tranpol.2020.12.003.

Hensher, D.A., Balbontin, C., Beck, M.J., Wei, E., 2022. The impact of working from home on modal commuting choice response during COVID-19: implications for two metropolitan areas in Australia. Transp. Res. Part A Policy Pract. 155, 179–201. https://doi.org/10.1016/J.TRA.2021.11.011.

ISFORT, 2021. 8° Rapporto sulla mobilità degli italiani.

Khursheed, S., Ahmad Kidwai, F., 2022. Post-COVID-19 performance evaluation of urban metro transit system in Delhi and influence on access mode. Case Stud. Transp. Policy 10, 1862–1871. https://doi.org/10.1016/j.cstp.2022.07.015.

Kong, X., Zhang, A., Xiao, X., Das, S., Zhang, Y., 2022. Work from home in the post-COVID world. Case Stud. Transp. Policy 10, 1118–1131. https://doi.org/10.1016/j.cstp.2022.04.002.

Matowicki, M., Amorim, M., Kern, M., Pecherkova, P., Motzer, N., Pribyl, O., 2022. Understanding the potential of MaaS – An European survey on attitudes. Travel Behav. Soc. 27, 204–215. https://doi.org/10.1016/J.TBS.2022.01.009.

Matyas, M., Kamargianni, M., 2019. The potential of mobility as a service bundles as a mobility management tool. Transportation (Amst). 46, 1951–1968. https://doi.org/10.1007/s11116-018-9913-4.

Megahed, N.A., Ghoneim, E.M., 2020. Antivirus-built environment: Lessons learned from Covid-19 pandemic. Sustain. Cities Soc. 61, 102350 https://doi.org/10.1016/J.SCS.2020.102350.

Ministero della Salute, 2022. Covid-19 [WWW Document]. URL https://www.salute.gov.it/portale/nuovocoronavirus/homeNuovoCoronavirus.jsp?gclid=Cj0KCQjwy5maBhDdARIsAMxrkw391cJz5XzdV9VFQfaizjwsJUOKfTYppFBYDWJD7e2mwPcodoBJ9gIaAinDEALw_wcB.

Mouratidis, K., Papagiannakis, A., 2021. COVID-19, internet, and mobility: The rise of telework, telehealth, e-learning, and e-shopping. Sustain. Cities Soc. 74, 103182. doi: 10.1016/J.SCS.2021.103182.

Mulley, C., 2017. Mobility as a Services (MaaS) – does it have critical mass? Transport Reviews 37 (3), 247–251.

Paiva, S., Mourao, F., 2021. Mobility-as-a-Service Challenges and Opportunities in the Post-Pandemic. 2021 IEEE Glob. Conf. Artif. Intell. Internet Things, GCAIoT 2021 136–141. doi: 10.1109/GCAIOT53516.2021.9693025.

R Core Team, 2020. R: A Language and Environment for Statistical Computing. Austria, Vienna.

Rotaris, L., Intini, M., Gardelli, A., 2022. Impacts of the COVID-19 Pandemic on Bike-Sharing : A Literature Review.

Shemer, L., Shayanfar, E., Avner, J., Miquel, R., Mishra, S., Radovic, M., 2022. COVID-19 impacts on mobility and travel demand. Case Stud. Transp. Policy 10, 2519–2529. https://doi.org/10.1016/j.cstp.2022.11.011.

Tirachini, A., Cats, O., 2020. COVID-19 and public transportation: current assessment, prospects, and research needs. J. Public Transp. 22, 1. https://doi.org/10.5038/2375-0901.22.1.1.

Ton, D., Arendsen, K., de Bruyn, M., Severens, V., van Hagen, M., van Oort, N., Duives, D., 2022. Teleworking during COVID-19 in the Netherlands: understanding behaviour, attitudes, and future intentions of train travellers. Transp. Res. Part A Policy Pract. 159, 55–73. https://doi.org/10.1016/j.tra.2022.03.019.

Utriainen, R., Pöllänen, M., 2018. Review on mobility as a service in scientific publications. Res. Transp. Bus. Manage. 27, 15–23. https://doi.org/10.1016/J.RTBM.2018.10.005.

Vij, A., Ryan, S., Sampson, S., Harris, S., 2020. Consumer preferences for mobility-as-a-service (MaaS) in Australia. Transp. Res. Part C Emerg. Technol. 117, 102699 https://doi.org/10.1016/j.trc.2020.102699.

Zhang, J., Hayashi, Y., Frank, L.D., 2021a. COVID-19 and transport: findings from a world-wide expert survey. Transp. Policy 103, 68–85. https://doi.org/10.1016/J.TRANPOL.2021.01.011.

Zhang, N., Jia, W., Wang, P., Dung, C.H., Zhao, P., Leung, K., Su, B., Cheng, R., Li, Y., 2021b. Changes in local travel behaviour before and during the COVID-19 pandemic in Hong Kong. Cities 112, 103139. https://doi.org/10.1016/J.CITIES.2021.103139.

Zhang, R., Zhang, J., 2021. Long-term pathways to deep decarbonization of the transport sector in the post-COVID world. Transp. Policy 110, 28–36. https://doi.org/10.1016/J.TRANPOL.2021.05.018.

Zhu, P., Mason, S.G., 2014. The impact of telecommuting on personal vehicle usage and environmental sustainability. Int. J. Environ. Sci. Technol. 11, 2185–2200. https://doi.org/10.1007/s13762-014-0556-5.