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# How to build a more sustainable passenger air transport system: multimodal experience

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ABSTRACT

A fully integrated passenger multimodal system is a new concept in the transport industry, and consequently, data on system interoperability is lacking. In this paper, a qualitative research method is applied, to get the transport experts' opinions and information on how the multimodal system should be designed. Although they are aware that the collaboration should result in an increase in the volume of passengers, the most challenging task is to convince transport operators to share the data with each other, due to legal issues. To determine the passengers' perspective on making multimodal choices in their journeys, the travel demand model is developed, based on online survey data. The proposed (Binary Logistic Regression) model reveals the importance for policymakers and transport operators serving the airport to address access time reliability by carefully considering the passengers' preferences in terms of their needs and age.

## 1. Introduction

Seamless door-to-door (D2D) travelling which includes air transport is a new trend in the transport industry [1]. A major strategy of this new concept of mobility is the development of one multimodal journey instead of separate segments within one journey. Although nowadays technology allows the creation of seamless multimodal transport, the majority of transport services are still being delivered to the passenger in a disconnected way. Namely, if a passenger travels from home to the given destination, the journey involves switching from a surface mode of transport (e.g., car, metro, train, or bus) to an airplane and again to the same or another type of surface mode. In addition, the passengers have to pay separately for each segment of the journey i.e., to purchase separate tickets for each segment from the different operators providing corresponding transport service.

To improve transport services, there is an increasing need to look for new ways of providing services for passengers and simplifying the service provision for operators [2]. Single ticket would be one of the main characteristics of multimodal travel, followed up with document-free passenger service (one ID), a single information platform for communication of all transport operators involved, etc. [3]. In a system like this, timetables should be fully coordinated, the responsibility should be shared among transport operators and passengers, terminals, and stops should be better located to provide shorter walking distance between terminals during transfer, the possibility of remote check-in would be offered, additional access facilities at transfer points (at terminals and stations) for all modes of transport should be provided. Therefore, seamless D2D service for air passengers requires a holistic, cooperative, and collaborative decision-making environment, where the efficient use of different modes of transport, separately and in combination, needs to be balanced to achieve sustainable use of resources. The main goal is to make travel experiences more efficient, safer, and greener, with less inconvenience, while optimizing total journey time, which will be aligned with the EU goals set up by Flightpath 2050 [2]. More precisely the vision for aviation is to create a seamless D2D air transport system that can transport passengers within four hours of travel time, by revolutionizing urban mobility. Achieving seamless D2D air transport within four hours of travel involves a combination of technological advancements, logistical optimizations, and infrastructural enhancements.

For that purpose, we investigated the opportunities for collaboration and data sharing in a multimodal journey by taking into account

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experts' opinions, as well as passengers' perspectives for making travel choices in a multimodal journey (SYN+AIR project[1], 2022). Therefore, we applied a qualitative research method to obtain experts' opinions related to opportunities, benefits, and barriers to data sharing in multimodal D2D trips. Additionally, we developed a travel demand model for users' behaviour, i.e., Binary Logistic Regression, for capturing the travel mode choice as well as the attributes that influence such choice in a multimodal trip.

Thus, to make this multimodal concept successful, it is important to encourage more passengers to use it. Therefore, this new D2D service must become more attractive i.e., to be easier and more convenient for people to make their D2D journeys using sustainable transport (e.g., public transport PT and/or shared mobility option). This means that by providing multimodal D2D service by sustainable means, this service has to be convenient, seamless, and as easy as getting in the car.

The paper is organised as follows. After the introduction, the literature review is given in Section 2 reviewing the concept of multimodality in passenger transport as well as the passenger mode choice of transport to/from the airport. Section 3 provides the description of the methodology, underpinned with two subsections providing and discussing the main results regarding transport operators' perspective and travel demand model for users' behaviour in multimodal system. Finally, the conclusion and further research recommendations are provided in Section 4.

## 2. Literature review

In the relevant literature, papers with different aspects and approaches to multimodal transport service can be found. It should be emphasized that, in a group of papers, the use of more than one transport mode within a given period of time, is referred to as multimodality [4,5]. Studying multimodality and its impact on ground access mode choice to airports is crucial for understanding passengers' transport preferences and behaviour, as well as for contributing infrastructure planning, policy-making, and transport management strategies. Therefore, this research aims to cover both aspects and in the following subsections, the literature review on concept of multimodality and mode choice behaviour modelling of ground access to airports is provided.

### *2.1. Multimodality in passenger transport*

The important issue related to the multimodality introduction is its influence on the use of more sustainable transport. Studying trends in individual multimodality can provide valuable insights into transport behaviours and preferences, as well as inform policy decisions aimed at reducing dependency on cars and promoting sustainable transport options. The question: Does a high level of multimodality in England mean less car use? is investigated based on data collected through the period of 20 years (1995–2015), [6]. The authors were motivated to investigate if the trend in individual multimodality follows some homogenous pattern in terms of similar characteristics of the users. Their results revealed that in developed countries travel behaviour and mode choices are very diverging, with dominant use of private car, although car ownership is declining. Moreover, multimodality is decreasing due to the very limited availability of different modes of transport.

The several other studies [7–10] reported that multimodality had increased. Also, multimodality in addition to allowing passengers to travel more efficiently, is seen as an environmentally friendly concept of travelling because multimodal passengers are likely to choose to travel more by public modes instead of cars [11–14].

What should be emphasized is that none of the above-mentioned research considers multimodality in the view of seamless D2D transport, nor the view of integrated transport systems. Moreover, none of the research considers air transport as a part of the multimodal system. There are some papers that investigate the integration of specific modes of transport, e.g., rail and air (Yuan et al. 2021; Jiang et al. 2021), but in most cases this covers only part of D2D service. As mentioned above, in multimodal transport, various transport operators play crucial roles in facilitating the movement of passengers across different modes of transport, but in order to be efficient they need to collaborate and coordinate their activities. In this research we attempt to investigate the main factors that can encourage transport operators to engage in coordinated activities within a multimodal transport as defined by Babić et al. [3] and to identify the preconditions and incentives which would foster cooperation.

### *2.2. Ground access mode choice to airports*

Mode choice of transport to/from the airport has been studied in many cities and regions across Europe to identify the attributes that affect the mode choice behaviour e.g., [15–20]. Based on previous studies it is found that many attributes are contributing to the individuals' choices of transport mode to/from the airport and they are: socio-economic and demographic characteristics, characteristics of the trip, characteristics of the transport facilities, etc. However, their main focus was exclusively on the ground access dimension.

The literature review offers diverse approaches regarding the study of airport ground accessibility which has been largely investigated in different ways, such as access mode choice in the light of passengers' preferences and behaviours, modal split to determine market share, integrated airport choice, and access mode choice, integrated choice of airport, airline, and access mode, access mode choice in an airline type choice context (LCC and FSC), modal splits for relocated airports or, an assessment of the introduction of a new mode. The ground access mode choice was considered by many authors [19–26] using different models, such as descriptive analyses and regression model, binary, multinomial and mixed logit model. A more detailed literature review with their key results can be found in a paper published by Colovic et al. [27].

Modelling accessibility to airports is very important for improving airport landside planning but also for improving/integrating air transport into a multimodal system. One way to move towards the multimodal system is to integrate air transport with the whole surface network system which will further support sustainability objectives, such as promoting the use of appropriate modes, improving service levels and operational performances, optimizing D2D transport, etc. This paper aims at addressing this topic, contributing to previous literature by focusing on passengers' mode choice behaviour when they are confronted with airport ground access and what will encourage them to shift to public transport.

## 3. Methodology

The introduction of the new multimodal service that will consider the multimodal chain consisting of different modes of transport, and that will enable seamless D2D transport requires certain changes from both transport operators and passengers' behaviour. Since multimodality as a concept is based on the data sharing and strong cooperation between transport operators to provide seamless D2D transport to passengers, the perspective of operators is crucial in providing necessary preconditions for the new service. On the other hand, to benefit from the new multimodal service, passengers should also agree to share some data. Therefore, the passenger perspective is important as well.

Moreover, by studying multimodality and its impact on ground access mode choice to airports, it is possible to develop more sustainable, efficient, and inclusive transportation systems that meet the evolving needs of passengers while supporting broader social, economic, and environmental objectives. This involves a multi-layered methodology that captures both, operators and passenger perspective, by employing a

[1] Synergies between transport modes and Air transportation (SYN+AIR) project under grant agreement No. 894116, funded by SJU.

multidisciplinary methodology that integrates qualitative and quantitative research methods. The main steps of the research approach proposed to investigate multimodality from both operator and passenger perspectives, are shown in Fig. 1 and described.

Multimodal system (as defined by Babić et al. [3]) is a new, not generally established, concept in the passenger transport industry, and that is why data on system interoperability is lacking. This is the reason why in this research we had to involve various stakeholders to conduct data on best practices, success factors, and lessons learned in transport operator collaboration.

Thus, we applied a qualitative research method (interviews and workshop) to actively engage stakeholders and obtain the experts' opinions and data on how the multimodal system could and should be designed. The interviews and the workshop with different transport operators (airlines, taxi operators, public transport, railway, etc.) provided several opportunities that can encourage the development of multimodal transport systems. Also, the participants of the events highlighted the major barriers to the implementation of new multimodal services in terms of responsibility, revenue sharing, data protection, etc. All the results are given in Section 3.1.

To determine the passengers' perspective on making multimodal choices in their journeys, the travel demand model for users' behaviour is developed. The proposed travel demand model is based on data from the survey that was conducted online. The main goal of the survey was to quantify the trade-offs that user considers when selecting travel alternatives and specifically trade-offs regarding the selection of a particular transport mode. After being identified, the explanatory variables that affect the traveller's choice in their trips to/from the airport are analysed. This analysis is further used to reveal the main travel attributes that determine passenger's travel behaviour. For this purpose, a Binary Logistic Regression model is developed. The results obtained by the given model are shown in Section 3.2.

### 3.1. *Transport operators' perspective regarding multimodal service*

In multimodal system transport operators mutually collaborate and coordinate their activities to ensure the smooth and efficient movement of passengers. This is possible by leveraging the strengths of each mode of transport and integrating their services. Even though this new concept brings a lot of benefits to transport operators, most of them are faced with various challenges and barriers that hinder their collaboration.

To determine the opportunities and barriers related to developing the multimodal service from the transport operators' point of view, several interviews and a workshop are organized. The goal was to engage representatives from different sectors and organizational levels to capture diverse viewpoints, and to examine factors such as infrastructure investments, regulations, technology adoption, business models, and stakeholder partnerships influencing multimodal transport operations.

Both tasks aimed to explore the willingness of transport operators to collaborate and share defined data sets with each other. The interviews are conducted as one-hour discussions with the transport operator's representatives to gather insights on their experiences, perspectives, and challenges related to multimodality and collaboration. The participants have experienced representatives of transport operators from different modes of transport such as airlines, associations, metro, tram, bus, taxi, information systems, and management control [28,29].

On the other hand, the workshop was organized as a hybrid event, with three groups of participants – two of them participated online, while one group was onsite in Barcelona. The participants in the workshop were not only the transport operator representatives (e.g., airports, taxi, railway operators, etc.), but also the representatives from other relevant organizations (e.g., universities, associations, etc.), [28]. A wide range of topics related to multimodal transport was covered in the workshop, among others, the possible collaboration among different transport operators, the main obstacles of this type of collaboration, and other issues related to the service characteristics and performances. The main findings from these events are summarized below.

#### 3.1.1. *Opportunities and willingness to share the data*

Several opportunities for transport operators arose from offering the multimodal service with new or improved public transport infrastructure. The interviews and workshop considered three specific opportunities in developing multimodal transport systems such as improving service level, providing a user-centric environment, and increasing efficiency (reducing costs and increasing revenue), Fig. 2. For these three benefits, data sharing among transport operators is required.

*Improving service level.* Many transport operators, potential partners in multimodal service, are motivated to collaborate and recognize data sharing as beneficial and worth introducing. Establishing mechanisms for sharing real-time information, data, and performance metrics among transport operators can improve coordination, planning, and decision-making. They want to provide a product of a higher quality and to make their service more attractive, for current and future passengers. The workshop participants discussed that an increasing implementation of barcodes and QR codes can facilitate the usage of single ticket in different modes of transport. For example, to improve travellers' experience, agreements with airlines should be set, allowing the use of other modes of transport by showing the boarding card as a required ticket. The inclusion of an integrated baggage system should be considered, too. Formalizing partnership agreements can promote cooperation and joint planning in multimodal transport operations. These agreements

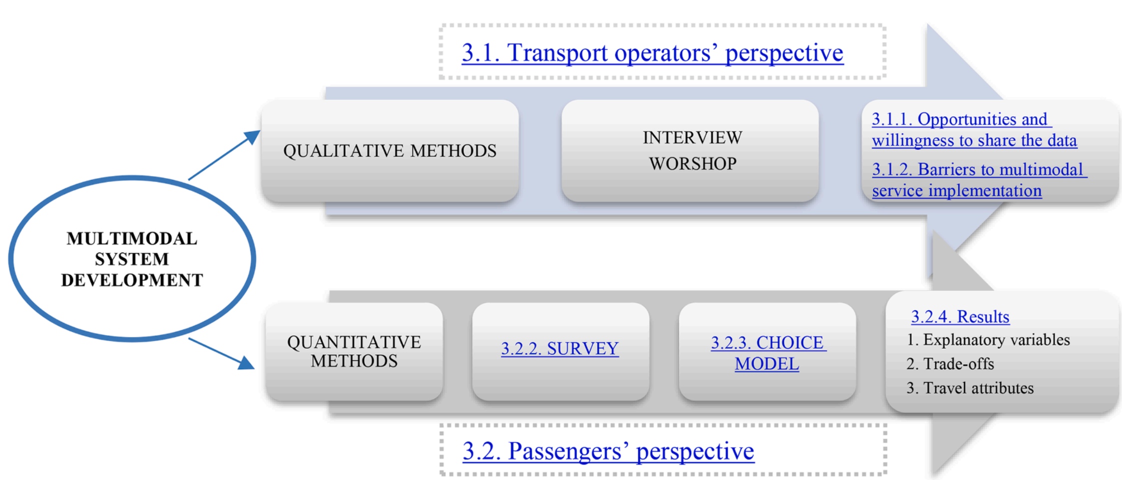


**Fig. 1.** Research approach.

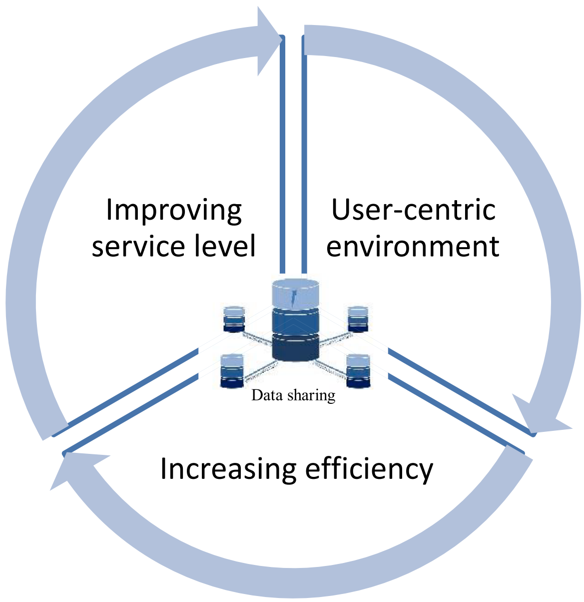


**Fig. 2.** Specific opportunities in developing multimodal transport system and data sharing.

may also involve revenue-sharing arrangements and risk-sharing mechanisms to enhance the efficiency and reliability of multimodal services.

*User-centric environment.* Transport operators' representatives agreed that the key prerequisite for the implementation of the new service is an integrated data sharing platform. The goal is to create a user-centric environment and to put the user in the focus, therefore, transport operators should serve users in a synergic way instead of providing transport only for them. The information systems play a significant role in transport operators' collaboration, providing appropriate digital platforms for data and information sharing among them, but also for communication with users as well. Those data sharing platforms should be used for two-way communication, i.e., for transport operators to feed the platform with data for users, but also for users to feed the platform with the data back to transport operators. Those would be very valuable data about user behaviour which, in turn, will allow the transport operators to improve upon their services.

*Increasing efficiency.* The workshop participants also referred to how multimodality can improve the efficiency and performance of transport operators. In particular, data sharing can improve planning activities by encouraging some innovation or supporting research that can help transport operators plan better services and operate more efficiently. For example, transport operators' data sharing related to transport routes, schedules, and vehicles, could encourage the development of suitable travel applications that provide trip planning and vehicle arrival information to users. Another example is to enable cost savings for transport operators by using outside resources for data processing and analysis. It is also pointed out that the loyalty cards could be used to motivate and encourage people to shift to more environmentally friendly transport. Also, the cooperation among transport operators could increase the visibility on the market for each partner by the greater presence through other partners' platforms and services, which in turn should attract more passengers, and ultimately generate more revenue.

Although many transport operators are willing to cooperate and share the data, when it comes to realization, many of them hesitate to enter into this type of partnership because they need legal guarantees and some regulatory framework (rules and procedures on data sharing) that will support this collaboration. Moreover, the collaborative process must indicate which participants are responsible for making particular decisions. Also, data preparation for sharing can be technically very challenging for some transport operators in terms of data cleaning, processing, and storing, including the application of appropriate cybersecurity and privacy protection measures. Data standardization is another issue in data sharing especially for the route, schedule, and vehicle location data. The data provided must be accurate and updated in a timely manner, and this is the only way to ensure that each transport operator will be able to make optimal decisions, and ultimately for the multimodal system to function and be efficient.

#### 3.1.2. Barriers to multimodal service implementation

Generally, barriers to the implementation of a fully integrated multimodal system refer to all the risks related to digital data sharing that must be addressed by transport operators. Each transport system generates a substantial amount of data, and commonly those datasets include information on routes, schedules, vehicle location, records of passenger boarding and fare transactions, and disruption alerts. Most types of passenger data contain records of personal data or records of a specific card or device that has the potential to identify an individual. This is a critical distinction for data sharing because the sharing of individual records possesses a privacy risk. This means that each transport operator should take full responsibility for the protection of their passenger data. More precisely, consent from passengers' needs to be provided allowing them to share their data among different operators. The workshop participants suggested having defined in advance which kind of data is available to which transport operators, i.e., to have limited access to the data, and corresponding terms of use or a data sharing agreement, which will be defined by smart contract framework. In the European Union, the General Data Protection Regulations (GDPR), define a comprehensive set of regulations related to privacy. But again, for developing new multimodal services, it should be improved to help transport operators access more external data and to remove barriers to the sharing of their data.

Besides passengers' data, transport operators can be requested to reveal part of their private information, such as intended routes, vehicle location data, operations data, and financial data. It is reasonable to assume that they might hesitate to share all confidential information due to competition or legal issues. Although these data types typically do not contain privacy risks, there may be security risks or the risk of data misuse (for example, the concern that it could be used to attack transport infrastructure and the people who use it). These are just some of the problems that bother transport operators. Another possible obstacle could be the ownership of the transport operator, which could prevent collaboration between public and private actors since it usually includes political influence. However, the current trend (e.g., the emerging field of Mobility-as-a-Service) shows that this distinction between private and public stakeholders is less and less important.

The responsibility issue in the case of disruptions (e.g., schedule disturbances) and the case of passengers with reduced mobility should be addressed, and precisely defined, as well. This includes taking responsibility for enabling the journey to be finished, as well as the provision of real-time information to passengers. Only in this way, the multimodal transport service providers can keep the passengers' satisfaction at a high level.

### 3.2. Passengers' perspective regarding multimodal service

Multimodal transport could bring certain benefits to all parties involved (transport operators, passengers, municipalities, environment, etc.). To gain as many benefits as possible, public transport (PT) should be extensively used by passengers. Generally, private car is the dominant passengers' choice for accessing the airport [29]. One of the goals of multimodality is to influence airport access choice by shifting people from private vehicles to more sustainable and more environmentally friendly modes of transport.

To consider the passengers' perspective in terms of multimodal system development, this paper presents the results of the proposed travel demand model which reveals the main factors that drive a shift from private vehicles to public transport. The proposed travel demand model is based on data collected from the survey that was conducted online (because of Covid19 pandemic) and distributed in five languages (Greek, Spanish, Italian, Serbian, and English). The survey was distributed across multiple channels (websites, social networks, e-mails, etc.) starting from 31st of March 2021 and finishing on 18th of May 2021.

The survey consists of 29 questions related to socio-demographic information, passengers' habits, the purpose of travel, travel frequency, the factors that influence the mode choice, and provided scenarios regarding the combination of travel modes. The total sample includes a large number of respondents (2199 respondents in total), originating mostly from Spain, Italy, Serbia, and Greece, but also from other countries [29]. For example, 194 answers were collected from Spain, 719 from Greece, 444 from Italy, 562 from Serbia, and 280 from other European counties.

For the paper, we focused only on the questions relevant for the airport access mode choice analysis. Therefore, considered questions are related to gender, household income, the most common purpose of travel, mode choice to/from the airport in the case of different transport modes available, and factors that influence mode choice when travelling to/from the airport. It should be noted that factors that influence mode choice are rated by passengers using the Likert scale (from the lowest importance 1 to the highest 5). The respondents to the survey are predominately female with 54.4 % of the share, male respondents with 44.5 % of the share, and 0.1 % of individuals chose not to declare their gender. The average respondent was 39 years old, with the majority of the sample being between from 18 to 60 years old. The average income of the respondents, on a scale from Low to High, was an average of 61.1 %, while 20.6 % indicated that their household income is High. In terms of employment, 51.7 % of respondents are employed in the private sector, 27.5 % employed in the public sector and 10.5 % of the sample are students, while the rest are either retired, unemployed or 'other'.

Regarding the travel purpose, Mostly for business travel 28.2 % and Only for leisure 26.7 % of respondents. The lower percentage, 3.1 %, travel Only for business, while the largest percentage can be observed Mostly for leisure, 42 %, Fig. 3.

### 3.2.1. *Binary logistics regression*

To explore how passengers make their choices and what factors influence those choices, statistical analysis and Binary Logistic Regression are used. In the first section are reported the main findings from the conducted survey related to the variables/questions that have the most influence on passengers' travel mode choice. Based on this outcome, Binary Logistic Regression was performed to determine passengers' attitude when making multimodal choice. The model specifications of Binary Logistic Regression are reported in the next section.

### 3.2.2. *The outcomes of survey*

Based on the outcomes of the conducted survey, the main explanatory variables that affect passengers' choice for arriving to/from the airport are related to: i) travel mode choice options (If all of the following transport modes are available, which one would you choose to travel to/from the airport?). The descriptive statistics of travel mode choice question showed that most of the respondents, about 40,11 %, selected the "Car (someone drops me off/picks me up)" as a mode choice. Also, about 16,96 % of respondents selected Metro mode choice, while Taxi, Train, and Combination of modes (e.g., bus and train) are selected by 12,64 %, 7,05 %, 5,05 % respondents, respectively. On the other side, the minimum percentage of the answers, i.e., 2,59 %, is related to the bus mode choice.

Besides these common factors that affect mode choice, special attention was given to other factors that may have crucial importance in choosing the way how the passenger will travel to/from the airport. The main results are given in Fig. 4. The significance (importance) of the factors that affect the mode choice is represented from yellow to green color shades. Yellow shades represent the higher percentage and significance of responses. For example, 42.5 % of responses that rated "waiting time" as important factor is represented as yellow shade, while 0,86 % of responses that rated "reliability" as "non important" factor are shown with green shade. For most passengers the reliability of service execution is important. The highest number of responses of 34.88 % rated the factor "reliability" as "more important" than the others when making the mode choice. An almost equal percentage of the respondents (33.97 %) rated this factor as "most important". Additionally, the factor "travel time" was rated as "important" by the highest number of participants in the survey, when selecting the mode of transport. Also, the factor "travel costs", was selected to be "important" when making the mode choice by 39.79 % of the respondents. Likewise, the factor "waiting time" was selected as "important" by 45.20 % of respondents when making the mode choice. Furthermore, in all the cases, less than 10 % of the answers rated the factor "reliability", "travel costs", and "waiting time" as "not important".

The outcomes of the descriptive statistics showed that certain patterns of passengers can be individuate by distinguishing those that selected private and public travel mode alternatives. Also, the analysis showed the importance of the factor "reliability" related to the preference of public solutions versus private ones if socio-graphic aspects of the respondents are neglected. This output, in general, can be interpreted as the response of the system related to any unexpected events or delays, during the journey to and from the airport, by public transport. Indeed, in such situation, users expect a high degree of reliability, otherwise, the choice would shift from public to private modes of transport. For this reason, The Binary Logistics Regression is carried out by performing the comparison between private and public modes of

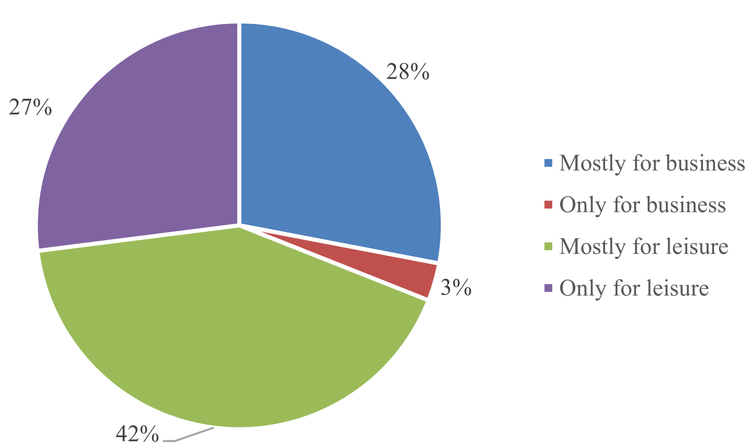


**Fig. 3.** Percentage of the responses related to the purpose of travel.

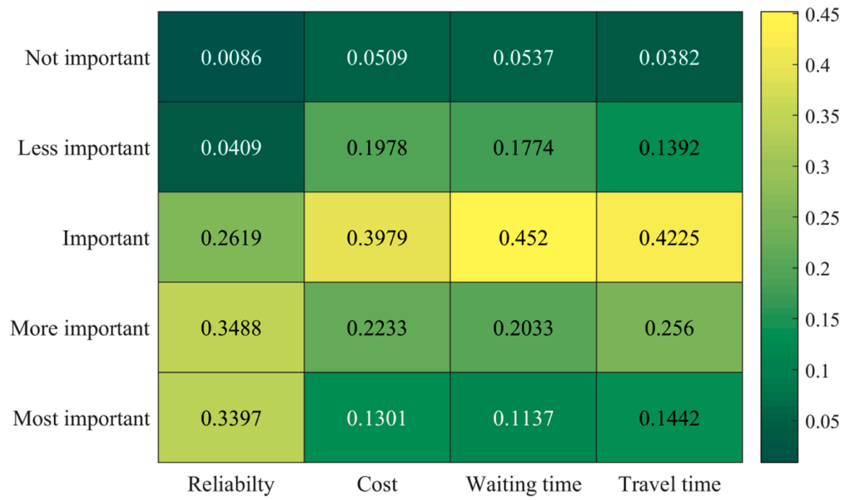


**Fig. 4.** Share of the responses related to the factors that influence mode choice.

transport.

### 3.2.3. *Choice model description*

Binary Logistic Regression is applied to reveal the factors affecting the choice of private transport (i.e., Car (park at/near the airport), Car (someone drops me off/picks me up)) and public modes of transport (i.e., Bus, Metro, Other, Taxi, Train), [30]. Considering transport mode as a dependent variable, available alternatives are merged into two possible choices: private (car) and public transport (train, taxi, bus, and metro). In Binary Logistics Regression model, the choice of private modes is coded with 0, and with 1 if public modes are chosen, as depicted in Fig. 5. A combination of modes was not considered, because theoretically, it could be formed by both private and public modes.

The considered sample consists of 2083 valid responses: 1220 respondents preferred private (binary choice equal to 0), while 863 preferred public transport (binary choice equal to 1). To determine the factors that affect public transport as airport access mode choice, binary logistic regression is used in Eq. (1), where with

$$Odds = \frac{p}{1-p} \tag{1}$$

$p$ is the probability of choosing public transport modes, while (1-$p$) represents probability of not choosing public transport modes. The logarithm of the odds is represented as a linear function of independent variables Eq. (2), [31]:

$$log(odds) = B_0 + B_1x_1 + \ldots + B_kx_k \tag{2}$$

where, $B_0$ is the constant, $xk$ are $k$ explanatory variables, $B_k$ is the parameter related to $xk$ (which can take binary, categorical, ordinal or continuous values). Therefore, the odds, considering exponentiated parameters, can be expressed by Eq. (3), as follows:

$$odds = e^{B_0+B_1x_1+\ldots+B_kx_k} \tag{3}$$

According to Eq. (2), i.e., $Odds = (B)$, is equal to 1 for null values. In the case when Odds>1 the result indicates positive effect, while Odds<1 for negative one. Focusing on the probability, the Binary Logistic Regression model is formulated by Eq. (4):

$$p = \frac{e^{\left(\sum_i B_i x_i\right)}}{1+e^{\left(\sum_i B_i x_i\right)}} = \frac{1}{1+e^{-\left(\sum_i B_i x_i\right)}} \quad \forall\, i \in [1,k] \tag{4}$$

The odds ratio (OR) is a ratio of two odds, indicating how likely the event of interest is to occur in the context relative to another. For example, if in (3), we increase variable $x_1$ by one unit, the OR is

$$OR = \frac{e^{B_0+B_1(x_1+1)+\ldots+B_kx_k}}{e^{B_0+B_1x_1+\ldots+B_kx_k}} = e^{B_1} \tag{5}$$

The odds increase multiplicatively by $e^{B_i}$ for every one-unit increase in variable $x_i$.

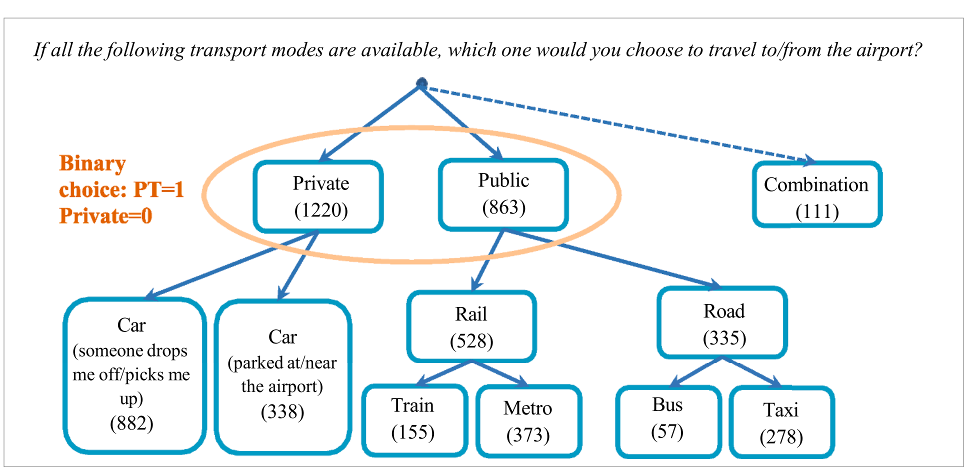


**Fig. 5.** Binary choice related to public and private modes.

## 4. Results

The maximum likelihood method was used to estimate the model's parameters. The interpretation of parameters consists of the change of the log-odds considering a unit change in the related predictor, maintaining unchanged the others. For example, a unit increase of importance of factor that influence mode choice (expressed in Likert scale from 1 to 5), for example from 3 to 4 in Likert scale, would lead to a positive effect on the probability of choosing public transport option. Furthermore, this shows how increasing grade of importance for respondents can enhance the probability of choosing public mode (versus the private ones), and thus shifting to a sustainable mobility choice. In general, at first, the selection approach of the independent variables considers Eq. (3) with only constant parameter $B_0$. Secondly, the independent variables $\chi_k$, with the largest increase of performance are included in Eq. (3). This process is repeated as long as adding the variables does not improve the model. The variables are included if their significance value (*Sig.*[c] in Table 1) is lower than a chosen threshold (here, p-value $\leq$ 0.05 for all variables, except for reliability which was not significant on a 5 % level, but proved significant with a p-value $\leq$ 0.1).

All the attributes that are not correlated with the mode choice of transport have been excluded and analysis has been repeated for those which are significantly correlated only for more accuracy. Based on binary logistic regression analysis of data, the mode choice model has been derived and attributes of reliability, travel purpose, gender, age, income, and vehicle ownership were found statistically correlated to the mode choice of transport, in the countries covered by the survey. Explanatory variables are given in Table 1, as well as the corresponding *OR* related to the use of PT such as the importance of reliability in the choice of the transport mode (*OR*=1.089), business purpose of travel (*OR*=1.458), male gender (*OR*=1.705), age from 50 to 65 (*OR*=1.560), high income (*OR*=1.882) and non-possession of cars (*OR*=2.437). Therefore, these predictors have a positive effect on the choice of public modes ($B > 0$, or *OR*=*Exp(B)*>1).

According to the results given in Table 1, a unit increase of importance for the Reliability factor (measured by Likert scale), would result in a positive effect on the probability of choosing public modes. On the other hand, the unreliability would, therefore, lead to a modal shift from public to private transport alternatives. However, the factor reliability appears to be less significant than other variables, but since it is important for this analysis, we included it in predicting the use of public modes versus private ones. On the other hand, the *OR* value of the binary variable related to the business purpose of travel shows that business travellers are about 1.46 more likely to choose the PT than other travellers. A similar interpretation is shown for the rest of the *OR* values for binary variables (male gender, age from 50 to 65, high income, and non-ownership of cars).

The accuracy of the derived model is one of the logistic regression analysis outcomes which is showing the number and percentages of correct predictions and false predictions for each option, as well as the overall accuracy as shown in Table 2. It can be noted that the independent variables (i.e., the importance of reliability in the choice of the transport mode, business purpose of travel, male gender, age from 50 to 65, high income, and non-ownership of cars) can correctly predict 62.7 % of the cases. In particular, the proposed model is much more accurate for those who preferred private transport mode (82.5 %), than for those who have chosen public modes (34.8 %), Table 2. Moreover, the model predicts the values of the dependent variable (the use of public modes versus private ones) with the variance scores ($R^2$), 7.7 % and 10.4 %. More precisely, the proportion of the variance in the dependent variable is explained by the independent variables. These variance scores are defined by Cox & Snell and Nagelkerke respectively, and for the logistic regression, these values are much lower than in the case of linear regression.

## 5. Conclusions

The results presented in this paper are expected to help in planning and estimating the effects of introducing the new multimodal D2D service. The framework developed in this study precisely aims at tackling the challenges addressed from the transport operator's perspective, as well as from the passenger's perspective. The motives for the collaboration of transport operators could be found in the fact that a revenue increase is expected, as well as an increase in the volume of passengers. The most challenging task is to convince transport operators to collaborate and share the data with each other. The requirements concerning current challenges in terms of the necessity for creating a good policy framework, as well as the diversity of parameters and features all over Europe (e.g., social habits, purchasing power, transport features, etc.), are pointed out.

On the other hand, the proposed (Binary Logistic Regression) model reveals the importance for policymakers and transport operators serving the airport, to address the access time reliability by carefully considering the passengers' preferences in terms of their needs and age. The increase in transport service reliability should result in a higher probability of choosing public transport when traveling to/from the airport. Therefore, the increase of the capability of public modes to prevent and solve unexpected events for passengers (e.g., delays, traffic congestions, etc.) could decrease the preference of private mobility solutions. The derived

**Table 1**
Variables in the equation - binary logistic regression: public vs. private transport.

| Variables in the Equation | *B* | *S. E.*[a] of *B* | Wald | *df*[b] | *Sig.*[c] | *OR = Exp(B)* | 95 % *C. I.*[d] for *Exp(B)* Lower | Upper |
|---|---|---|---|---|---|---|---|---|
| Q17c_Reliability | 0.085 | 0.051 | 2.768 | 1 | 0.096* | 1.089 | 1.001** | 1.184** |
| Q2_bin_business | 0.377 | 0.105 | 12.809 | 1 | <0.001 | 1.458 | 1.186 | 1.793 |
| Q19_Male | 0.534 | 0.099 | 28.920 | 1 | <0.001 | 1.705 | 1.404 | 2.072 |
| Age_50_65 | 0.445 | 0.126 | 12.453 | 1 | <0.001 | 1.560 | 1.219 | 1.997 |
| Q23_High income | 0.632 | 0.117 | 29.306 | 1 | <0.001 | 1.882 | 1.497 | 2.366 |
| Q25_0 cars | 0.891 | 0.140 | 40.434 | 1 | <0.001 | 2.437 | 1.852 | 3.207 |
| Constant $B_0$ | −1.370 | 0.220 | 38.786 | 1 | <0.001 | 0.254 | | |

[a] Standard Error.
[b] Degree of freedom.
[c] Significance level.
[d] Confidence Interval.
[*] *Sig.*[c] $\leq$ 0.1.
[**] 90 % C. I. for Exp(B)

*Sig.*[c] reports the significance level for the Wald statistic based on its chi-square distribution, where the Wald statistic (considering variables having a single degree of freedom *df*[b]) is the squared ratio of B and its standard error *S. E.*[a] The reported *Sig.*[c] are for values minor than 0.05; (B) can take the values between the lower and upper limits considering the confidence level *C. I.*[d] of 95 %.

**Table 2**
Performance: binary logistic regression: public vs. private transport modes.

| | | Predicted | | Percentage correct | % $R^2$ | |
|---|---|---|---|---|---|---|
| | | Private | Public | | Cox & Snell. | Nagelkerke |
| Observed | Private | 1006 | 214 | 82.5 | 7.7 | 10.4 |
| | Public | 563 | 300 | 34.8 | | |
| Overall accuracy percentage | | | | 62.7 | | |

model correctly predicts the mode choice for 62.7 % of respondents.

Establishing multimodal service can improve access to airports by providing multiple transport options from various origin locations. By enhancing connectivity between airports and surrounding areas through well-integrated ground transport systems it is possible to facilitate seamless travel experiences and improve overall accessibility for passengers. Understanding the relationship between multimodality and ground access mode choice can help in mitigating traffic congestion on airport roads and parking facilities by encouraging mode shift towards more sustainable transport options. This type of studies on multimodality will inform airport and transport authorities regarding infrastructure planning and investment priorities. For example, this includes developing and improving roadways, parking facilities, public transport services, and multimodal connections to accommodate diverse travel preferences and optimize ground access to airports.

Several areas for further research were identified in terms of developing multimodal transport systems such as: What are the environmental impacts of multimodal transport systems? Is the multimodal system implemented in a particular country (city) transferable to other locations in Europe? etc. Bearing in mind all mentioned, the issue of developing a multimodal transport system is a very complex problem, but its positive effect on society will be very important.

## CRediT authorship contribution statement

**Danica Babić:** Writing – review & editing, Writing – original draft, Methodology, Investigation. **Aleksandra Colovic:** Writing – review & editing, Writing – original draft, Investigation. **Slavica Dožić:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization. **Milica Kalić:** Validation, Formal analysis. **Tatjana Krstić Simić:** Validation, Formal analysis. **Katarina Kukić:** Writing – review & editing, Writing – original draft, Validation, Methodology, Formal analysis. **Michele Ottomanelli:** Validation. **Salvatore Gabriele Pilone:** Validation.

## 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.

## Data availability

The authors do not have permission to share data.


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