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Crowdedness information and travel decisions of pedestrians and public transport users in the COVID-19 era: A stated preference analysis

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ABSTRACT

The COVID-19 pandemic has impacted people's everyday lives, as avoiding being in crowded places became the number one societal rule. Crowdedness has therefore increasingly affected decisions such as a place visit via a specific path, the selection of a public transport stop, itinerary, etc., thereby making related information increasingly relevant. The objective of this study is to examine the route and travel choices of pedestrians and public transport users, with the provisioning of travel information related to crowdedness levels. To that end, a choice experiment was designed to elicit travelers' preferences. Discrete choice models were estimated based on data collected from 465 individuals in Greece. Results showed that crowd avoidance plays a significant role in shaping mobility decisions for both pedestrians and public transport users. Factors such as place of residence, age, the importance of COVID-19 measures and arrival time are found to affect the likelihood of switch routes in response to information about high levels of crowdedness.

1. Introduction

The outbreak of the COVID-19 virus in the first months of 2020 forced the European governments to impose measures to stop its rapid spread. These periods of lockdowns and targeted restrictions gradually reinforced people's avoidance of crowded places. The applied measures by governments aimed at mitigating the effects of COVID-19 by controlling human mobility. Being a prominent non-pharmaceutical intervention, restriction of mobility significantly changed people's personal travel choices (Rafiq et al., 2022). The COVID-19 pandemic had a significant impact on walking (Campisi et al., 2022; Nikiforiadis et al., 2022) and public transport ridership (Lucchesi et al., 2022; Shelat, van de Wiel, et al., 2022; Shelat, Cats, & van Cranenburgh, 2022). The fear of infection made people hesitant to walk in public spaces, such as busy sidewalks or parks, since the proximity to others increased the risk of exposure to the virus. In this case, using a car instead of walking provided a sense of physical distance and a perceived lower risk of infection. In addition, the reduced services of public transport systems and the avoidance of crowds in public transport reinforced car use (Campisi et al., 2022; Lucchesi et al., 2022; Nikiforiadis et al., 2022;Shelat, Cats, & van Cranenburgh, 2022 ; Zavareh et al., 2022). The increased concerns about COVID-19 transmission in crowded areas like pedestrian zones and public transport were expected to lead to a shift towards car use (Shelat, Cats, & van Cranenburgh, 2022; Zavareh et al., 2022). This increasing car use and the diminishing trend of walking and public transport used to minimize exposure to crowds is a serious concern to the development of sustainable cities. These changes in travel behavior may be sustained in the post-pandemic era and have a significant effect on people's confidence in traveling with sustainable modes of transport which are prone to crowdedness, such as public transport (Hörcher et al., 2022; Rafiq et al., 2022; Hartleb et al., 2021).

These challenges further intensify the need of new technologies and real-time information systems to promote the public transport use and support switching to active transportation with a lesser risk of COVID-19 transmission (Hartleb et al., 2021; Hörcher et al., 2022). Real-time information systems that ensure the respect of social distancing are expected to recover the confidence of people in traveling with others. This demands the need to further understand people's travel decision-making under different crowdedness levels. To this end, the objective of this study is to examine the route and travel choices of pedestrians and public transport users, upon travel information provision concerning crowdedness levels. Hence, the research question that this study seeks to answer is how real-time information about crowdedness levels during the COVID-19 pandemic is shaping pedestrians' and public transport

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users' decisions regarding their travel choices and what factors influence the decision?

To evaluate pedestrians' and public transport users' behavior under different crowdedness levels and how they respond to real-time information, we conducted a Stated Preference (SP) experiment. Pedestrians and public transport users are in the focus of this study because walking and public transport are among the most common ways of commuting in many urban areas and are often affected by crowdedness levels. The data collection period began on March 29th, 2021, and ended on April 30th, 2021. In the experiment, 465 participants from Greece responded about their COVID-19 mobility choices after transport information was provided to them by a designated social media account related to sustainable urban mobility. Each respondent had to select between two hypothetical scenarios, thinking of his/her daily main trip. The two alternatives include respondents' usual travel choice and a suggested travel choice with a lower crowdedness level. Scenarios for pedestrians refer to route choice and include three attributes: crowdedness level, walking time, and walking environment. Public transport users' scenarios refer to changes in public transport stop and itinerary and include four attributes: crowdedness level, travel time, walking time and arrival time.

To explain pedestrians and public transport users' choices, discrete choice models are estimated. Personal and trip characteristics, crowdedness levels, and COVID-19 related aspects (i.e. mandatory use of face masks, social distancing, etc.) are used as independent variables to predict participants' travel choices.

The rest of the paper is structured as follows. A review of the literature is provided in Section 2. Section 3 describes the methodological approach of this study. Descriptive statistics and model estimation results are reported in Section 4. The last section concludes the findings of the research.

2. Literature review

2.1. Walking and social distancing

The COVID-19 pandemic has highlighted the importance of maintaining social distancing in public spaces, particularly in dense crowds. In recent studies, researchers have conducted controlled experiments to examine the impact of variables such as pedestrian density, walking speed, and prescribed safety distance on social distancing. In the study of Echeverría-Huarte et al. (2021) controlled laboratory experiment was conducted to examine the impact of variables such as pedestrian density, walking speed and prescribed safety distance, on social distancing within relatively dense crowds. The experiment took place in a building of University of Navarra (Spain) on 23 June 2020 and was conducted for 3 h approximately. An interesting finding was that to keep a distance of 1 m, the density should not be higher than 0.16 pedestrians per square meter (around 6 m^2 per pedestrian). Seres et al. (2022), in their experiment, measured distances kept (with or without facemask) before and after mandatory mask use in stores by calculating waiting lines in front of stores in Berlin, Germany. The first field experiment, before the face mask mandate, took place in April 2020. The second phase of data collection followed one month later, in May 2020 when the mask use was mandatory. The analyses showed that individuals became less careful in their distancing behavior once relaxation measures became effective. Findings also showed that distancing declined in areas where stores reopened, possibly making it more difficult to keep safe distancing due to crowded sidewalks. Pedestrian physical distancing indicators to quantitatively evaluate different levels of physical distancing were developed by Mohammadi et al. (2021). In addition, levels of pedestrian physical distancing that can be used for implementation of appropriate mobility interventions were proposed. A mathematical procedure for relative risk estimation of COVID-19 transmission between pedestrians under different walking conditions was also developed. Finally, the application of the proposed approach was demonstrated by the authors by means of a microscopic pedestrian simulation software.

Researchers have explored different approaches to monitor and ensure the respect of social distancing in real-time, combining pedestrian dynamics with infection judgement frameworks to model the probability of transmission. Other studies have used pedestrian microsimulation modelling frameworks to evaluate the effectiveness of different social distancing scenarios in improving pedestrian flow and reducing contact violations. Xiao et al. (2022) developed a simulation-based approach that combines physical-distancing pedestrian dynamics with an infection judgement framework. The approach captures the spatial factors influencing the ability of social distancing for COVID-19 prevention and models the probability of transmission in various spatial configurations. In this direction, Alam et al. (2022) developed a pedestrian microsimulation modelling framework that evaluates different scenarios for a commercial street Halifax Regional Municipality (HRM), Nova Scotia. The results revealed that the social distancing strategy in the pandemic scenarios significantly improved the pedestrian flow in terms of contact violations reduction. Simulation findings indicated that an increase in sidewalk width can influence contact rates and travel time. In addition, the tested scenario that incorporated wider sidewalks showed a decrease both in total travel time and contact rates. In the work of Möllers et al. (2022) data from automated pedestrian and bicycle counting stations as well as information data about weather conditions and calendar events were used. The data were used to estimate the isolated impacts of COVID-19 and government interventions on walking and cycling in ten German cities. Results showed that pedestrian levels decrease with more severe government intervention. During all hours of the day, the COVID-19 spread had a negative impact on pedestrian flows, especially on Saturdays. The impact of feelings such as anxiety and stress on walking for either leisure or work in the COVID-19 era was examined by Campisi et al. (2022). A statistical analysis was done based on questionnaire data about walking trips for either leisure or work in urban areas of Sicily. Results showed that there is a strong correlation between age and anxiety and between stress and gender, namely older people and men tend to feel more anxiety while walking during the pandemic period. Most respondents strongly agree that anxiety has an impact on walking during the COVID-19 period.

2.2. Public transport use and crowding

The COVID-19 pandemic has presented significant challenges for public transport systems, including reduced demand and the need to implement new occupancy standards. Based on previous studies, crowding played already a significant role in passengers' route choice in public transport prior to the COVID-19 outbreak (Yap et al., 2020). Recent studies have investigated the impact of COVID-19 on crowding perception and disutility in public transport systems. The findings of these studies provide insights into how passengers perceive and respond to crowded conditions, as well as the impact of social distancing measures on perceived comfort levels. The great challenges for public transport systems induced by the pandemic, including the sharp reduction of public transport demand, the occupancy levels and their new standards were thoroughly discussed in the work of Tirachini and Cats (2020). A year later, Aghabayk et al. (2021) investigated the impact of COVID-19 on crowding perception and crowding disutility in metro rail system of Tehran, revealing that the value of crowding increased during the pandemic. Stated preference data before (October 2019) and during COVID-19 (October–November 2020) were used to develop mixed logit models. Results showed that an increase in density of standees and of occupied seats leads to a decrease in the perceived comfort level. The difficulty of maintaining social distance reinforces a feeling of insecurity resulting in low comfort scores.

A public transport traveler behavior related to COVID-19 risks was also analyzed by Shelat, van de Wiel, et al. (2022) and Shelat, Cats, and van Cranenburgh (2022). The authors conducted a stated choice experiment with train travelers in the Netherlands at the end of the first pandemic wave in the first week of December 2020. The data were analyzed using a latent class choice model with two classes 'COVID Conscious' and 'Infection Indifferent'. Older and female travelers are more likely to belong to the first class of 'COVID Conscious' while more frequent users of trains during the pandemic tend to be 'Infection Indifferent'. Results showed that the first class has a significantly higher valuation of crowding, prefers to sit alone and are quite sensitive to the infection rate. By contrast, the second class has a slightly higher value of crowding than pre-pandemic estimates and is relatively unaffected by infection rates. Chen et al. (2022) examined the impact of COVID-19 policies on travel decisions influenced by the latent aspects. Stated preference data were used to develop a hybrid choice model to investigate the impact of COVID-19 related policies on individuals' transportation mode choices during pandemic in Netherlands. The data were gathered from 15 December 2020 until 15 January 2021. Findings showed that attributes like travel time and cost become less relevant during pandemic compared to normal situations. Moreover, the travel preferences during the pandemic are significantly associated with latent factors of social responsibility, infection fear, risk perception, and travel anxiety. In general, public transport is identified as an insecure alternative compared with private modes of transport.

Real-time information systems are used to improve passengers' onboard experience and the performance of the system by influencing passengers' route choices (Fonzone et al., 2016; Karatsoli & Nathanail, 2020; Karatsoli & Nathanail, 2021). In the work of Drabicki et al. (2021) the authors investigated the instantaneous real-time crowding information systems in public transport networks of Kraków, Poland. A passenger path choice model was developed accounting for the impact of real time information on passengers' travel experience and crowding. Based on the findings instantaneous real-time crowding information can result in improved travel experience but also substantial inaccuracy risk. After the spread of COVID-19, studies focused on real time crowding information systems (Krusche et al., 2022; Peftitsi et al., 2022) or other methods such as dynamic pricing (Hörcher et al., 2022; Saharan et al., 2020) that bring benefits to the public transport system while make safer its use. A discrete model was developed by Hadas et al. (2022), to assess the factors that affect the choice of whether to board an overcrowded vehicle or not in Israel. The model examined to what extend attributes such as age, income level, extra waiting time, crowdedness level, and discount and penalty levels affect the willingness of passengers to wait for the next vehicle. The findings of the research indicated that the longer the waiting time, the lower the willingness to board the next vehicle. It was revealed that participants older than 50 were less willing to wait for the next bus. Moreover, the willingness to wait was higher when a penalty was introduced as opposed to a discount.

2.3. Study contributions

The study aims to fill a research gap by investigating the potential and impact of information provision on travel choices under pandemic circumstances, specifically focusing on the travel behavior of pedestrians and public transport users. While previous studies have examined travel behavior during the COVID-19 era, there is limited knowledge regarding the influence of real-time information about crowdedness levels on individuals' travel decisions.

The contributions of this study to the existing literature are twofold. Firstly, the study examines the travel choices of both pedestrians and public transport users when provided with travel information specifically related to crowdedness levels during the COVID-19 pandemic. By exploring how individuals respond to this information, the study sheds light on the role of real-time information in shaping travel decisions. Secondly, the study integrates personal and travel characteristics, crowdedness levels, and COVID-related aspects (such as the mandatory use of face masks and social distancing) within participants' final travel choices. By considering these factors, the study provides a comprehensive understanding of the multiple influences on individuals' decision-making processes when it comes to crowdedness and COVID-19 concerns.

By examining the interplay between various factors and individuals' travel decisions, the study contributes to the development of strategies and policies that can effectively promote sustainable and safe travel behavior in urban areas.

3. Methodological approach

The response of pedestrians' and public transport users to available information about crowdedness levels consists of a series of actions and decisions that occur over time. Fig. 1 illustrates the methodological framework for switching from a habitual travel pattern to a safer - less crowded alternative in the presence of information about crowdedness levels. Travelers' decision-making is influenced by both personal and trip characteristics (Polydoropoulou et al., 1994; Polydoropoulou et al., 1996; Polydoropoulou & Ben-Akiva, 1999; Tsirimpa et al., 2007). An additional category with COVID-related context characteristics (such as mandatory use of facemasks, social distancing, cleanliness, sense of security) that strongly affect travel decisions under the influence of information about crowdedness levels, is included. Personal characteristics include socioeconomic information such as gender, age, educational level, city of residence, income. Trip characteristics refer to general travel pattern that travelers are likely to encounter during daily main trip.

3.1. Survey timeline and design

Our study takes place in Greece, where the first measures and restrictions against the spread of COVID-19 were implemented at the end of February 2020. The data collection period began on March 29th, 2021 and ended on April 30th, 2021. Fig. 2 shows the timeline of the experiment and the restrictions that took place in Greece.

The questionnaire was developed (in Greek) using Survey Monkey, targeting individuals who reside in Greece. The questionnaire consisted of six parts (Part A–Part F), as shown in Fig. 3. The first part (Part A) referred to the general trip characteristics, i.e., trip purpose, departure/arrival time flexibility, mode used in daily main trip. Part B collected the mode specific trip characteristics – trip duration, trip distance, route selection, use of travel applications, perceptions about the quality of the trip – based on respondents' responses concerning the daily main trip mode in Part A. Only pedestrians' and public users' choices with respect to crowdedness in the COVID-19 era were considered in this study (Fig. 3) and were directed to third part (Part C1 and Part C2, respectively). The third part included the stated preference scenarios and constitutes the core of the survey. This part examined whether shared information on social media about crowdedness level affects route and travel choices of pedestrians (Part C1) and public transport users (Part C2_1 and Part C2_2). The following sections include details about the shared information on social media (Section 3.1.1) and the attributes and attribute levels of the SP scenarios (Section 3.1.2). Furthermore, the fourth part (Part D) examined the impact of information and message appearance on the final decision. Similar to Part C, this part was answered only by pedestrians and public transport users. The last two parts (Part E and F) were addressed to all respondents. The fifth part (Part E) collected information about the impact of COVID-19 on the daily main trip, while the last part (Part F) recorded the socio-economic characteristics of the respondents, by collecting personal information such as gender, age, employment status, place of residence and income.

Descriptive statistics of the general trip characteristics, the impact of COVID-19 on daily main trip and the socio-demographic characteristics of car/motorbike and bicycle users are not included in the following analysis as this particular study focuses on pedestrians and public transport users.

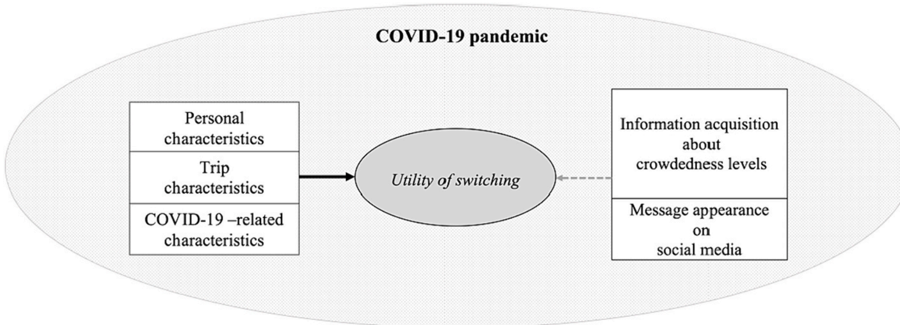

Fig. 1. Methodological approach.

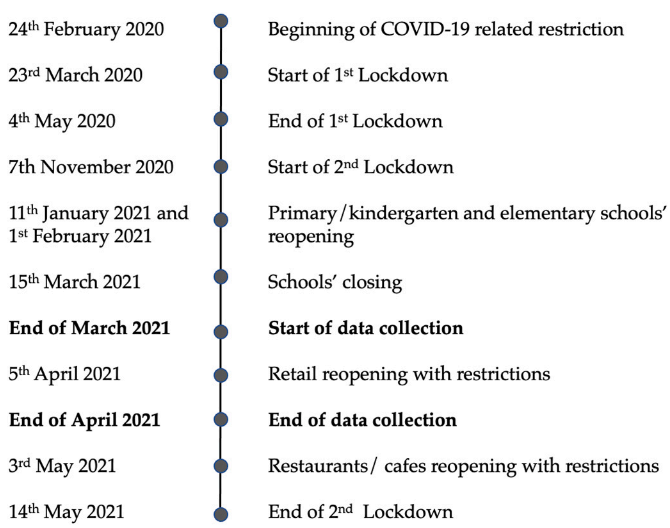

Fig. 2. COVID-19 restrictions in Greece and experiment timeline.

3.1.1. *Shared information on social media*

Social media platforms were selected for the dissemination of transport-related information regarding crowdedness levels within the hypothetical scenarios of the survey. This choice was motivated by their user-friendly interface and accessibility. Specifically, the Facebook platform was used to create a social media account related to sustainable urban mobility. Realistic content about crowdedness levels in the stated preference scenarios was created and shared through this Facebook account. The content included a post informing respondents about the high crowdedness levels on their usual routes, followed by the presentation of a suggested travel option with lower crowds. Each respondent was required to choose between these two alternatives, considering their daily main trip—a routine commute with a specific purpose and destination established before the pandemic outbreak in March 2020. The attributes of these two alternatives are described in detail in Section 3.1.2.

To ensure the authenticity of the scenarios, the posts were prepared and shared on Facebook, to get screenshots and include them in the presented scenarios of the stated preference survey. Fig. 4 depicts the appearance of these Facebook posts on the mobile devices of both pedestrians and public transport users.

3.1.2. *Attributes and attribute levels*

Once the two alternatives of the choice experiment were devised, it was necessary to determine which attributes and their corresponding levels should be included to describe them.

Due to the large number of attributes and attribute levels involved, it was not feasible to create a complete factorial design. Instead, the levels of the presented scenarios were chosen based on a cleaned random experimental design (Matyas & Kamargianni, 2019; Walker et al., 2015).

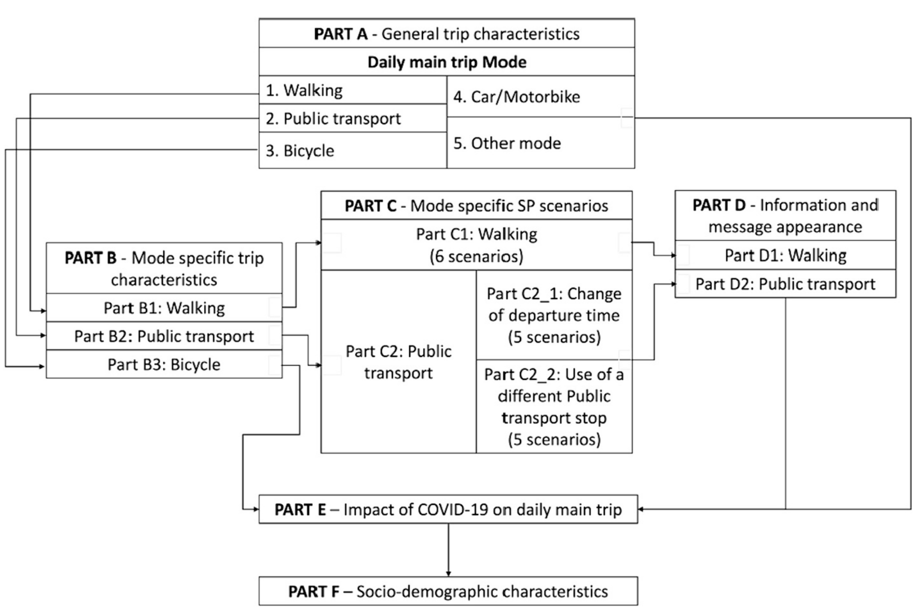

Fig. 3. Flowchart based on survey's sequence.

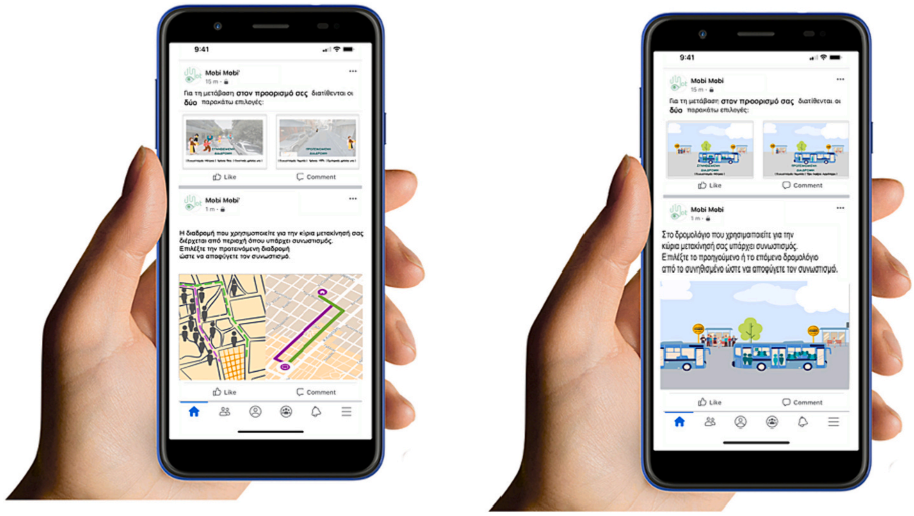

Fig. 4. Post appearance of the designated account related to sustainable urban transport on a mobile phone of (a) a pedestrian; (b) a public transport user.

Walker et al. (2015) suggest that a random design performs equally well compared to other designs, and its performance improves further when irrelevant scenarios, where one alternative clearly dominates the others, are removed. Therefore, a condition was applied to ensure that the scenarios in this study were internally consistent and aligned with the research topic. This approach maintains the validity of the findings and helps to minimize the occurrence of strictly dominating alternatives, which could introduce significant bias into the estimates (Bliemer et al., 2014).

Pedestrians' scenarios refer to route choice, as shown in Table 1. The first alternative - Usual route - includes the attributes: crowdedness level and walking environment. Importantly, travel time for this alternative is based on the actual time reported by the respondent in a prior question in Part B, (trip characteristics). The second alternative - Suggested route - includes three attributes: crowdedness level, travel time and walking environment. The walking travel time includes three levels. One level corresponds to the reported travel time by the respondent, while the other two levels reflect travel times increased by +10 % and +30 %. These percentages were determined based on both the values of stated travel times and findings in the literature regarding typical walking times for main activities (Panter et al., 2011). The use of increased values for walking travel time was driven by the aim to create realistic, behaviorally relevant scenarios that provide insights into how individuals perceive and make trade-offs concerning travel time when crowdedness is a factor. Each participant was presented with six stated preference scenarios, and the appearance of the alternatives was designed to correspond to the levels of the attributes, enhancing the realism of the choice environment.

The public transport users' scenarios include options related to changes in departure time (five scenarios) and public transport stop choice (five scenarios). The scenarios involving changes in departure time (itinerary choice), include two alternatives (Table 2). The first alternative - Usual itinerary - includes the attribute of crowdedness with moderate and high levels. The second alternative - Suggested itinerary - refers to a departure time change and suggests a departure time change to avoid peak-hour crowdedness, offering three attributes: crowdedness level, travel time on the public transport mode, and arrival time. The crowdedness level could be low or moderate and the arrival time could be earlier or later. The travel time includes three levels. One level is the stated time as was reported by the respondent in a previous question. The other two levels were the stated values of travel time decreased by −10 % and −20 %. The percentages were decided based on the values of the stated travel times. A reduction of travel time was assumed since a choice of an off-peak hour itinerary reflects a less crowded road network and/or a lower number of boarding/alighting than an overcrowded itinerary during peak hours. Five SP scenarios were presented to each participant. The appearance of the alternatives was differentiated and was related to the appeared attribute's levels, to improve the realism of the choice experiment.

Lastly, the remaining five scenarios refer to the use of a different public transport stop, as detailed in Table 3, and include two alternatives. The first alternative, -Usual public transport stop- includes the

Table 1
Alternatives, attributes, and attributes' levels for pedestrians.

Alternative	Attribute	Attribute levels
Usual route	Crowdedness level	Moderate
		High
	Travel time	Same as reported[a]
	Walking environment	Commercial
		Residential
		Sightseeing/natural beauty
Suggested route	Crowdedness level	Low
		Moderate
	Travel time	Same as reported[a]
		+10 %[b]
		+30 %[b]
	Walking environment	Commercial
		Residential
		Sightseeing/natural beauty

[a] Respondents were asked about the estimated travel time for their main daily trip.
[b] The attribute levels were pivoted around the stated values of travel time.

Table 2
Alternatives, attributes, and attributes' levels for public transport users- change of departure time.

Alternative	Attribute	Attribute levels
Usual itinerary	Crowdedness level	Moderate
		High
Suggested itinerary	Crowdedness level	Low
		Moderate
	Travel time (on the public transport mode)	−10 %[b]
		−20 %[b]
		Same as reported[a]
	Arrival time	Earlier
		Later

[a] Respondents were asked about the estimated travel time (on the public transport mode) of their main daily trip.
[b] The attribute levels were pivoted around the stated values of travel time.

Table 3
Alternatives, attributes, and attributes' levels for public transport users- use of different public transport stop.

Alternative	Attribute	Attribute levels
Usual public transport stop	Crowdedness level	Moderate
		High
Suggested public transport stop	Crowdedness level	Low
		Moderate
	Walking time	+50 %[a]
		+100 %[a]

[a] The attribute levels were pivoted around the stated values of travel time.

attribute of crowdedness with moderate and high levels. The second alternative - Suggested public transport stop - refers to the use of a different stop with a reduction of 10 % in time on the mode. This percentage was decided based on the stated time on the mode and the average travel distance between stops. The decrease in time that someone remains in the mode was mentioned for each scenario. The second alternative includes two attribute levels: the crowdedness with low and moderate levels and the walking time with two levels. One level was the stated values of walking time to the stop increased by 50 % and the other one by 100 %. The percentages were decided considering an average walking speed of 4.5 km/h (Alves et al., 2020) and assuming a distance range between stops 200 m–400 m (bus stops), 400 m–600 m (tram stops) and 500 m–1000 m (metro stops) (Tennøy et al., 2022; van Soest et al., 2020). The appearance of the alternatives was differentiated and randomized to mitigate potential biases.

The following figure shows an example of the presented stated preference experiments (Fig. 5).

3.2. Methodological approach for data analysis

3.2.1. Choice modelling

The collected data (socio-demographic characteristics, trip characteristics, revealed and stated preference data) is used to estimate mixed multinomial logit models and estimate the probability of an individual choosing a less crowded alternative based on the random utility theory (Ben-Akiva & Bierlaire, 2013; Train, 2013). Since in the SP survey the respondents faced several scenarios, the models account for repeated observations from the same individuals in the data set (panel data). The utility equations for the two alternatives in each model are presented in Section 5.1. All the variables are specific to the suggested alternative and not to the usual choice. This decision is made to emphasize the impact of different aspects on the switching behavior and to interpret the results based on the willingness to change. The procedure for selecting the variables in the final models, as presented in Section 5.1, involved a manual approach. Emphasis was placed on careful consideration of the theoretical and empirical relevance of each variable within the context of the research objectives. Variables were chosen based on data availability and the estimation results of alternative models. Notably, a broader set of variables, including socio-demographic and trip-related factors, was examined beyond those presented. The final selection of variables was determined based on the best estimation results, with a focus on identifying variables with the most significant influence on the

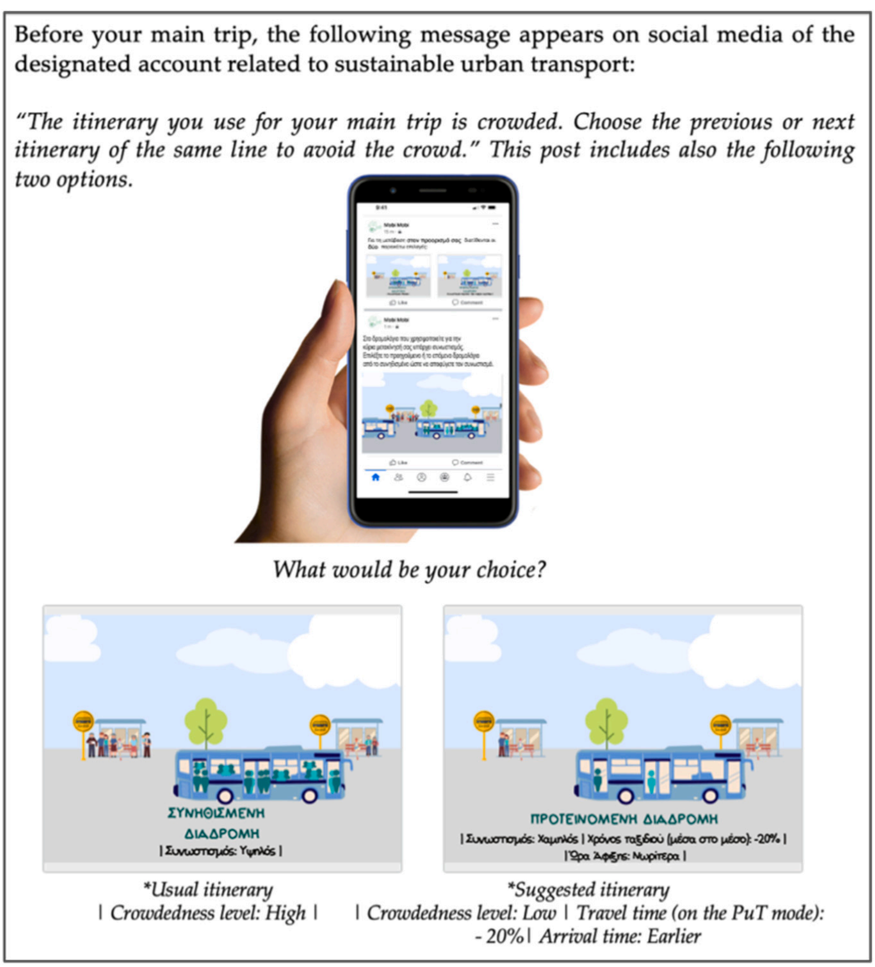

Fig. 5. Example of a Stated Preference experiment addressed to public transport users (the specific example advises to take the previous itinerary). The original text of the experiment was in Greek.

outcomes. Concerns regarding potential confirmation bias were addressed through the inclusion of a diverse range of variables and by conducting sensitivity analyses to assess the robustness of the selected variables. These measures aimed to ensure a comprehensive and unbiased variable selection process.

3.2.2. Factor analysis

The exploratory factor analysis was used to reduce aimed to reduce the dimensionality of the dataset by transforming a set of correlated variables into a smaller set of summary variables, referred to as factors. Principal Component Analysis (PCA) was applied to achieve this dimension reduction while retaining the essential information contained in the original dataset. PCA is a widely recognized and robust technique for factor analysis that seeks to maximize the variance explained by the derived factors. The PCA process involves a series of mathematical operations to orthogonalize the original variables into linear combinations that constitute the newly extracted factors. These factors capture the underlying patterns and structures in the data, allowing for a more concise representation of the information while minimizing redundancy.

To ensure the appropriateness of the factor analysis, two essential tests were conducted: The Kaiser-Meyer-Olkin (KMO) and the Bartlett's Test of Sphericity. The KMO measure assesses the sample adequacy for factor analysis, with higher values indicating a more suitable dataset for dimension reduction. Additionally, the Bartlett's Test of Sphericity examines whether the correlations between variables are sufficiently different from zero for factor analysis to be meaningful. In our analysis, the KMO measure confirmed the adequacy of the sample for factor analysis, indicating that the dataset exhibited a strong structure suitable for factor extraction. Moreover, the Bartlett's Test of Sphericity yielded a significant result ($p < 0.05$), supporting the presence of inter-variable correlations necessary for meaningful factor analysis.

4. Data collection - sample recruitment

4.1. Pilot study

A small sample of 20 respondents was used for piloting the survey. This step is an important stage of the research and aims at getting an assessment of the survey design by identifying potential problematic areas, deficiencies, or ambiguities in the research instruments. No attempt was made to recruit a representative sample of respondents because the intention of the pilot survey was not to collect usable data, but rather to test the survey design and methodology. The pilot study revealed that some questions were unclear or confusing to participants, making it difficult for them to provide accurate or meaningful responses. These issues were identified and addressed before the questionnaire was shared with a larger group. Valuable feedback was provided and used to improve the questionnaire and ensure that it is effective in achieving the research goals.

4.2. Survey distribution

The online survey was targeted to respondents who use social media. As a first step, emails were sent to 3436 contacts of a Transportation Research laboratory contact list comprised of research institutions, ministries, municipalities, associations, groups, companies, actions, projects, and postgraduate students. The emails were sent from the email account of the laboratory. As a second step, the questionnaire link was shared on first author's personal social media accounts. The link to the questionnaire was active for one month, April 2021. Along with the invitation to participate, information about the purpose and the design of the survey was sent. An initial sample of 1349 responses were collected with a completion rate of 69 %. The final sample size comprised 925 users, who fully completed the questionnaire. However, as the aim of the study dictates, the main analysis in this paper was made based on 465 respondents, who use walking or public transport for their daily main trip. The collection period was approximately one month, i. e., 29th March 2021–30th April 2021.

4.3. Sample characteristics

Respondents of the analyzed groups were approximately evenly distributed between gender categories (pedestrians: 56 % female and 44 % male; public transport users: 49 % female and 51 % male). Table 4 presents the frequencies and descriptive statistics of the pedestrians' and public transport users' characteristics.

With regards to the respondents' commuting habits and the impact of COVID-19 on their daily main trip. Most of the public transport users (about 57 %) chose the trip to work as daily main trip, while the option Other was indicated as daily trip by 36 % of pedestrians. Walking is typically chosen for more flexible in terms of arrival time activities compared to work/education. A social visit, entertainment, outdoor physical exercise or going to the gym are some activities that the 36 % of the pedestrians in the "Other" category could have as a purpose of their daily main trip. As indicated, for half of the pedestrians (about 46 %) there is no limit on the arrival time, while most of the public transport users have a flexibility of 5–15 min on their arrival time. During a lockdown period 46 % of the public transport users did not perform the trip at all, while 66 % of the pedestrians performed the trip with less frequency compared to a non-lockdown period. The spread of COVID-19 had also an impact on the frequency of the daily main trip on a period without a lockdown. Specifically, 37 % of pedestrians and 38 % of public transport users perform the trip with less frequency, while 19 % of

Table 4
Sample characteristics- pedestrians and public transport users.

Variables	Pedestrians (n = 353)	Pedestrians (%)	Public transport users (n = 112)	Public transport users (%)
Gender				
Female	198	56	55	49
Male	155	44	57	51
Age				
18–23	183	52	45	40
24–40	144	41	65	58
41–65	24	7	2	2
>66	2	<1	–	–
Monthly income				
0–500	234	66	59	53
501–1000	73	21	33	29
1001–1500	30	8.5	12	11
>1501	16	4.5	8	7
Occupation				
Students	205	58	52	46
Part-time job	19	6	14	13
Full-time job	71	20	39	35
Freelancer	24	7	7	6
Household	5	1	–	–
Unemployed	22	6	–	–
Retired	4	1	–	–
Other	3	1	–	–
Place of residence				
Large-sized (Athens)	82	23	55	49
Medium-sized (Thessaloniki, Patra, Heraklion, Larisa, Volos)	177	50	50	45
Small-sized	94	27	7	6

public transport users don't perform the trip at all. Due to the spread of COVID-19, a change in the transport mode of the daily main trip was recorded in both groups. 51 % of pedestrians and 58 % of public transport users changed their transport mode.

Statistically significant differences between the two groups were reported in ordinal variables measured on the 5-point scale. Participants responded by rating items ranging from 1 (lower scores) to 5 (higher scores) with 3 as a midpoint. The Mann-Whitney two-sample *U* test is performed to assess these differences between the two groups (see Table 5).

5. Data analysis

5.1. Choice model estimation

In total, three models are developed for both pedestrians and public transport users. Specifically, the first model (Model I) refers to the SP of pedestrians' group and the other two models (Model IIa and Model IIb) to the two SPs of public transport users: a) change of departure time and b) use of a different public transport stop. The utility equations of the two alternatives for the three developed models are presented below. The presented model specification is a standard linear-in-the-parameters specification, used in most of such models. The actual choice of variables is determined based on data availability and estimation results of alternative considered models. More variables (socio-demographic, trip-related etc.) than the presented were examined but the final choice was based on the best given estimation results. The utilities of Model I specific to individual n, n = 1…N are:

$$U_{UR,n} = \mathrm{ASC}_{\mathrm{UR}}$$

$$U_{SR,n} = \mathrm{ASC}_{\mathrm{SR}} + \beta_{RESID\_A} \times RESID_A + \beta_{RESID_B} \times RESID_B + \beta_{TT_{DIFF}} \times TT_{DIFF} + \beta_{CROWD_A} \times CROWD_A + \beta_{CROWD_B} \times CROWD_B + \beta_{COVIDIMP} \times COVIDIMP + \beta_{COVIDPERP} \times COVIDPERP + \beta_{ACTIVCHANGE} \times ACTIVCHANGE + \beta_{ROUTECHANGE} \times ROUTECHANGE + \beta_{WILLMIN} \times WILLMIN + \sigma_{PEDES} \times \varepsilon_{PEDES,n}$$

The utilities of Model IIa specific to individual n, n = 1…N are:

$$U_{UR,n} = \mathrm{ASC}_{\mathrm{UR}}$$

$$U_{SR,n} = \mathrm{ASC}_{\mathrm{SR}} + \beta_{AGE\_B} \times AGE\_B + \beta_{AGE\_C} \times AGE\_C + \beta_{AT\_SR} \times AT\_SR + \beta_{CROWD\_A} \times CROWD\_A + \beta_{CROWD\_B} \times CROWD\_B + \beta_{STTDI} \times STTDI + \beta_{STTDU} \times STTDU + \beta_{STWDU} \times STWDU + \beta_{TRIPPER} \times TRIPPER + \beta_{COVIDIM} \times COVIDIM + \beta_{STOPCHANGE} \times STOPCHANGE + \sigma_{PuT} \times \varepsilon_{PuT,n}$$

The utilities of Model IIb specific to individual n, n = 1…N are:

$$U_{UR,n} = \mathrm{ASC}_{\mathrm{UR}}$$

$$U_{SR,n} = \mathrm{ASC}_{\mathrm{SR}} + \beta_{GENDER} \times GENDER + \beta_{WT\_DIFF} \times WT\_DIFF + \beta_{CROWD\_A} \times CROWD\_A + \beta_{CROWD\_B} \times CROWD\_B + \beta_{STWDU} \times STWDU + \beta_{INFTYPE\_A} \times INFTYPE\_A + \beta_{INFTYPE\_B} \times INFTYPE\_B + \beta_{INFTYPE\_C} \times INFTYPE\_C + \beta_{STOPCHANGE} \times STOPCHANGE + \sigma_{PuT} \times \varepsilon_{PuT,n}$$

The U_{UR} and U_{SR} denote the utility derived from the alternatives: usual route and suggested route, respectively. The coefficient ASC_{UR} represents the alternative-specific constant of the usual choice alternative, while the remaining alternative serves as the base case. A description of the tested variables and their abbreviations for pedestrians and public transport users are given in Tables 6 and 7, respectively. Random effects for the alternative associated with the suggested option has been introduced into the MMNL model specification, while the usual choice is used as the reference. The random terms σ are normally distributed, and ε are zero-mean, standard, normal error terms.

5.2. Factor analysis

Four variables (COVIDIMP and COVIDPERP for pedestrians, TRIPPER and COVIDIM for public transport users) are specified based on a factor analysis.

The first latent variable is labelled "COVIDIMP- Importance of measures after COVID-19 spread" and includes the recorded importance of eight measures against the spread of COVID-19 based on the pedestrians' responses (see Table 8). The second one is labelled "COVIDPERP- Performance of the measures after COVID-19 spread" and includes the recorded performance of the eight measures against the COVID-19 spread, based on pedestrians' responses (see Table 8). The Cronbach's alpha values were >0.8 indicating a very good level of reliability.

The collected data of public transport users' responses regarding the COVID-19 measures and the trip performance are used to determine the two factors COVIDIM and TRIPPER, respectively. The first latent variable is labelled "COVIDIM-Importance of the measures after COVID-19 spread" and includes the recorded importance of eight measures against the spread of COVID-19 with Cronbach's alpha = 0.838 (see Table 9). The second one is labelled "TRIPPER- Trip performance with a public transport mode" and includes the recorded performance of a trip in terms of crowdedness, duration, walking time to the public transport stop, arrival time and surrounding area of the walking route (see Table 9).

6. Model estimation results

This section presents the model estimation results. The developed MMNL models have been estimated using the software package Biogeme (2023) and consider the panel effect for repeated observations from the same individuals in the dataset. After testing various specifications, the final presented models are selected based on statistical goodness-of-fit (likelihood ratio tests, estimated coefficient significance *t*-tests, the rho-square (ρ^2), and adjusted rho-square ($\bar{\rho}^2$) statistics). 10,000 random draws are used for models' estimation. To ensure the stability and reliability of coefficient estimates and model statistics throughout the estimation process, the values assigned to estimated coefficients at each iteration of the optimization process were closely monitored and examined for consistency across multiple runs. Additionally, the stable values of log-likelihood were also used as an indicator of optimization convergence. Goodness-of-fit measures were evaluated across different runs of the optimization to verify that the statistics consistently demonstrated stability and reliability. It was verified that the coefficient estimates and the model statistics, had converged before reaching that number, therefore, it was confirmed that 10,000 draws are sufficient. All the estimated coefficients are specific to the suggested option.

6.1. Pedestrians

A total of 2118 SP observations were collected from 353 individuals, who use walking for their daily main trip. The model estimation results for pedestrians are presented in Table 10.

The negative sign of the estimated alternative-specific constant value (ASC_UR: corresponding to the usual route) shows that there is tendency towards the suggested route with the lower crowdedness levels, all else being equal. The negative signs of the place of residence show that pedestrians who live in Athens or in other medium sized cities are less likely to change their usual route compared to residents of small sized Greek cities.

The stated preference data that are used to estimate the choice probability in the presented model concern difference in travel time and crowdedness levels. The travel time difference seems to increase slightly the possibility a pedestrian to shift away from the crowded usual route. The positive values of the estimated coefficients associated with the crowdedness levels (CROWD_A and CROWD_B) indicate that pedestrians have a high tendency towards changing the usual route when the crowdedness level is high. The results show that, as expected, travelers are more likely to change their route to experience moderate crowdedness level rather than high (CROWD_A) and, respectively, to experience low crowdedness level rather than high (CROWD_B) as compared to moderate to low (CROWD_C, reference variable).

The positive value of the estimated coefficient associated with the importance and performance of measures against the spread of COVID-19 indicates that pedestrians that rated highly the importance and performance of measures are more likely to change their usual route due to high levels of crowdedness in their trip. Pedestrians that stated intermediate stops for activities do not affect at all or affect very little their daily main trip after getting information, are more likely to change their usual route in response to information about crowdedness levels. This is captured by the positive sign of the related dummy variable ACTIVCHANGE (1: Not at all, A little; 0: Moderate, Much, Very much).

Pedestrians that are not willing at all or exercise a low willingness to change the usual route after receiving information about high levels of crowdedness on their main trip, are less likely to use the less crowded suggested route in response to this information. This is captured by the negative sign of the related dummy variable ROUTECHANGE (1: Not at

Table 6
List of tested variables for pedestrians.

Variable name	Type	Abbreviation
Pedestrians		
Socio-demographic characteristics		
Place of residence: large-sized (Athens)	Dummy	RESID_A
Place of residence: medium-sized (Thessaloniki, Patra, Heraklion, Larisa, Volos)	Dummy	RESID_B
Place of residence: small-sized (reference)	Reference	RESID_C
Stated preference attributes		
Travel time difference between suggested and usual route	Continuous	TT_DIFF
Crowdedness level from high to moderate	Dummy	CROWD_A
Crowdedness level from high to low	Dummy	CROWD_B
Crowdedness level from medium to low (reference)	Reference	CROWD_C
Crowdedness and Covid-related characteristics		
Importance of measures against COVID-19 spread (Factor analysis see Section 5.2)	Factor	COVIDIMP
Performance of measures against COVID-19 spread (Factor analysis see Section 4.3.2)	Factor	COVIDPERP
Impact of stops for activities at intermediate destinations on final decision regarding changes on main trip after getting information about crowdedness levels (1: not at all, a little; 0: moderate, much, very much)	Dummy	ACTIVCHANGE
Willingness to change the usual route after receiving information about high levels of crowdedness on main trip (1: not at all, a little; 0: moderate, much, very much)	Dummy	ROUTECHANGE
Additional minutes that someone is willing to travel more on a less crowded route, after receiving information about high levels of crowdedness on their main trip	Continuous	WILLMIN

Table 5
Trip characteristics of the analyzed samples-pedestrians and public transport users.

Variables	Groups				Test parameters relation	Pedestrians vs. Public transport users	
	Pedestrians		Public transport users				
	M	SD	M	SD		U	p-Value
(i) Willingness to be informed via applications such as Google maps or social media about the crowdedness levels of the main trip	2.94	1.255	3.65	1.113	$r_{Ped} < r_{PuT}$	**13,513**	**<0.001***
(ii) Willingness to change the usual travel choice after receiving information about high levels of crowdedness on the main trip	3.18	1.046	2.85	1.024	$r_{Ped} > r_{PuT}$	**16,273**	**0.003***
(iii) Importance measures against the COVID-19 spread							
- Public health	4.63	0.661	4.79	0.560	$r_{Ped} < r_{PuT}$	**17,350**	**0.010***
(iv) Performance of measures against the COVID-19 spread							
- Mandatory use of face mask in outdoor spaces	2.93	1.154	2.63	1.148	$r_{Ped} > r_{PuT}$	**16,800.5**	**0.013***
- Public health	3	1.224	2.64	1.154	$r_{Ped} > r_{PuT}$	**16,418.5**	**0.005***
(v) Evaluation of daily main trip							
- Crowdedness level	3.71	0.948	2.54	1.122	$r_{Ped} > r_{PuT}$	**8624**	**<0.001***
- Travel time	3.89	0.870	3.11	1.110	$r_{Ped} > r_{PuT}$	**11,702**	**<0.001***

*statistically significant value.

Table 7
List of tested variables for public transport users.

Variable name	Type	Abbreviation
Public transport users		
Socio-demographic characteristics		
18–23 (reference)	Reference	AGE_A
24–40	Dummy	AGE_B
41–65	Dummy	AGE_C
Female: 1 male: 0	Dummy	GENDER
Stated preference attributes		
Arrival time at suggested option (1: later 0: earlier)	Dummy	AT_SR
Difference of walking time to the public transport stop between usual and suggested option	Continuous	WT_DIFF
Crowdedness level from high to moderate	Dummy	CROWD_A
Crowdedness level from high to low	Dummy	CROWD_B
Crowdedness level from medium to low	Reference	CROWD_C
Travel information		
Applications such as Google maps	Dummy	INFTYPE_A
Public transport applications	Dummy	INFTYPE_B
Social media	Dummy	INFTYPE_C
None (reference)	Reference	INFTYPE_D
Trip characteristics		
Stated travel distance (on transport mode)	Continuous	STTDI
Stated travel duration (on transport mode)	Continuous	STTDU
Stated walking duration to the public transport stop	Continuous	STWDU
Performance of the main daily trip	Factor	TRIPPER
Crowdedness and Covid-related characteristics		
Importance of COVID-19 measures	Factor	COVIDIM
Willingness to use a different public transport stop than usual after receiving information about high levels of crowdedness on your main trip? (1: not at all, a little; 0: moderate, much, very much)	Dummy	STOPCHANGE

all, A little; 0: Moderate, Much, Very much) associated with the willingness to change the usual route. The additional minutes that someone is willing to travel longer on a less crowded route, after receiving information about high levels of crowdedness on their main trip, seem to slightly increase the probability of change their route.

6.2. Public transport users

In the estimated models of public transport users (change of departure time and use of a different public transport stop) a total of 560 observations were collected from 112 individuals.

6.2.1. Change of departure time

Table 11 shows the model estimation results for change of departure time. The negative sign of the estimated alternative-specific constant value (ASC_UR: corresponding to the usual route) shows that there is tendency towards the suggested option of less crowdedness levels which involves changing the departure time.

Among the socioeconomic characteristics only the independent variable of 41–65 aged group is found significant. The positive and high value of the estimated coefficient indicates that people aged 41–65 are more likely to change their departure time than younger people, aged 18–23 years.

The presented model uses also stated preference data to estimate the choice probability. We find that public transport users are less likely to change their departure time if they will arrive later at their destination compared to an earlier arrival. This is captured by the negative sign of the related dummy variable associated with the arrival time (1: Later, 0: Earlier). The positive values of the estimated coefficients associated with the crowdedness levels (CROWD_A and CROWD_B) indicate that public transport users have a high tendency towards changing their departure time when the crowdedness level of their usual choice is high. The results show that travelers are more likely to change their trips' departure time to experience moderate crowdedness level rather than high (CROWD_A) and, respectively, to experience low crowdedness level rather than high (CROWD_B) as compared to moderate to low (CROWD_C, reference variable).

The stated travel distance (in transport mode) and the stated walking duration to the public transport stop seem to increase slightly the possibility to change the departure time, while the stated travel duration (on-board time) seems to decrease slightly this possibility. An explanation could be a specific arrival time in mind, a good preparation for the challenges of crowded trips (packed with necessary supplies, such as masks or hand sanitizer) or even an on-board activity (e.g., reading, listening to music/watching videos, working). The negative sign of the estimated coefficient associated with the trip performance factor

Table 8
Factor analysis for pedestrians (COVIDIMP and COVIDPERP variables).

Variables	Component
COVIDIMP: importance of the following measures after COVID-19 spread	
Mandatory use of face mask in outdoor spaces	0.387
Mandatory use of face mask in indoor spaces	0.422
Social distancing	0.437
Levels of cleanliness and disinfection in public spaces	0.502
Public health	0.466
A sense of security (absence of worry of infection/illness)	0.528
A sense of individual responsibility of people around you	0.606
Personal hygiene measures	0.441
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.	*0.836*
Bartlett's Test of Sphericity	*<0.001*
Cronbach's alpha	*0.827*
COVIDPERP: performance of the following measures after COVID-19 spread	
Mandatory use of face mask in outdoor spaces	0.253
Mandatory use of face mask in indoor spaces	0.391
Social distancing	0.428
Levels of cleanliness and disinfection in public spaces	0.676
Public health	0.676
A sense of security (absence of worry of infection/illness)	0.666
A sense of individual responsibility of people around you	0.528
Personal hygiene measures	0.373
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.	0.850
Bartlett's Test of Sphericity	<0.001
Cronbach's alpha	*0.853*

Table 9
Factor analysis for public transport users (COVIDIM and TRIPPER variables).

Variables	Component
COVIDIM: importance of the following measures after COVID-19 spread	
Mandatory use of face mask in outdoor spaces	0.326
Mandatory use of face mask in indoor spaces	0.555
Social distancing	0.467
Levels of cleanliness and disinfection in public spaces	0.463
Public Health	0.470
A sense of security (absence of worry of infection/illness)	0.603
A sense of individual responsibility of people around you	0.574
Personal hygiene measures	0.568
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.	*0.860*
Bartlett's Test of Sphericity	*<0.001*
Cronbach's alpha	*0.838*
TRIPPER: trip performance with a public transport mode	
Crowdedness level (on public transport vehicle or/and at the station)	0.545
Trip duration (on public transport vehicles)	0.732
Walking time	0.078
Arrival time at the final destination	0.710
The surrounding area of the walking route	0.287
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.	*0.728*
Bartlett's Test of Sphericity	*<0.001*
Cronbach's alpha	*0.678*

(TRIPPER) with a public transport mode (in terms of Crowdedness level (on-board the public transport mode or/and at the public transport station); Trip duration (on-board the public transport mode); Walking time; Arrival time at the final destination; Surrounding area of the walking route) indicates that travelers who rated higher their usual public transport trip are less likely to change their departure time when they receive information about high crowdedness levels.

The positive value of the estimated coefficient associated with the importance of measures against the spread of COVID-19 indicates that public transport users that rated the importance of measures as high are more likely to change their departure time due to high levels of crowdedness along their usual trip. Public transport users that are not willing at all or show low willingness to use a different public transport stop than usual after receiving information about high levels of crowdedness on their main trip, are less prone to change their departure time in response to this information. This is captured by the negative sign of the related dummy variable (1: Not at all, A little; 0: Moderate, Much, Very much) associated with the willingness to change of public transport stop.

Based on the estimation results the coefficient σ_Put, (corresponding to the standard deviation of the random error terms for the alternative suggested route) is highly significant, suggesting that the model allows for capturing intrinsic correlations among the observations of the same individual.

6.2.2. *Change of public transport stop*

Table 12 shows the model estimation results referring to the willingness to use a different public transport stop than the usual one after receiving information about high levels of crowdedness on your main trip. The positive sign of the estimated alternative specific constant value (ASC_UR: corresponding to the usual route) shows that there is a tendency to stick to the usual public transport stop despite the lower crowdedness levels experienced if switching. None of the coefficients associated with the socioeconomic characteristics are found significant.

Public transport users are less likely to change the public transport stop if they will walk more to the public transport stop compared to their usual trip. This is captured by the negative sign of the related continuous variable associated with the difference of the walking time. The positive values of the estimated coefficients associated with the crowdedness levels (CROWD_A and CROWD_B) indicate that public transport users have a high tendency towards changing the stop when the crowdedness level of their usual choice is high. The results show that travelers are more likely to change their trips' departure time to experience moderate crowdedness level rather than high (CROWD_A) and, respectively, to experience low crowdedness level rather than high (CROWD_B) as compared to moderate to low (CROWD_C, reference variable). The stated travel walking duration seems to increase slightly the possibility to use a different public transport stop.

The three variables (INFTYPE A, INFTYPE B, INFTYPE C) capture the effect of the three means for travel information provision: Applications such as Google maps; Public transport applications; social media respectively. The category None was used as a reference variable. In all cases, the provision of information by the three means increases the propensity of the public transport users to switch from their usual public transport stop, as expected. The travelers' propensity towards a stop change is increased when there is information on crowdedness levels is shared on social media compared to no sharing at all.

Public transport users that are not willing at all or have a low willingness to use a different public transport stop than usual after receiving information about high levels of crowdedness on their main trip, are less prone to use a different public transport mode in response to this information. This is captured by the negative sign of the related dummy variable (1: Not at all, A little; 0: Moderate, Much, Very much) associated with the willingness to change of public transport stop.

7. Concluding discussion

The COVID-19 pandemic has led to changes in people's lifestyles and mobility habits. It has also affected travel choices and had a significant impact on both pedestrians and public transport users. Due to social distancing measures and lockdowns, many people have been

Table 10
Model estimation results - pedestrians.

Variable name	Coef. est.	*t*-Test
Alternative-specific constant (ASC) (base case: suggested route)		
ASC_UR	−0.996	−4.58
Socio-demographic characteristics		
B_RESID_A	−0.464	−2.02
B_RESID_B	−0.39	−2.02
Stated preference attributes		
B_TT_DIFF	0.0322	0.0129
B_CROWD_A	1.88	10.7
B_CROWD_B	0.779	5.52
Covid-related characteristics		
B_COVIDIMP	0.445	5.58
B_COVIDPERP	0.135	1.63
B_ACTIVCHANGE	0.247	1.54
B_ROUTECHANGE	−0.853	−4.57
B_WILLMIN	0.0217	1.88
σ_Put (specific to suggested route)	0.856	7.62
Summary statistics		
N	Number of observations	2118
LL_0	Initial log likelihood	−2917.274
LL_b	Final log likelihood	−910.9256
ρ^2	Rho-square	0.693
$\overline{\rho}^2$	Adjusted Rho-square	0.689

Table 11
Model estimation results: public transport users- change of departure time.

Variable name	Coef. est.	*t*-Test
Alternative-specific constant (ASC) (base case: suggested route)		
ASC_UR	−2.16	−2.86
Socio-demographic characteristics		
B_AGE_B	0.676	1.56
B_AGE_C	6.27	2.6
Stated preference attributes		
B_AT_SR	−2.86	−5.26
B_CROWD_A	2.86	3.53
B_CROWD_B	2.72	6.07
Daily main trip characteristics		
B_STTDI	0.0692	1.92
B_STTDU	−0.0487	−3.15
B_STWDU	0.027	1.57
B_TRIPPER	−0.454	−1.9
Covid-related characteristics		
B_COVIDIM	1.19	4.88
B_STOPCHANGE	−1.17	−2.53
σ_Put (specific to suggested route)	−1.35	−4
Summary statistics		
N	Number of observations	560
LL_0	Initial log likelihood	−952.8573
LL_b	Final log likelihood	−157.0244
ρ^2	Rho-square	0.835
$\overline{\rho}^2$	Adjusted Rho-square	0.822

encouraged or even required to avoid crowded places and shift to alternative ways of transport. This has resulted in a decrease in walking and public transport usage in many cities around the world (Nikiforiadis et al., 2022). Additionally, many public transport systems have implemented measures such as increased cleaning and capacity limitations to reduce the spread of the virus. As a result, waiting times for public transport trips became longer, and some commuters chose to avoid it. Overall, the pandemic has led to significant changes in the way people use public spaces and transport (de Palma et al., 2022; Downey et al., 2021).

The use of real-time information about crowdedness levels during COVID-19 can help individuals decide where to go and when to avoid areas that may be at higher risk for spreading the virus. It can also help businesses and organizations to implement social distancing measures and adjust their operations to reduce the risk of transmission. Additionally, it can assist public health officials in identifying and addressing hotspots of transmission, which can help slow the spread of the virus and reduce the overall impact of the pandemic (Stroom et al., 2021).

Based on research findings, it can be concluded that crowd avoidance plays a significant role in shaping mobility decisions for pedestrians and public transport users during pandemics. Results showed that pedestrians in Athens as well as in other medium-sized Greek cities are less likely to change their usual route compared to those in smaller Greek cities which is consistent with a previous study (Karakikes & Nathanail, 2022). The level of familiarity with the city and the high crowdedness levels of larger cities in general are factors that could explain this finding. Residents of smaller cities may have a more intimate knowledge of their city and be more familiar with alternative routes to take. In addition, Athens and other medium-sized cities may face high crowdedness levels in general, so residents may be more accustomed to dealing with crowdedness and less likely to change their usual route. Consistent with previous studies, pedestrians who rated high the importance and performance of measures against COVID-19 are more likely to change their usual route due to high levels of crowdedness in their trip. This group of people is more likely to prioritize its own health and safety (Shelat, Cats, & van Cranenburgh, 2022). These individuals may believe that measures such as social distancing and mandatory mask use are effective in reducing the spread of COVID-19 and are more likely to take action to avoid crowded areas. Additionally, they may also be more proactive in obtaining information about the measures and crowdedness level and have access to reliable sources that they are willing to follow.

The decision to change departure time is affected by factors such as arrival time at destination and the perceived quality of the usual public transport trip. Public transport users are less likely to change their departure time to avoid the crowd if they will arrive later at their destination compared to an earlier arrival which is in line with the study of Hadas et al. (2022). In addition, travelers who rated higher their usual public transport trip are less likely to change their departure time when they receive information about high crowdedness levels. People prioritize different factors depending on their personal circumstances before every trip which can lead to different decisions about their departure time to avoid crowds. The importance of arriving on time to work or other commitments, the level of inconvenience or discomfort associated with a crowded public transport trip, and the perceived importance of measures to prevent the spread of COVID-19 are some factors that play an important role on the final decision.

Our research focused on understanding how the COVID-19 pandemic has impacted travel behavior. However, the findings hold broader significance beyond the immediate circumstances. While the pandemic undoubtedly influenced people's approach to crowded places, the core aspects that are identified – the preference for less crowded options and the willingness to balance travel time with crowdedness – are fundamental to understanding mobility choices in general.

This highlights the importance of developing accessible, efficient, and safe transportation systems that cater to these preferences. The desire to avoid crowded spaces isn't solely pandemic-driven; it reflects a broader societal concern for comfort, well-being, and sustainability. In a non-pandemic era, these findings offer valuable insights into factors influencing travel choices and perceptions of crowdedness across different transportation modes. This knowledge can inform urban planners, policymakers, and transportation authorities as they design user-centric and sustainable mobility solutions.

Table 12
Model estimation results: public transport users- change of public transport stop.

Variable name	Coef. est.	*t*-Test
Alternative- specific constant (ASC) (base case: suggested route)		
ASC_UR	3.04	1.57
Socio-demographic characteristics		
B_GENDER	−1	−1.52
Stated preference attributes		
B_WT_DIFF	−0.16	−3.47
B_CROWD_A	2.03	4.87
B_CROWD_B	2.14	5.05
Daily main trip characteristics		
B_STWDU	0.0798	1.86
Travel information		
B_INFTYPE_A	5.21	2.67
B_INFTYPE_B	4.8	2.54
B_INFTYPE_C	6.02	2.56
Covid-related characteristics		
B_STOPCHANGE	−1.64	−2.35
σ_Put (specific to suggested route)	2.73	6.29
Summary statistics		
N	Number of observations	560
LL_0	Initial log likelihood	−654.1905
LL_b	Final log likelihood	−233.0567
ρ^2	Rho-square	0.644
$\bar{\rho}^2$	Adjusted Rho-square	0.627

Despite the study's valuable insights into travel behavior, it is important to note that there are limitations to consider. Firstly, the data collected, and the respective analysis is limited one country, with specific sociodemographic and mobility characteristics. Secondly, the information about the crowdedness levels can only be estimated and may not be accurate or available in all areas. This type of information is not widely available, and the way it is presented can impact how respondents value it. It is important to note that the choices observed in the study are hypothetical and may not reflect the actual constraints faced by individuals in different societal circumstances. Finally, we acknowledge that our observations and participants' behavior may change as the pandemic continues to evolve and people adapt to a new reality. However, research's findings are still valuable because they provide an insight into traveler preferences at crucial phases of the pandemic which can assist in making proactive decisions in the future. In addition, the results can be useful for governments in developing policies that effectively control the spread of a pandemic and improve public transport services. Additionally, our findings suggest that targeted communication and information-sharing campaigns, tailored to specific groups and trip types, could be an effective strategy for promoting crowd avoidance behaviors.

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CRediT authorship contribution statement

Maria Karatsoli: Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Eftihia Nathanail:** Writing – review & editing, Validation, Supervision, Methodology, Funding acquisition, Conceptualization. **Socrates Basbas:** Writing – review & editing, Supervision, Conceptualization. **Oded Cats:** Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare no conflict of interest.

Data availability

Data will be made available on request.

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