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The role of ride-hailing services to airport accessibility: exploratory insights from the Lisbon airport

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ABSTRACT

New personalized mobility services such as ride-hailing have arisen in the urban mobility context and offer new market competitive solutions. Airport accessibility is also affected by the new ride-hailing services resulting into new modal splits. To better understand the aspects that affect the airport access mode choice in the presence of ride-hailing, an ad-hoc survey is conducted and mode choice models for the case study of Lisbon airport are developed. It is found that the travel cost, spatial aspects, the mobility behaviour of the passengers in the urban context and their personal traits significantly impact their choices. Moreover, a multivariate scenario analysis is implemented to explore the impact of four key future drivers: changes in the ride-hailing cost structure, the share of business passengers, the evolution of demographics in the region, and the share of ride-hailing frequent users. This analysis highlights that the share of ride-hailing is expected to settle around 14% to 36% and provides a viable means to explore the evolution of ride-hailing use at the airport context. Ultimately, this study provides new insights into airport access mode choice upfront the entry of this innovative mobility service, thus supporting both policymakers and airport managers toward anticipating modal shifts and make informed strategic planning decisions.

1. Introduction

Airport accessibility constitutes a crucial and strategic pillar of airport planning. Ground access and egress transportation are integral and important parts of a passengers' door-to-door experience (Belobaba et al., 2015), contributing to airport attractiveness and competitiveness against neighboring airports (Campisi et al., 2025). Additionally, ground accessibility is important for the overall environmental impact of airport activities, thus raising additional issues regarding its sustainability (Guzman and Gonzalez, 2026). In particular, the fast growth of air traffic demand coupled with extensive use of private vehicles generates negative externalities, such as road congestion and greater pollution from vehicle emissions in the airport accessibility area (Liang and Gong, 2020). Many airports worldwide have been looking at public transport as a means to mitigate these negative aspects, including bus and dedicated rail services, yet airport accessibility is still heavily reliant on private cars and taxis (Kalic et al., 2025) due to their generally perceived better passenger experience.

In this domain, ride-hailing appears as an attractive mode for ground access and egress trips at airports. In recent years, the uptake of ride-hailing companies—also referred to as transportation network companies (TNCs)—have revolutionized urban mobility in several cities around the world (e.g., Lavieri and Bhat, 2019; Young and Farber, 2019), underpinned by convenience, flexible on-demand services, and affordable prices. With respect to conventional taxis, the provision of ride-hailing services relies on modern mobile applications that make it easier for passengers to reserve trips of their preference, and for providers to plan routes and pick-up riders with much greater frequency, ultimately promoting a more efficient matching of supply and demand (Luo et al., 2024). Additionally, the ride-hailing business model is based on widespread service availability and crowd-sourced supply, which, along with greater utilization rates, contributes to significantly lower costs for passengers. With respect to private cars, the use of ride-hailing then saves ownership costs and avoids the burden of parking costs and arrangements while connectivity to public transport has also been addressed (Li et al., 2025).

All these features make ride-hailing an attractive mobility option not only for commuting and urban trips but for air trips connecting to the airport as well. This is clear for tourist passengers, who abroad most likely do not have a private car available and may not be familiar with

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the local transit systems, and it is also true for residents, who may find it more convenient to be picked up at their place and save money from paid parking. Evidence from the international case studies confirms this trend. For example, the aggregate market share of two major Transport Network Companies (TNCs), Uber and Lyft, at San Francisco International Airport (SFO) grew from 4% of drop-off mode share in 2014 to 29% in 2017 (Streeting et al., 2018). Similarly in Denver and Seattle, a recent study on mode replacement (Henao et al., 2020) has indicated that ride-hailing does not only substitute conventional taxis but also other modes—mostly private cars and public transport—remarking the importance to undertake further research into the access mode choice behavior.

While ride-hailing represents an attractive alternative for air passengers, it raises concerns for airport operators and airport-based companies as it puts at risk revenue stemming from parking fees and the profitability of rental car companies and taxis who are important airport stakeholders (Mandle and Box, 2017; Wadud, 2020). According to a recent report (Streeting et al., 2018), ground transport revenue may span about 25% of overall airport revenue, highlighting the significant potential (negative) impact of ride-hailing on an airport's financial underpinnings. Some ride-hailing providers are introducing additional features that are expected to increase the attractiveness of ride hailing for ground access. For example, Uber has recently launched a new pilot initiative to reserve rides at airports,[1] with the promise to further expand the attractiveness of ride-hailing for airport accessibility. All this adds complexity and makes an in-depth assessment of adoption rates and mode choice transitions induced by ride-hailing a key priority. Understanding and anticipating changes into mode adoption is indeed essential to proactively devise new ways and strategies to compensate for potential airport revenue losses and achieve a socially efficient outcome. Despite the relevance of the topic, only a few studies in the literature have thoughtfully investigated the use of ride-hailing in the context of airport access/egress (Dong and Ryerson, 2020; Wadud, 2020), with only two contributions (Hermawan and Regan, 2017; Pasha et al., 2020) focusing explicitly on the modeling of airport ground access mode choice.

This study contributes to this body of knowledge. Based on data collected from an online survey for Lisbon air trips, the largest airport in Portugal and one of the fastest growing in Europe, coupled with data on travel time and costs obtained from transport search engines, a discrete choice model is developed to characterize the choice of the access mode by passengers with a focus on ride-hailing options. In the area under study, ride-hailing is a widely used mobility service. Our study expands the literature on transport mode choice and airport accessibility by exploring a novel case study for a major airport in Europe and considering novel features, including spatial aspects and urban mobility behaviour, that help explain the use of ride-hailing by different passenger segments. Results confirm the attractiveness of ride-hailing—with its market share spanning from 16% (for business passengers) to 23% (for leisure passengers), explained by the frequency they use ride-hailing for their trips in the urban context, the frequency of travelling by airplane and the cost of the trip. Ultimately, a set of sensitivity analyses are conducted to show how the proposed model can be used to predict modal shifts and thus practically support airport strategic decision making. The results demonstrate that airport accessibility studies need to consider ride-hailing as an alternative as it affects both airport planning aspects and city-transport aspects.

The reminder of this paper is articulated as follows. Section 2 overviews current airport accessibility studies and identifies the main drivers of passenger choices. The next section, section 3 presents the methodological approach while Section 4 presents the results of the analysis and discusses the evolution of ride-hailing market share under various scenarios reflecting changes in the transport cost of ride hailing and the composition of the passenger mix. Finally, Section 5 makes conclusions on the proposed approach, the outputs and the outcomes of the study.

2. Literature review on airport access mode choice

The modeling and management of airport accessibility has long been acknowledged as a key strategic factor for airport success and efficient operations. The level of service and availability of ground transport services indeed affect the overall passenger experience (Lee and Yu, 2018), and impact on the ability of an airport to attract and accommodate large volumes of air passengers. With the fast growth of air travel demand, leading to increasing flows to and from airports and associated congestion issues in many regions worldwide, modeling passenger accessibility has gained increasing momentum in recent years. The topic has drawn the attention of an increasing number of researchers and practitioners, aiming at systematically understanding the drivers of passengers' access mode choice behavior to make informed decision towards the planning and upgrade of airport landside transport facilities.

The earliest studies on modelling accessibility to airports dates back to the 1970s with the seminal work by Ellis et al. (1974), and subsequent works by Harvey in the San Francisco Bay Area (Harvey, 1986, Harvey, 1987). The literature mainly relies on case studies using surveys conducted at the airport(s) or online to collect data on travelers' airport access mode choice preferences, along with their socioeconomic information and trip characteristics. The choice set usually includes transport modes that are already available in the region or airport under analysis, either as a baseline or as the focus of the analysis, or it can be extended through the use of stated preference and hypothetical scenarios to assess the introduction of new transport mode alternatives (e.g., Jou et al., 2011). Access mode choice decisions are then modelled by means of statistical methods, mostly discrete choice models, to explore the concurring contribution of several variables and quantify the relative importance of various factors (see, e.g., for a review Ben-Akiva and Lerman, 1985). Table 1 reports some of the most relevant studies of the last 30 years, which will be discussed in the remainder of this section to provide a comprehensive overview of the state-of-the-art and to clarify the positioning of this paper.

The review of the previous studies of Table 1 shows that it is consensus to divide the drivers of airport access mode choice into two broad categories. First, the set of available transport alternatives and their alternative-specific characteristics, such as travel time, travel cost, and comfort, among others. The second class of drivers is related to the decision maker. These attributes are generally referred to as "individual-specific" and encompass socioeconomic features, such as the gender, age, and income, along with perceptions and attitudes, which bring heterogeneity of passenger behavior and may impact choices in several different ways. Individual attributes can also be related to characteristics of the trip itself, such as the trip purpose and duration, which were also found to impact access mode choice to a significant extent. For example, most research adopted market segmentation to better define travel parameters and preferences for macro groups of passengers. The most common distinction is between business and non-business travelers, which tend to be characterized by different willingness to pay and elasticity to alternative-specific attributes (Gosling, 2008). Another important distinction is between residents and visitors. While the former typically have access to a private vehicle or can be more likely dropped-off/picked-up at the airport by someone they know, the latter would rather rent a car or take a taxi to meet their transportation needs. On the other hand, residents may know better the local transport system, which could contribute to determine a higher usage of it (Tam et al., 2011).

Regarding alternative-specific attributes, access travel time and cost have been reported in previous studies as among the most significant factors influencing the choice of access mode. In general, studies in the literature consistently (and coherently) show that these two parameters

[1] https://www.uber.com/us/en/drive/basics/airport-trips/.

Table 1
Airport access studies.

Reference	Research Context	Mode Choice Set	Model
Harvey (1986)	San Francisco Bay Area, US (SFO, OAK and SJC)	Drive; Drop-off Transit; Airporter; Taxi	Multinomial logit
Psaraki and Abacoumkin (2002)	Athens International Airport in Greece	Drive and park; Lift and accompanied; Drop-off; Taxi; Public bus; Tourist buses; Rental cars	Heteroscedastic extreme value models, MNL and random parameter models
Gupta et al. (2008)	New York and New Jersey Area, US (JFK, LGA, EWR, SWF, Macarthur ISP, HPN, ACY, ABE, TTN)	Auto drop-off; Auto-Park; Taxi and limos; Shared vans, shared limos, and hotel courtesy vehicle; Rental cars; Rail; Local buses; Chartered buses	Multinomial & Nested logit
Jou et al. (2011)	Taoyuan International Airport (TIA) in Taiwan	Self-driving; Pickup; Taxi; Public Bus; High Speed Railroad; Mass rapid transit system	Mixed Multinomial logit
Akar (2013)	Port Columbus International Airport	Private car; Alternative modes.	Binary logit
Chang (2013)	Sample of Taiwanese respondents	Public transport; Public transport	Binary logit
(Gokasar and Gunay, 2017)	Atatürk International Airport (IST), Istanbuk	Automobile; drop-off; public transit; and taxi	Multinomial logit
Hermawan and Regan (2017)	Los Angeles Aiport, United States	Private car; Rental car; Taxi; Ride-hailing (TNCs); Shuttles; Limousine; Shared vans/shuttles; Public transit; Direct shuttle bus	Multinomial & Nested logit
Zaidan and Abulibdeh (2018)	Hamad International Airport (HIA) in Doha, Qatar	Park at airport; Drop-off; Van; Taxi; Metro; Bus	Binary & Multinomial logit
Birolini et al. (2019)	Milan-Bergamo Airport, Italy	Car; Drop-off; Taxi; Bus; Train	Mixed Multinomial logit
Bergantino et al. (2020)	Apulia Area, Italy (BRI, BDS, FOG and TAR)	Train; Bus; Car; Airport shuttle; Drop-off; Taxi	Nested logit, Mixed multinomial logit & Mixed Nested logit
Pasha et al. (2020)	Brisbane Airport, Australia	Bus; Train; Car; Shuttle; Taxi; Ride-hailing (Uber)	Multinomial & Mixed multinomial logit

negatively affect the choice of a specific transport mode, i.e., the higher the cost and travel time, the less likely the passengers to choose it. However, the sensitivity and magnitude of these variables has been found to vary significantly among different regional contexts and passenger segments, especially between business and non-business, with business being generally less cost sensitive and more time sensitive (Gupta et al., 2008; Harvey, 1986; Pels et al., 2003). Additionally, the recent study by Birolini et al. (2019) using a Mixed Multinomial Logit Model (MMNL) found significant heterogeneity of cost and time even within the same group of users. Another important aspect of the modeling of travel time is its decomposition into various components to better reflect any difference in the perceived (dis)utility induced by various travel time components. The most common distinction is between in-vehicle travel time (IVTT) and out-of-vehicle travel time (OVTT) (Bergantino et al., 2020; Jou et al., 2011), which includes transfer and waiting times. As confirmed by empirical evidence, this distinction captures the additional burden associated with scheduled transit systems as compared to the private car, drop-off, or on-demand direct services. Some studies also explicitly captured the impact of travel time reliability (Birolini et al., 2019; Tam et al., 2011), highlighting how the burden of traffic congestion is extremely relevant for airport passengers who face a significant opportunity cost of missing their flights. The value of time under congestion tends to be significantly higher than IVTT and even OVTT, making the alleviating of traffic congestion one of the most impactful and key areas of improvement. On the other hand, the cost is not usually split into several components as its different components are all quantified in monetary terms. The cost variable included in most of the studies represents the total amount outlaid for the trip, including fuel cost, highway tolls, parking fees, and the ticket price for public transport (Birolini et al., 2019; Jou et al., 2011), typically normalized on a per-passenger basis.

Besides travel time and cost, other factors have been found to be significant in explaining airport accessibility choices, such as: (i) the size of the travel companions, with bigger groups being more likely to opt for private vehicles (Gokasar and Gunay, 2017; Gupta et al., 2008; Zaidan and Abulibdeh, 2018) although there might be an inversion of trend for very large groups; (ii) the number of pieces of luggage, which is generally found to negatively affect the utilization of public transport and increases the probability of choosing a personalized mode, with the reason probably lying on the discomfort of carrying heavy luggage through a multi-step trip and the lack of dedicated vehicle areas (Akar and Akar, 2013; Zaidan and Abulibdeh, 2018); and (iii) trip duration, which tends to discourage the use of private car for longer trips (Psaraki and Abacoumkin, 2002) mostly likely due to the high cost of parking.

Regarding alternative-specific attributes, gender and age are among the most commonly considered due to their general availability and relevance. Gupta et al. (2008) report that female travelers are less likely to drive for both business and non-business trips. Female passengers travelling for non-business purposes are also less likely to use public transit options, which the authors suggest may be because they are often accompanied by children. Similar conclusions had been reported many years earlier by Harvey (1986) who concluded women in general tend to favor the drop-off and taxi modes for accessing airports. Age also plays a significant role in airport ground access mode choice. Previous work indicated how elderly air passengers tend to exhibit stronger preference for private over public transport, with safety, user friendliness and convenience for storing luggage being among the most important factors driving their choice (Chang, 2013). By contrast, younger passengers appear to be more inclined towards the use of transit, taxis, and shared rides, which is also supported by their typically lower income and car availability when compared to older passengers (Gupta et al., 2008; Tam et al., 2011). However, it is important to remark that, especially for socioeconomic variables, these results may vary by geographical region and cultural context. For example, Zaidan and Abulibdeh (2018) have recently reported a different conclusion with respect to the impact of age, reporting that in Qatar it is the age group of 18 to 24 the one characterized by the highest dependency on the car mode to travel to the airport. This, in turn, remarks the limited transferability of behavioral insights from different studies and stresses the need to conduct ad-hoc studies, or refer to similar contexts.

Apart from the socioeconomic characteristics of passengers, their views, including satisfaction, on the transport alternatives and their familiarity with their characteristics are important determinants of access model choice. Tam et al. (2011), for example, captured the perceived service quality or "satisfaction" towards ground access modes using latent variables. Other examples include the work by Akar (2013) who incorporated in the utility function the attitudes toward using private car, derived from attitudinal questions and redirected to continuous variables using a principal component analysis, or similarly the work by Pasha et al. (2020) who studied how the degree of

familiarity with the available alternatives is an important factor affecting access mode choice.

As evident from Table 1, previous studies have thoroughly investigated the trade-offs and substitution patterns between conventional modes of transport, such as private car, drop-off, public transport and taxis, bringing evidence from studies throughout all the world. By contrast, empirical evidence on the potential of ride-hailing are more scant as only two studies—Hermawan and Regan (2017) in Los Angeles and Pasha et al. (2020) at Brisbane Airport—included this mode as a transport alternative in the choice set.

Although these studies provide initial insights into the attractiveness of ride-hailing for air passengers, they are not exhaustive and set the ground for further investigation. This study aims to contribute to the literature by considering a novel case study in Europe, focusing specifically on the impact and implication of ride-hailing as an access mode to the airport. From a practical standpoint, this study provides new insights into the management of accessibility upfront the entry of this new mobility service, thus supporting both policymakers and airport managers in anticipating modal shifts and make informed strategic planning decisions.

3. Research framework

Understanding which factors influence passenger ground access preferences and choices helps providing better airport ground transportation systems. To analyse passenger mode choice behaviour, an anonymous survey was designed to collect relevant information on the aspects that are expected to affect passenger choices and aspects that comprise the passenger experience. In the following sections a more detailed description of the survey is provided.

3.1. Lisbon airport case study

Humberto Delgado Airport is also known as Portela Lisbon Airport and it is only 7 km away from the Lisbon city centre, the capital of Portugal. It has two civil terminals (T1 and T2 for Low-Cost Carrier departures), it acts as the main hub of the Portuguese front-carrier TAP Air Portugal and is run by ANA-VINCI. Lisbon Airport is the largest airport in Portugal, serving more than 50% of the entire country air passengers. In 2019, it served a total of 31.1 million commercial passengers, an increase of 7.4% compared to 2018, and accounted for 217.7 thousand aircraft movements which represents an increase of 1.9%. In 2019, The aviation business sector represented 73.2% of total ANA Group revenue while the remaining 26.8% revenues counted for the non-aviation business, with the rent-a-car and car parking businesses being responsible for 15.9% and 12,6%, of this non-aviation revenues. The car parking revenue stream is a result of several initiatives, such as: an overhaul online booking platform, allowing passengers to get the best rates and secure their parking space; a consolidation of the application of the recent Kiss & Fly parks (i.e. parking areas specially reserved for quick and free of charge stops, up to 10 min); a greater curbside control and management systems at Lisbon and Porto airports which are often congested areas, among others (ANA Aeroportos de Portugal Annual Report, 2019). These represented major infrastructure investment pursued by the airport management company, whose pay back might be put at risk by a significant/strong uptake of ride-hailing.

Nowadays, a passenger has many alternative ways to access or egress Lisbon Airport. Its proximity to the city centre allows for a diverse network of personalized and collective transport options that can ensure an easy and comfortable trip in just 20 min. Nonetheless, the widespread road congestion may compromise the offer of pleasant trips and reliable travel times on the roads. Overall, the possible alternatives of private and public transport modes for Lisbon Airport ground access are the following: direct metro connection, direct bus connection, public transport multimodal options (bus, train, metro and ferry), taxi, private vehicles, ride-hailing, rental car and drop-off. More information on the alternatives is provided in section 3.3.

3.2. Data collection

The designed survey was developed to collect quantitative data on passenger behaviour and thereby model this choice behaviour for the last trip the respondents made to/from Lisbon airport. It was a revealed preference web-based survey designed on Google Forms. Information was collected on the passenger, the flight and the airport terminal. Specifically, the collected information on the trip included the city destination or origin of the flight, the purpose of the trip, the passenger group size, the number of bags and the frequency of travelling by air and using the Lisbon airport. For the trip to/from the airport the chosen mode was asked, the origin/destination point in the Lisbon area was stated and the reasons for choosing that mode. Finally, socioeconomic aspects such as age, gender, city of residence, monthly income and vehicles available at the household were asked followed by the most frequent commuting mode and the frequency of using ride-hailing services in the urban context.

The first survey version was pre-tested before being launched gathering feedback and information of 29 random respondents. The purpose was to test all aspects of the survey, including question content, wording, sequence, form and layout, question difficulty and instructions. After a revision of the survey, another pre-test was conducted using the same sample size but different respondents. The third and final version was then officially launched.

In order to identify the origin/departure of their trip to the airport of each respondent to the Lisbon airport, the respondents were asked to indicate the geographical point at the NUT3 level, which is known as “Freguesia” in Portugal. With this information, it was then possible to estimate the travel time of each origin-destination ground trip pair from Rome2Rio,[2] as in the process followed in Birolini et al., (2019). In this way information on all the trip pairs for each alternative was obtained. It is noted that the travel times for the ride-hailing and taxi options are the same as for the car mode. Regarding the cost of the trips, the same approach was followed to extract the cost for the car, lift, taxi and public transport trips while for the ride-hailing alternative, the respondents were asked to specifically indicate the cost of their trip. The total cost considered for the car alternative is the sum of the fuel cost obtained from the application and the cost of parking given by the respondents’ data.

The data collection took place online between January and March 2020 for trips that were realized in the period January 2019 - January 2020. To collect consistent information on the behaviour of the respondents, trips until January 2020 were considered since in February 2020 the coronavirus pandemic appeared in Europe. This period was regarded as reliable and still not affected by the impact of coronavirus and memory bias of the respondents.

3.3. Sample statistics

In total, 319 valid and complete replies were collected from people living in the Metropolitan Area of Lisbon and having used the airport in the period January 2019-January 2020. The sociodemographic characteristics of the sample are presented in the Appendix. As it is shown the sample is balanced on the gender participation. Regarding age, a higher participation of younger people is observed which can be the result of higher exposure to social media and, hence, visibility to the survey invite. The advent of the pandemic did not allow the on-site data collection (at the airport) that could have triggered an increase in the number of respondents of older age brackets. However, it is considered that there is enough heterogeneity in this variable for the purpose of the study. In what concerns the employment status, a great share of the

[2] https://www.rome2rio.com/.

respondents are full-time employees (59%) and 24% are students which is also aligned with the share of young people (21%). Most of the respondents have a driving license and accessibility to a car (92%). The commuting behaviour of the sample shows preference to private car 63% followed by public transport 36% while 64% of the respondents reported they live in a distance lower than 1 km from the closest public transport station.

Regarding the characteristics of the trip, 66% of the respondents travelled within the European zone, 10% to international destinations and 24% within the country. The trip purpose is concentrated on leisure with approximately 50% of the trips while 24% of the respondents travelled for business purposes and for 50% of these passengers the trip costs were covered by the company.

A third of the respondents stated they were picked-up or dropped-off by a family member, friend, colleague, or someone else (32%) and a fifth of the respondents (21%) preferred to use a ride-hailing option, representing the second most chosen alternative. 20% of the people used their private vehicle and 12% preferred to take a taxi to go to or from the airport. The most chosen public transportation mode was the metro, accounting for 11% of all responses, and the remaining two options represent about 2-3% of the choices (bus – 1%; train – 3%).

In Table 2, a descriptive analysis of the alternative specific attributes is presented. The travel time of the personalized modes are similar while public transport reasonably presents significant differences. Regarding the cost associated to each trip, the use of car is associated with lower costs when considering only fuel consumption while ride-hailing and taxi are more expensive options. Indicatively, it can be observed that that the trip of 90% of the passengers who chose ride-hailing paid up to 20€, while the equivalent cost was 12€ for public transport, approximately 8€ for a lift, around 6€ for a private car and 38€ for a taxi. Public transport costs have considered the use of monthly cards (40€ for the Lisbon Metropolitan Area) and the value of 0.9 is the cost per trip considering a round trip in the Lisbon Metropolitan Area 6 days/week. It is noted that drop-off does not account for non-monetary costs incurred by the driver. For ride-hailing, there is a significant shift when comparing the costs bared by 75% and 90% of the users since while 75% of the users paid up to 9€ this cost doubles for the next 25% of the ride-hailing users. Finally, it is seen that taxi and ride hailing have been used for similar distances while the ride from a familiar person has been chosen in 90% of the cases for distances longer then 51 km. In the next section, all the collected information is employed to systematically analyse passenger choice behaviour through the estimation of discrete choice models.

Some relevant questions were also posed to better understand the passengers' propensity to switch from their current or past mode choice to other modes, in particular toward ride-hailing. Out of all the respondents (319), 77 (24%) reported that they have used the parking before, but they did not choose the car for the trip under analysis. These respondents who stated that in the past had used their own car and the parking area, were asked to indicate the reasons for not using the car and the parking area at the trip under analysis. The results showed that the total trip cost compared to other modes, the high parking cost and the convenience of the car trip were unappealing factors for the car alternative. Table 3 presents in more detail the reported reasons.

It is observed that a significant share of the passengers changed their choice behaviour and shifted towards other modes (24%). These passengers indicated that their current choices were other personalized alternatives (Table 4), predominantly drop-off/lift (48%) and ride-hailing (30%). This information is important for the airport managers as it could interpreted as lost revenues for their business and previous research has shown that the quality of the experience affects mode choice (Andersson et al., 2023; Lim et al., 2024).

3.4. Mode-choice modelling

In this section, the functional form of the considered utility functions is discussed These are outlined below:

$$U_{car} = ASC_Car + \beta_{cost_Car} \bullet cost_Car_SC + \beta_{parking_Car} \bullet daysAway + \beta_{TT_Road} \bullet TT_dist_CarOwn + \beta_{bridge_Car} \bullet bridge + \beta_{business_Car_Taxi} \bullet business_trip + \beta_{freqLow_Car} \bullet Trips_0To3 + \beta_{age_Car_Taxi} \bullet Age_55To64$$

Table 3
Revealed reasons for not using the car and airport parking.

Reason for not using the airport parking	No. of passengers	% of passengers
Higher total trip cost	33	43%
High parking cost	40	52%
Do not own a vehicle anymore	14	18%
Less convenient alternative	32	42%
Traffic	4	5%
Paid trip	3	4%

Table 2
Statistical information of trip characteristics per alternative.

		Ride-hailing (21%)	Public transport (15%)	Drop-off/Lift (32%)	Own car (20%)	Taxi (12%)
Travel time	min	2.0	7.0	3.0	3.0	3.0
	5%	3.0	7.0	3.2	4.0	3.0
	25%	5.0	21.0	8.0	9.0	6.0
	50%	6.0	36.0	16.0	17.5	11.0
	75%	9.5	56.0	22.0	22.0	15.0
	90%	20.6	88.0	25.8	27.5	22.4
	95%	30.0	107.2	29.0	29.0	24.4
	max	30.0	116.0	38.0	44.0	28.0
Cost	min	2.0	0.9	0.2	0.8	3.3
	5%	3.0	0.9	0.2	0.8	3.3
	25%	5.0	0.9	1.5	1.5	9.5
	50%	7.0	0.9	3.0	3.8	12.5
	75%	8.8	5.5	4.5	4.9	17.0
	90%	19.0	7.1	5.5	6.3	37.6
	95%	20.0	12.6	8.1	7.0	67.5
	max	30.0	16.0	8.5	8.5	67.5
Distance travelled	min	0.8	2.5	1.9	1.9	1.9
	5%	1.8	2.5	2.5	2.5	1.9
	25%	3.2	3.4	5.5	7.1	4.0
	50%	4.4	7.1	16.2	17.6	8.0
	75%	8.0	19.3	26.2	24.6	20.6
	90%	23.2	37.9	50.8	35.2	24.9
	95%	37.9	61.1	61.1	61.1	37.6
	max	37.9	84.6	81.7	82.2	37.9

Table 4
Shifting from own car to other alternatives.

Actual mode choice	No. of passengers who did not choose again the car in this trip	% Of passengers who did not choose again the car
Ride-hailing	23	30%
Public transport	9	12%
Drop-off/Lift	37	48%
Own car	2	3%
Taxi	6	8%

$U_{Ride\text{-}hailing} = ASC_RH + \beta_{cost_RH} \bullet cost_Uber_SC + \beta_{TT_Road} \bullet TT_dist_Uber + \beta_{frequent_RH} \bullet RH_frequent_3 + \beta_{freqLowRH} \bullet Trips_0To3$

$U_{PuT} = ASC_PuT + \beta_{cost_PuT} \bullet cost_PuT_SC + \beta_{TT_PuT} \bullet TT_dist_PuT + \beta_{commuter_PuT} \bullet PuT_commuter + \beta_{femaleTaxiLift} * female$

$U_{Taxi} = ASC_Taxi + \beta_{cost_Taxi} \bullet cost_Taxi_SC + \beta_{TT_Road} \bullet TT_dist_Taxi + \beta_{business_Car_Taxi} \bullet business_trip + \beta_{age_Car_Taxi} \bullet Age_55To64$

$U_{Lift} = ASC_Lift + \beta_{cost_Lift} \bullet cost_Lift_SC + \beta_{TT_Road} \bullet TT_dist_CarOther + \beta_{femaleTaxiLift} \bullet female + \beta_{freqLow_Car} \bullet Trips_0To3$

The cost and the travelled distance, in association to the travel time are expected to negatively affect all the utilities. Regarding the other aspects, for ride-hailing specifically, it is expected to be preferred by passengers who already use it frequently for their urban mobility. A positive attitude is expected also by passengers who travel less frequently by air as it may be seen as a more reliable solution for those who are less familiar with the air trip processes. Some evidence on this positive relationship was indicated in previous research that found that the probability of using ride-hailing in the city relates positively with the frequency of travelling by plane (Alemi et al., 2018). For the lift trips, the low frequency of air trips is expected to affect positively this alternative and is expected that the utility will be higher for women as it has been indicated in previous research.

The utility of the car alternative is expected to be increase for passengers who need to cross the bridge to get to the airport and have more uncertainty in their trip. Also, passengers for business, as the literature also suggests, are likely to choose the use of their own car. It is also assumed that the lower the frequency of travelling by air, the higher the expected utility of the car, however the impact here is expected to be higher compared to ride-hailing. Finally, older passengers are also expected to show a preference for the car alternative. In the case of taxi, it is expected that a common effect as in the car will be observed for the age and trip purpose variables. All the models were estimated using Biogeme software.

4. Access mode choice modelling in Lisbon Airport

4.1. Multinomial logit mode choice models

The results of the discrete choice models are presented in Table 5 expressing four consecutive phases of model evolution. First the impact of the alternative attributes was assessed. Then the additional contribution of spatial attributes to the mode choice was considered. In the next phase the mobility behaviour of the passengers was added in the set of variables that affect the mode choice and finally, the impact of passenger and trip characteristics was addressed.

The trip cost and travel time have a negative impact on the passengers' choices as expected and confirmed by the estimated parameters' values. The **cost** of all alternatives reduces their utility for the users. However, it is statistically highly significant for ride-hailing, indicating that there is strong evidence that (all the rest being the same) an increase in the cost of this mode would result into a decrease of the utility for the passengers. To analyse the impact of **travel time** on the mode choice, travel time was scaled by distance (travel time/distance). Different coefficients are estimated for the personalized transport modes and public transport. The estimation results show that travel time has a negative impact but very low statistical significance for all the alternatives contrary to other studies. This is in part explained by the context of our study, being focused on the residents living in the LIS metropolitan area. The airport in Lisbon is located very close to the downtown centre of the Lisbon city, a characteristic that is not often met in airports serving the capital of a country but is expected to result into different mode use patterns compared to other cases where the airport is (traditionally) located at a longer distance from the city centre. As indicated in the afore-presented Table 2, travel time is not very different across the different modes—except for public transport—and not a strong

Table 5
Modelling results.

	Base model with alternatives attributes		With spatial aspects		With mobility behaviour		With passenger and trip characteristics	
	Value	*rob p-v*	Value	*rob p-v*	Value	*rob p-v*	Value	*rob p-v*
ASC_Car	−1.090	*0.004*	−1.130	*0.004*	−0.445	*0.342*	−1.090	*0.050*
ASC_Lift	−0.559	*0.087*	−0.530	*0.098*	0.186	*0.652*	−0.454	*0.381*
ASC_PuT	−0.823	*0.129*	−0.813	*0.132*	−2.040	*0.009*	−2.910	*0.000*
ASC_Taxi	−1.620	*0.000*	−1.590	*0.000*	−0.929	*0.037*	−2.130	*0.000*
β_{cost_Car}	0.550	*0.414*	0.312	*0.660*	−0.011	*0.988*	−0.330	*0.678*
β_{cost_Lift}	−0.881	*0.121*	−0.881	*0.116*	−1.170	*0.044*	−0.944	*0.112*
β_{cost_PuT}	−1.570	*0.116*	−1.530	*0.126*	1.340	*0.129*	1.180	*0.170*
β_{cost_Taxi}	−0.223	*0.198*	−0.224	*0.183*	−0.260	*0.131*	−0.261	*0.134*
β_{cost_RH}	−1.540	*0.002*	−1.500	*0.002*	−1.370	*0.003*	−1.39	*0.002*
β_{TT_Road}	−0.342	*0.741*	−0.272	*0.791*	−0.124	*0.904*	−0.347	*0.774*
β_{TT_PuT}	−0.583	*0.310*	−0.559	*0.324*	−0.643	*0.299*	−0.800	*0.191*
$\beta_{parking_Car}$	−0.027	*0.045*	−0.029	*0.047*	−0.029	*0.048*	−0.030	*0.026*
β_{bridge_Car}			0.968	*0.012*	0.975	*0.012*	1.050	*0.008*
$\beta_{frequent_RH}$					1.120	*0.000*	1.160	*0.000*
$\beta_{commuter_PuT}$					2.110	*0.000*	1.900	*0.000*
$\beta_{age_Car_Taxi}$							0.721	*0.031*
$\beta_{business_Car_Taxi}$							0.915	*0.002*
$\beta_{femaleTaxiLift}$							0.471	*0.060*
$\beta_{freqLow_Car}$							−0.616	*0.073*
$\beta_{freqLow_RH}$							−1.060	*0.014*
Estimation characteristics								
LL(0)	−491.731		−491.731		−491.731		−491.731	
LL(beta)	−446.326		−443.612		−429.875		−417.058	
rho bar square	0.0679		0.0721		0.0953		0.111	

determinant given the relatively short distances travelled.

Another **spatial aspect** that is likely to affect passenger choices and is not often met in other airport cases is the fact that the area under study is separated by a river (Tagus) into two large zones that are linked through two bridges. The bridge that is closer to the airport connects a less densely populated area with less business activities compared to the other one that serves a bigger volume of population (and commuters). Despite the offer of frequent and reliable public transport connectivity, it is expected and shown by the results that passengers would prefer their own car for their connectivity to the airport when they need to link to the areas across the river due to the uncertainty entailed in the public perception of public transport for longer distances.

Regarding the impact of the **mobility behaviour** of the passengers on their mode choice to the airport, passengers who use ride-hailing frequently in their urban mobility also showed a strong preference for ride-hailing to get to/from the airport compared to the other alternatives. Previous studies on urban mobility have concluded that frequent users of ride-hailing services are likely to use them for non-regular trips as well (Alemi et al., 2018; Sabogal-Cardona et al., 2021). This appears to be confirmed by our evidence. Commuters moving with public transport are also more likely to choose public transport for this trip, as well, probably because of their familiarity with the system.

Air trip and passenger characteristics also influence passengers' access mode choices. Aligned with past studies, we find that women compared to men are more likely to have a lift to the airport by another driver. The utilities of the car and taxi increase for passengers travelling for business, but although tested, the length of the stay and the cost compensation by the company were not proven to add value to the model. Travelling by plane with low frequency disfavours the use of private car and ride-hailing compared to the other alternatives as a passenger might be discouraged to experience the airport car parking process and can easily encounter information on public transport through the website of the airport. In what the age of the passenger is concerned, older passengers are more likely to choose to use their own car to access the airport compared to all the other modes. Although it is expected that older people may be more willing to afford the parking fee because of their expected higher economic state and for this reason car would be their choice, the interaction of age and income was not statistically significant.

Passenger taste heterogeneity was also tested through the development of mixed logit models and market segmentation for several characteristics such as gender, location and cost. However, the techniques neither unveiled any strong heterogeneity in the choices by passengers nor improved the model performance significantly. Therefore, we decided to stick to simple yet meaningful and explainable MNL models.

The added-value of each variable was judged through the statistically significant improvement of the Log-Likelihood (chi-test). The estimation characteristics of Table 5 show that as more passenger-related aspects are added in the utilities of the alternatives, the Log-Likelihood value improves significantly, indicating that the inclusion of the variables in the utilities contributes to the explanation of the choices of the passengers. The mobility behaviour, especially, is providing significant information for the airport accessibility behaviour. This aspect is important since the sample comprises of residents of the Lisbon Metropolitan Area.

Compared to past research, this study corroborated past results and provides some contributions. In the study of Tirachini (2019) it is stated taxi and car have been influenced by the use of ride-hailing, in our study there is some indication in this direction by the use of some common parameters for these two utilities. Our study also corroborates previous evidence on the preference to car and taxi when a business trip is conducted. For the air trips, women tend to choose public transport and lift as it happens in the urban mobility context. Previous research had identified that ride-hailing is more likely to be used in the center of metropolitan areas (Alemi et al., 2018) where the availability of the service is usually higher. However, there was poor evidence up to date on the impact of the frequency of using ride-hailing and our study contributed to this direction.

4.2. Scenario analysis on ride-hailing cost and passenger mix

The market shares of the alternative modes may change when the aspects involved in the system under analysis change. For example, ride-hailing services tend to diffuse rapidly to the population of the areas where they are available and the value of the fee paid for ride-hailing, given that the competitive environment, is volatile. To consider the sensitivity of passenger choices to ride-hailing cost, the effect of variations of this cost to the market shares is analyzed for different passenger segments. Then, it is also combined with variations in the mix of passenger characteristics, specifically the frequency of using ride-hailing, travelling for business and crossing the bridge to connect to/from the airport. The results are presented and discussed below.

1) Ride-hailing frequent users

As ride-hailing is diffusing in the market, the change of the share of frequent users is possible. Hence, first variations in the mix of ride-hailing frequent users were explored along with changes in the trip cost. Table 6 presents the current mode choice of the frequent (35%) and non-frequent users (65%) of the sample. There is a clear difference among the two groups in what concerns the preference to ride-hailing options for the airport connection with 39% of frequent users choosing ride-hailing options, opposed to just 11% of non-frequent users. The most preferred mode for non-frequent users was the car lift (37%) followed by own car (24%).

Fig. 1 shows how the share of ride-hailing for frequent and non-frequent users may vary if changes in the cost of ride-hailing occur. It is noticed that a bigger change is observed in the share of non-frequent passengers that ranges from 8.27% (a 26% share reduction) to 16% (a 43% share increase) when the trip cost increases and decreases by 50% respectively. For the current frequent users, the respective values are 33% and 47.1% which correspond to a reduction of 15% compared to the current state and an increase of 21% compared to the actual share (38.9%). The results indicate that the shares are more sensitive to a reduction of the cost compared to an increase.

2) Share of Business passengers

The impact of the pandemic on professional activities and remote work has greatly influenced business trips. For this reason, the sensitivity of passengers travelling for business purposes to the ride-hailing cost is analyzed here (Fig. 2). In this case, business travellers are more sensitive to cost trip variations, resulting into a maximum reduction of ride-hailing share equal to 24% (11.9% market share) when the cost trip increases by 50% and into a maximum increase in the share equal to 43% when the cost reduces by 50%. On the other hand, the equivalent changes in the share of ride-hailing for passengers travelling for non-business trips varies from 18.6% (−18%) to 28.4% (+26%).

Table 6
Access mode choices of ride-hailing frequent and non-frequent users.

Transport mode	Use ride-hailing frequently		Travelling for business		Crossing the bridge	
	Yes (%)	No (%)	Yes (%)	No (%)	Yes (%)	No (%)
Ride-hailing	39%	11%	16%	23%	39%	17%
Public transport	18%	14%	12%	16%	9%	23%
Car lift	24%	37%	26%	34%	14%	15%
Own car	12%	24%	30%	17%	10%	12%
Taxi	7%	14%	17%	10%	28%	33%

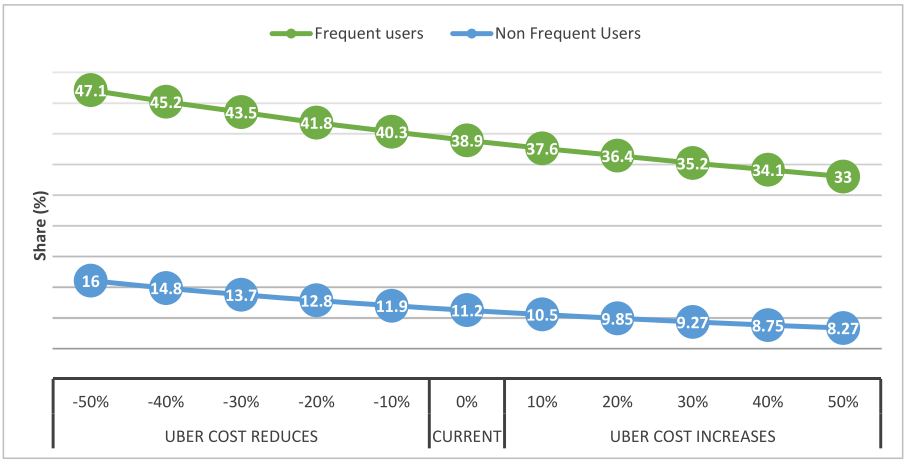


Fig. 1. Ride-hailing use frequency and cost sensitivity.

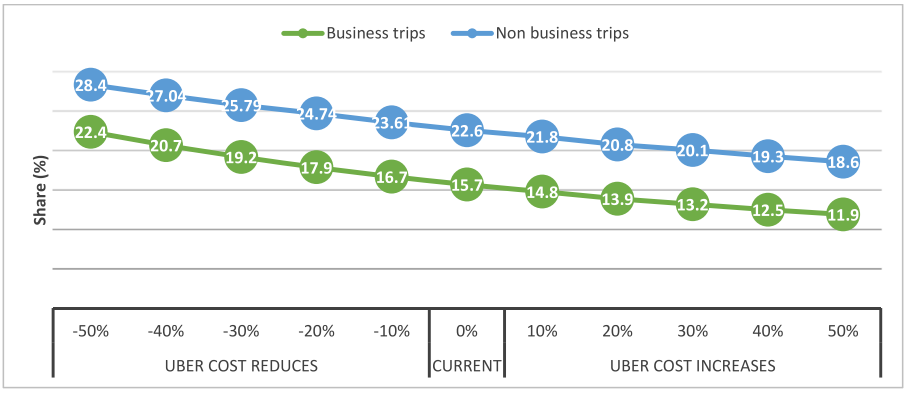


Fig. 2. Trip purpose and ride-hailing cost sensitivity.

3) Evolution of demographics

The preferences of the local population on their residential area have been changing throughout the past 10 years in the Metropolitan Area of Lisbon mainly due to the increase of the touristic sector, the attractiveness of start-up companies and larger international businesses in the city centre, and the consequent real-estate price changes in certain areas. As residents tend to move away from the city center towards more suburban areas, many people tend to choose to reside to the south bay of Lisbon where it is easier to find new construction, more public space and lower prices. Fig. 4 depicts the changes (red-coloured areas mean bigger changes) and Table 7 presents the aggregated data on the evolution of the population from 2011 to 2021 in the areas under study. The data shows that more people have moved to the southern part of the region which implies that more people will need to cross the river to connect to/from the airport in the future.

For this reason, the variable of crossing the river to reach the airport was analyzed joined with variations in the cost of ride-hailing trips. Fig. 3 shows that there is currently a low percentage of the sample that crosses the bridge and uses ride hailing (9.05%) while in the case of the north bay this share is more than double (22.8%). Under the consideration of a reduction in the cost of this service a maximum of approximately 16% could be achieved while an increase in the cost would result into a drop to 6% of the total share. This indicated that for passengers who need to cross the river, ride-hailing is not an attractive option but changes in the cost structure could capture more passengers.

Table 7
Aggregated variations in the population of Lisbon Metropolitan Area per household type.

	Aggregate households			Individuals' households		
	2021	2011	Δ%	2021	2011	Δ%
North Bay	860618	803234	7%	2062444	2042474	1%
South Bay	407596	351862	16%	980408	954535	3%

4.3. Multivariate scenario analysis

After assessing the individual impact of cost changes on different market segments, in this section, the combined effects of changes in the cost of the ride-hailing and the mix of passenger profiles are addressed. Based on our econometrics results, these variables are all important to the future evolution of access modes' market shares. To consider the combined effect of all these four variables, a simulation of the market shares was done considering first variations in the cost of the ride-hailing trip that varied from −50% to 50%. Then for each of these scenarios, sub-scenarios were created that considered that the percentage of the sample that uses ride-hailing services for their mobility trips varies by ±50% from the current state. Furthermore, the impact of the number of passengers that cross the bridge to reach the airport was also added in the scenarios and additional cases were addressed considering variations between −50% and 50% for this variable as well. Finally, given the changes in business trips during and after the pandemic, scenarios that assumed that the share of business trips varies ±50% were also added in the scenario list. In total 1375 scenarios were created and the market share of each alternative was simulated for each of them.

Fig. 5 depicts the results of the simulated scenarios for the share of the ride-hailing alternative. It is observed that the lowest share is

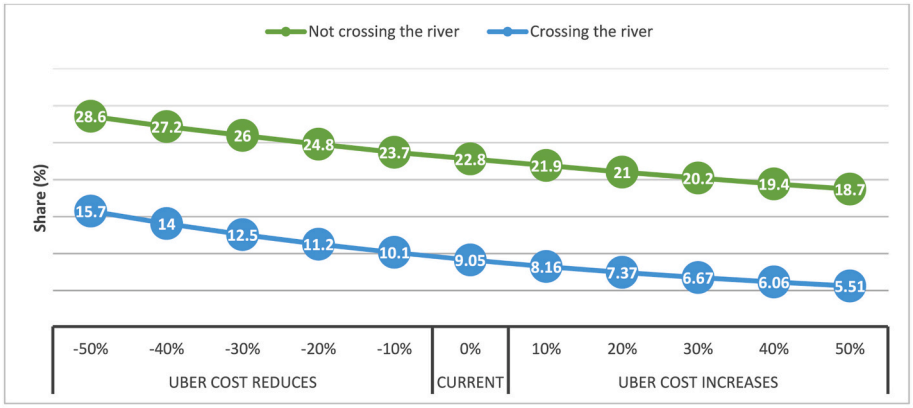


Fig. 3. Crossing the bridge with ride-hailing and cost sensitivity.

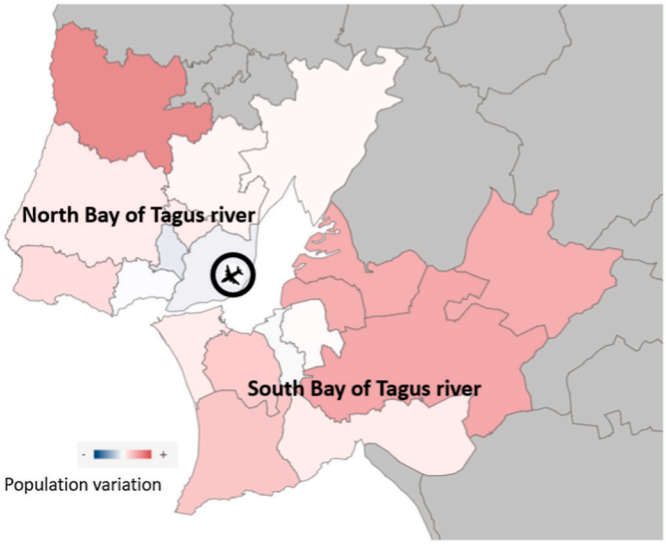


Fig. 4. Population variations in Lisbon Metropolitan Area (Source: INE).

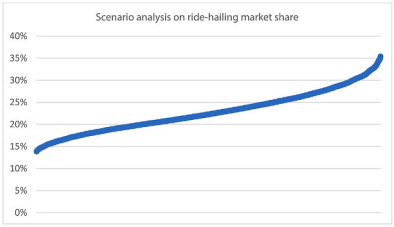


Fig. 5. Evolution of ride-hailing market share in response to changes in cost and socioeconomic variables.

13.84% and corresponds to the extreme scenario that the ride-hailing cost increases by 50%, the share of passengers who are frequent users of ride-hailing in the urban environment decreases by 50%, the share of passengers who need to cross the bridge increases by 50% and business trips also increase by 50%. The rest of the scenarios with similar shares, all, correspond to cases where the cost of ride-hailing increases. On the other hand, the highest share was estimated to be 35.37% and reflects a scenario in which the ride-hailing cost decreases by 50%, the number of frequent users increases by 50%, the passengers who cross the river drops by 50% and the same happens to the share of business trips.

It is observed that there is a high variation in the potential of this alternative depending on the market conditions. The aspect with the highest influence seems to be the cost of the trip while the frequency of use also is important.

To get a more detailed view of the geographical distribution of the market shares in the extreme cases of a 50% increase and reduction of the ride-hailing, the shares per municipality were estimated. Table 8 presents the forecasted market shares for all the modes. It can be seen that the expected shares of Public Transport and Taxi do not present high variations to the changes in the cost of ride hailing. On the contrary the shares of the private car and car lift are more affected. Fig. 6 depicts the geographical distribution of the shares of ride-hailing only in the two studied scenarios. As it would be expected, nearly located areas were forecasted to serve significantly higher part of the market. These areas are Alcochete that is located across the bridge next to the airport, Lisbon that is the city center and Loures that is located next to the airport at the North Bay. These results highlight that ride-hailing options are more attractive when passengers move in the North Bay of the Lisbon metropolitan Area which can be explained by the higher availability of these services in this area. The statistics of the survey demonstrate that ride-hailing has gained competitiveness and is indeed considered a transport mode alternative for airport accessibility in the North Bay while by fostering the service availability in the South Bay, more passengers could be attracted for this type of trips.

5. Conclusion

Urban transport systems continuously change with the advent of new technologies and the offer of new mobility services. In this environment, airport accessibility alternatives and passenger choices do not remain unaffected. Ride-hailing services are changing the shape of mobility systems in cities and the passenger behaviour as we knew them by now. Such new services are also being adopted by air passengers for their connection to and from airport terminals. Given these dynamics in the mobility supply, this study analyzed the behaviour of passengers when choosing the transport mode to access from/to the Lisbon airport in the era of ride-hailing services constituting the first study up to date to count for these alternative passenger options and assess the sensitivity of the projected market shares to changes in cost values, population characteristics and airport passenger mix. Through a revealed-preference survey the choices of passengers among the alternatives of private own car, lift by car, public transport, taxi and ride-hailing were addressed. The findings highlight that these services cannot be neglected in accessibility studies as they capture market share from other alternatives and may hold a significant portion in passenger choices. A peculiar characteristic of the airport under study is its proximity to the city centre and urban areas, and the consequent lower travel times and associated trip costs compared to other airports located in country capitals.

In the context of this case, ride hailing services held a significant part of the airport access market share (21%). In many cases they were used

Table 8
Market shares per municipality.

	Forecasted Ride-hailing cost reduced by 50%					Forecasted Ride-hailing cost increased by 50%				
	Car	Car Other	PuT	Taxi	Ride-hailing	Car	Car Other	PuT	Taxi	Ride-hailing
Municipality										
Alcochete	16%	25%	5%	12%	41%	24%	38%	8%	17%	13%
Alenquer	26%	40%	11%	8%	15%	30%	47%	12%	9%	1%
Almada	33%	26%	12%	9%	21%	37%	31%	14%	10%	8%
Amadora	19%	30%	11%	12%	28%	22%	35%	13%	14%	16%
Arruda dos Vinhos	22%	22%	28%	8%	20%	27%	27%	34%	10%	3%
Barreiro	26%	37%	8%	9%	19%	30%	42%	10%	11%	7%
Cascais	23%	35%	19%	8%	15%	26%	40%	22%	9%	3%
Lisbon	13%	25%	13%	10%	39%	15%	29%	15%	12%	29%
Loures	17%	20%	8%	12%	43%	19%	24%	9%	14%	34%
Mafra	25%	39%	15%	6%	14%	28%	45%	17%	7%	3%
Moita	44%	23%	6%	11%	16%	50%	26%	7%	13%	5%
Montijo	41%	23%	10%	9%	17%	48%	27%	12%	10%	3%
Odivelas	13%	38%	10%	10%	28%	15%	45%	12%	12%	16%
Oeiras	24%	28%	12%	10%	25%	30%	34%	14%	12%	10%
Palmela	29%	31%	13%	9%	17%	33%	36%	15%	11%	5%
Seixal	35%	22%	14%	7%	22%	40%	27%	17%	9%	7%
Sesimbra	31%	27%	8%	11%	22%	38%	33%	9%	14%	6%
Setubal	24%	32%	14%	13%	18%	28%	37%	16%	15%	4%
Sintra	20%	30%	15%	10%	24%	25%	37%	18%	12%	9%
Vila franca de Xira	21%	30%	13%	15%	21%	24%	36%	15%	17%	8%

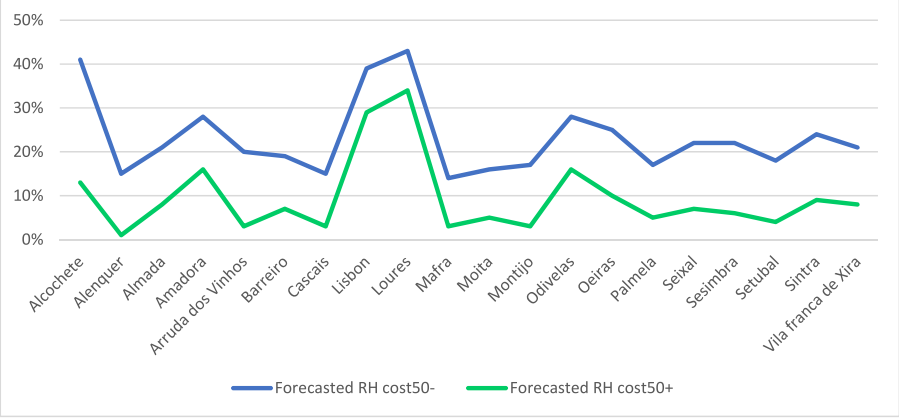


Fig. 6. Ride-hailing forecasted market shares per Municipality.

for a specific geographical range as many trips connected the airport to an average distance of 8.5 km with a standard deviation of 9.5 km while all other modes were chosen for longer distances. This aspect may be affected by the availability of these services in this catchment area around the airport, but it is indicative of the impact on the market. It was also shown that people who use frequently these services for motives of their urban mobility, are also more likely to opt for ride-hailing to connect to the airport. An increase in the availability of these services and the consequent engagement of more people to them could indicate the potential of further market acquisition of this mode. Such an increase would have an impact on the other modes, especially conventional taxi and the individual car with implications for airport parking revenues as well. From a revenue perspective and airport operator could possibly want to adjust their parking policy options to control car use or introduce new charges for ride-hailing services to create a new revenue stream for the airport's business model.

For an airport operator access modes are very important as they represent the first/last step of passengers trips and ultimately affect the overall passenger experience. The airport area needs to be designed respectively and the proper space allocation to the modes that serve the passengers should be ensured. Currently, at the airport under study the alternatives of ride-hailing and car-lift share the same space that consists of a dedicated kiss-and-ride area, located in a 50m distance from the terminal entrance, that can be visited for free the first 10min and is charged for longer periods. Often the high number of vehicles in queues to approach the terminal area demonstrate a clear underestimation of the demand for this service and highlight the need for more accurate predictions on the use of this area. On the other hand, the taxi services can use the dedicated curbside outside the airport building. Given the unbalanced queues created in the airport access area, an airport operator could reconsider the distribution of space and the use rights of different stakeholders, accompanied by a potential redesign of the access areas separated in zones for different users (private cars and ride-hailing services), in order to ensure the minimum time loss in waiting time to access the terminal. The analysis of the profile of the users who prefer this option can also assist in improvements that could be implemented in the public transport system to better accommodate the needs of the passengers or also promote multimodality options including ride-hailing in the passenger trip. As the passenger behaviour in the urban context also changes with the appearance of more personalized mobility options and the regulatory frameworks may undergo changes, the airport accessibility area may also need to adjust to accommodate the various volumes of each mode.

This study provides some evidence of not only the actual shares of each access mode but also the aspects that may affect passengers in their decision-making process. The travel cost, spatial aspects, mobility

behaviour of the passengers in the urban context and passenger personal traits were found to affect the mode choice to connect to/from the airport. In addition to that modal split changes were explored through scenario analysis and it was found that the cost of ride-hailing and the frequency of using these services in the urban context can significantly influence the share of ride-hailing providers.

Future research could check an equal probability scenario approach but with a future foresight on the evolution of ride-hailing and the changes in the passenger composition and geographical distribution. In this case, future applications could weight the scenarios based on the probability of occurrence and the results could further enhance policy making to increase the accuracy and deployment of the proposed methodology. A larger sample size could also enable the exploration of market segmentation models to better comprehend passenger choices. Finally, our future research could include a process simulation model to simulate different scenarios and identify successful optimised management decisions considering the evolution of other modes.

Ultimately, results of this study reveal important and useful empirical data that can be used to inform airport authorities and help them meeting the ground accessibility needs of airport's users, while providing new solutions that accompany the fast-growing mobility service industry. Noticeable, the benefits of ride-hailing services are expected to be even stronger with the upcoming automation and electrification, which is expected to further lower operating costs and provide sustainable and even more accessible services. By investigating key adoption drivers of ride-hailing in an airport context, this paper strives to support further assessments concerning the evolution and impact of ride-hailing technologies toward more sustainable airport accessibility.

CRediT authorship contribution statement

Sofia Kalakou: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Visualization, Writing – original draft. **Sebastian Birolini:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Visualization, Writing – original draft. **Sofia Vasconcelos:** Formal analysis, Software, Writing – original draft.

Declarations of interest

None.

Acknowledgments

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Appendix

Sociodemographic		
Gender	female	50%
	male	50%
Age	18-21	29%
	25-34	20%
	35-44	17%
	45-54	13%
	55-64	18%
	>64	2%
Employment status	Full-time	59%
	Student	24%
	Self-employed	5%
	Part-time	2%
	Not employed	2%
Driving license	Yes	92%
	No	8%
Trip characteristics		
Destination	Domestic	24%
	International	10%
	Europe	66%
Purpose	Business	25%
	Leisure	54%
	Friends/Relatives	21%
Low-cost airline	Yes	36%
	No	64%
Urban Mobility characteristics		
Commute with public transport	Yes	36%
	No	64%
Commute with private car	Yes	63%
	No	37%
Ride-hailing frequent user	Yes	35%
	No	65%
Air Trip characteristics		
Baggage to check in	0	67%
	1	23.5%
	2	6.5%

(*continued on next page*)

(*continued*)

	3 or more	3%
Passenger check-in mode	Online	53.3%
	Counter	21.5%
	Mobile	15.6%
	Machine	9.6%
Passenger group size	Alone	28.2%
	2 passengers	38.2%
	3 passengers	14.1%
	4 or more passengers	19.5%
Travel with children	Yes	15.72%
	No	84.28%

Data availability

Data will be made available on request.

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