

FACULDADE DE ENGENHARIA DA UNIVERSIDADE DO PORTO

Understanding the factors and features of a tourist-oriented mobile ticketing solution

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September 2020

Abstract

Considering the growing importance of the tourism sector in the past years, the pressure that it imposes on the transport infrastructures of the most visited cities worldwide, and the widespread use of smartphones with internet access, it becomes clear that promoting the use of public transport by tourists is not only vital but also feasible due to the appearance of mobile ticketing technologies.

The main objectives of this project are to understand what factors influence the adoption of a public transport mobile ticketing service for tourists, and, if this service is developed, which features tourists would value the most.

To achieve such objectives, a mixed methodology composed of three steps was followed: (i) a literature review, (ii) a qualitative study through a set of semi-structured interviews, and (iii) a quantitative study composed by a two distinct statistical analysis.

The literature review covered the most relevant topics in the context of this research, and supported the preparation of a set of interviews for a group of people about their experiences regarding the use of public transport in the context of tourism. Subsequently, a questionnaire was developed and applied to support the quantitative study. This study resulted in a descriptive statistical analysis of the features of the hypothetical public transport mobile ticketing service and a multivariate statistical analysis on the adoption factors of this service.

Our research reveals that obtaining information about mobility at the destination, buying public transport tickets, and validating those tickets are the most important features of the proposed service for tourists.

Regarding the adoption factors of a public transport mobile ticketing service for tourists, the results demonstrate that the usefulness of the service is positively impacted by its ease of use and compatibility. Additionally, usefulness and mobility explain the intention to use such a service.

Acknowledgments

This work ends a cycle of 5 years since I first started my Master's Degree. These 5 years were a real test of my persistence and determination – I am proud to have arrived here.

I thank my wife, my parents, my brothers, my parents in law and the rest of my family for supporting and encouraging me during the realization of not only this work but the whole Master's Degree.

I also thank the supervisors of this Dissertation, Prof. Teresa Galvão, and Prof. Marta Campos Ferreira, for the guidance given throughout this research, for pushing the limits of my knowledge and getting me out of my comfort zone. Needless to thank all the availability they had to meet with me for the past few months.

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1. Introduction

1.1. Context

Over the past few decades, urban areas have seen remarkable development at many levels, such as sanitation systems, or health and education infrastructures, making them desirable places to live in for many people all over the world, since that living standards tend to be higher in such areas.

It is estimated that, around 2007, for the first time, more people in the world lived in urban areas than in rural areas, with the compound annual growth rate of the urban population at almost 1% between 1960 and 2017 (see Figure 1) (Economic and Affairs 2019).

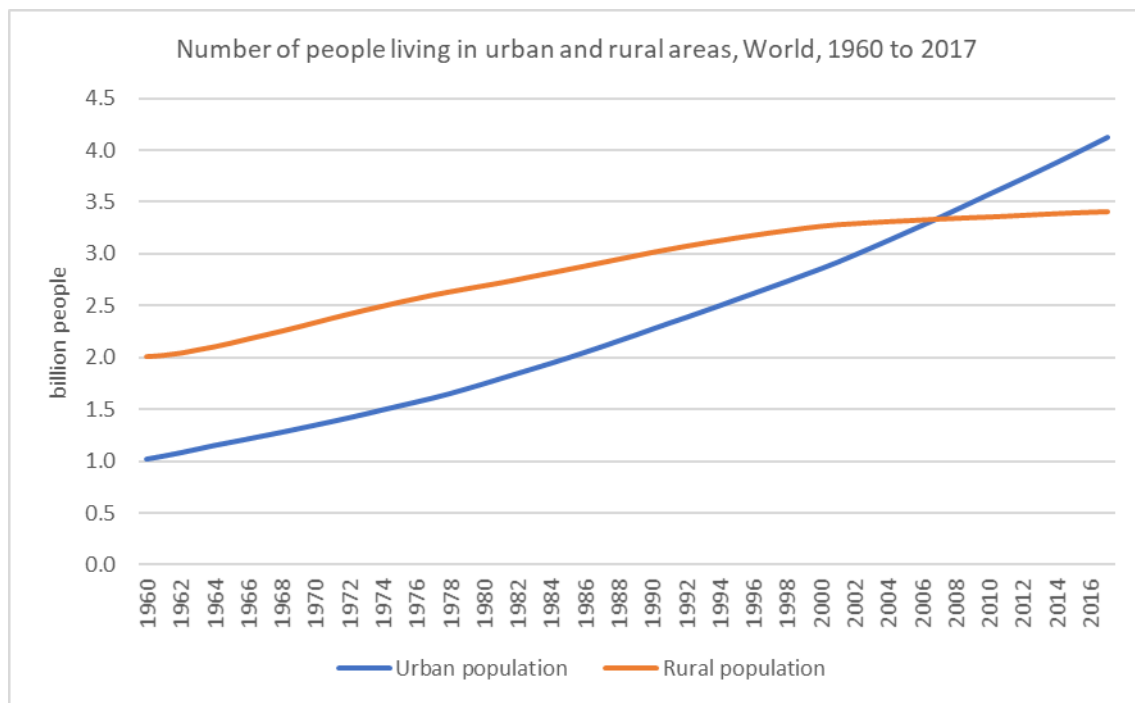


Figure 1 - Number of people living in urban and rural areas; source: UN World Urbanization Prospects (2018)

Parallel to the demographic increase in urban centers, the world has increasingly enjoyed tourist activity - the United Nations World Tourism organization defines tourism has a “social, cultural, and economic phenomenon which entails the movement of people to countries or places outside their usual environment for personal or business/professional purposes”. (Publications 2017)

Since the '90s decade that the international tourist arrivals more than tripled (see Figure 2) (Roser 2017), and the importance of the sector in many European economies today surpasses 10% of their gross domestic product (GDP).

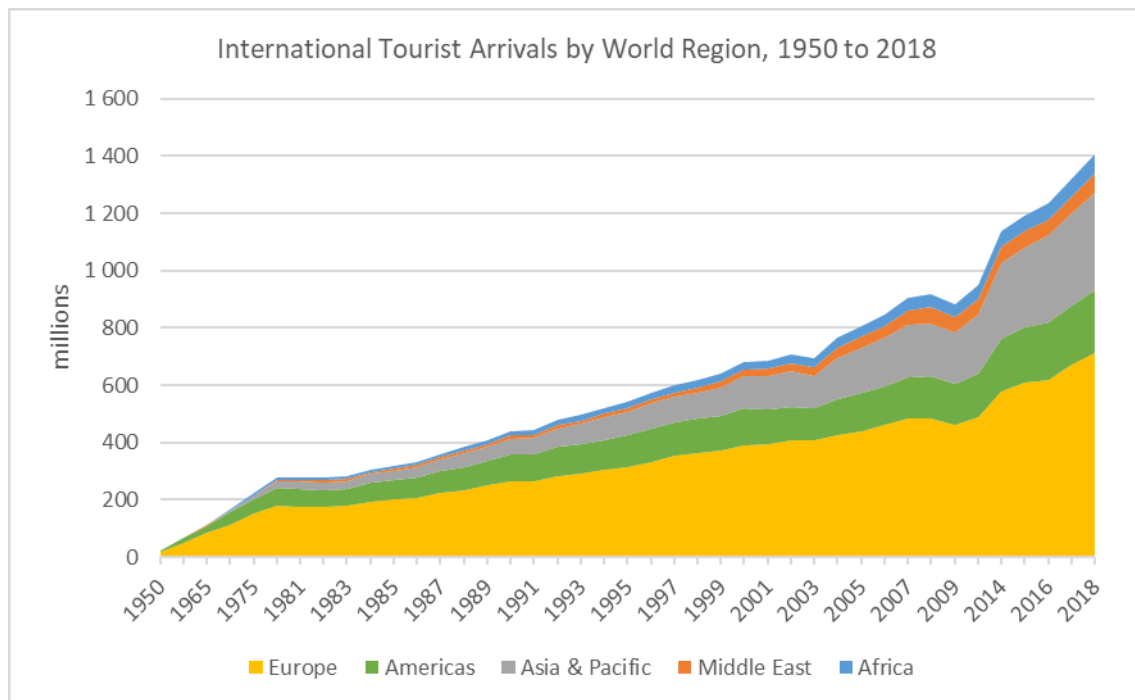


Figure 2 - International Tourist Arrivals by World Region; source: 2019 Tourism Barometer of the United Nations World Tourism Organization

Urbanization – the phenomenon of population shifting from rural to urban areas – and the growth in tourist activity reinforced the importance of public transport in the large metropolises of the world, as the use of private transport, such as own cars, created an unbearable pressure on road networks of these locations.

Many countries and cities have been investing in the growth of public transport networks since the last century (the greater London area, for example), but only more recently have they paid attention to the ticketing systems that support such networks.

Ticketing systems typically functioned through paper tickets, which would be bought from a physical store located at each station, and then validated on tourniquets placed at the access to the transport network. Yet, such systems had some disadvantages such as queues, or the need to have change, to purchase tickets.

Not only due to the sharp development of information and communication technologies but also to the increased use of mobile phones, new solutions have been found to improve the ticketing systems mentioned above. It is in this context that mobile ticketing emerges, with an excellent use context in public transport.

Since the appearance of the first mobile ticketing systems applied to public transport they have evolved enormously, with newer and better technologies supporting them. Unfortunately, most of them only tend to focus on the needs of local users of public transport networks.

Given the growing importance of the tourism sector, based on the upward trend in the number of tourists traveling in urban areas, and the advent of smartphone use, we believe that the study and development of a public transport mobile ticketing service for tourists are of utmost pertinence.

Therefore, our research aims to meet that pertinence through the intersection of three topics: public transport mobile ticketing, technology adoption, and tourism (see Figure 3).

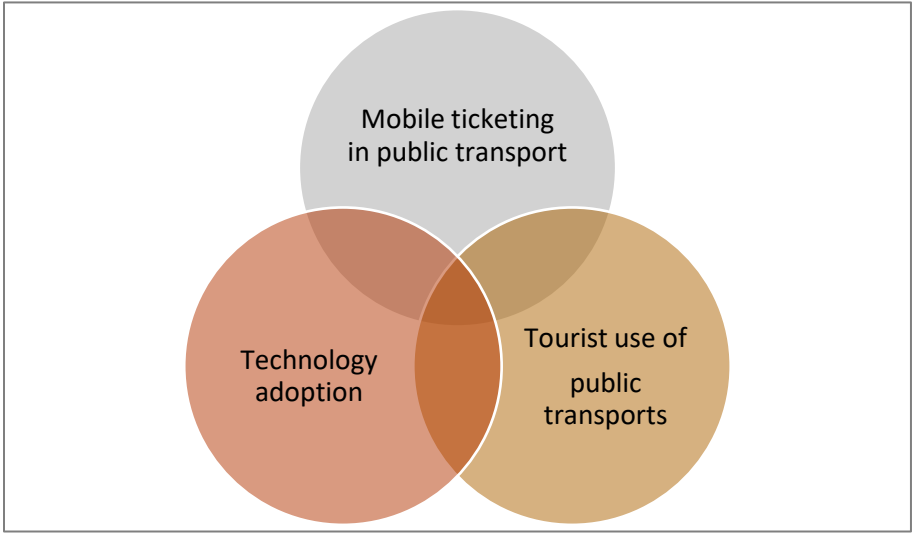


Figure 3 - Research topics

1.2. Motivation and goals

As previously exposed, there is some scientific research on mobile ticketing services, particularly in the context of public transport. However, the application of such solutions in the tourism context is scarce.

While a local user of public transport may have certain needs, those needs may be completely different from a tourist user visiting a new city, for example. Additionally, one user may be willing to adopt such technologies in his local town, whereas he may not while abroad.

Therefore, the main objectives of this study are to understand, for a public transport mobile ticketing service for tourists:

- i. What factors explain its intention to use;
- ii. What features should this service offer its users.

1.3. Document structure

After this introductory section, the present document has 6 more chapters: in chapter 2 there is a literature review, where we present the state of the art of main topics related to our investigation; in chapter 3 we describe the methodology followed to accomplish the objectives of our research; in chapter 4, we describe a set of semi-structured interviews conducted with a few potential users of a public transport mobile ticketing service for tourists; in chapter 5, we present a descriptive statistical analysis about the most important functionalities of a hypothetical public transport mobile ticketing service for tourists; in chapter 6, we develop a multivariate data analysis to understand the factors that explain the adoption of the public transport mobile ticketing service for tourists; finally, in chapter 7, we sum up our research and critically analyze the results obtained.

2. Literature Review

As explained in the previous chapter, this study aims to explore the intersection of three distinct topics – mobile ticketing in public transport, technology adoption, and tourist use of public transport – through the study of the adoption factors of a public transport mobile ticketing service for tourists, and the features that such a solution should have. Therefore, the first step of our research was to perform a literature review on the concepts underlying these topics, which will be presented in this chapter.

2.1. Public transport mobile ticketing

Mobile ticketing is directly related to the use of mobile phone applications to convey an electronic version of tickets. Much like mobile payments, this innovation is possible due to the widespread use of the internet, as well as to the increased use of mobile phones by individuals, contributing to the exponential growth of mobile commerce in general, and mobile ticketing in particular.

Several mobile ticketing definitions can be found in the literature. Some include the whole payment actions (Au and Kauffman 2008), while others relax this requirement and consider it as the use of a mobile device to hold a virtual ticket (Puhe, Edelmann et al. 2014). Ferreira, Dias et al. (2020) define mobile ticketing as the use of a mobile device to purchase and/or validate a travel ticket or to initiate a journey. This definition includes the use of a mobile device to previously purchase and/or validate a travel ticket or to start a trip through a declared check-in or through a be-in/be-out scheme, whose information will then allow to calculate the price to be paid for the journey.

The next subsection illustrates a general application context of the mobile ticketing in the public transport sector, followed by a description of the main technologies used in mobile ticketing solutions. Then, the main advantages and disadvantages of mobile ticketing services are identified, as well as cases of implementation worldwide.

2.1.1. Application of mobile ticketing to public transport

A general application context of the mobile ticketing in the public transport sector is described in Figure 4.

Essentially, customers acquire tickets through their mobile phones, possibly registering themselves to enable fine-grained billing and flexible prices with some discounts (step 1 in Figure

4). The trip begins when customers enter the transport vehicle and check-in (step 2a in Figure 4), which is performed through a reading device that is installed in the transport vehicle. After the validation, the reading device forwards the ticket ID to the on-board processing unit, which registers the check-in time and the geographical coordinates. Once the customers reach the final destination, they check out and leave the transport vehicle (step 2b in Figure 4). As it happens in the check-in, the time and location are registered once again, forming the travel record of customers, which is communicated to the back-end system to apply the price and the fine-grained billing (see step 3 in Figure 4).

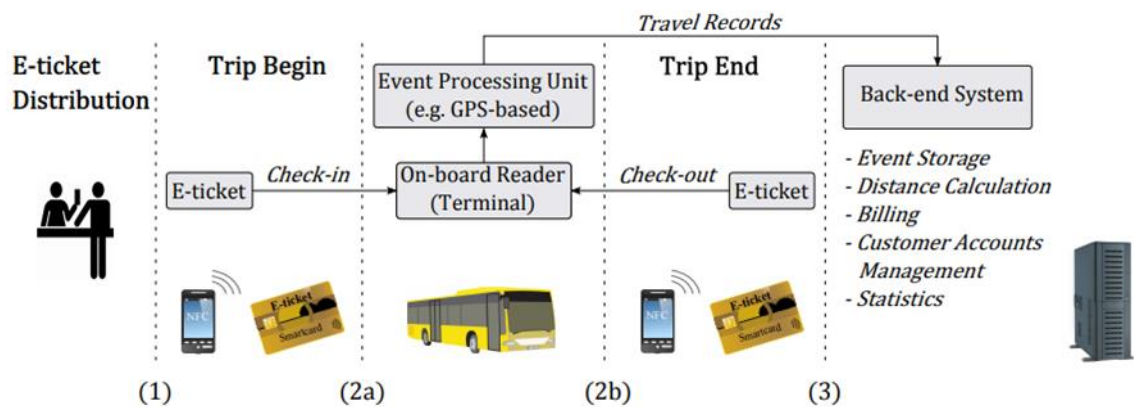


Figure 4 - Mobile ticketing general application context (Gudymenko 2015)

2.1.2. Available technologies for public transport mobile ticketing services

According to Ferreira, Dias et al. (2020) five technologies are mostly used to support mobile ticketing solutions: SMS and phone calls, Wi-Fi and mobile telecommunications, *Near Field Communication* (NFC), *Bluetooth Low Energy* (BLE), and Quick Response Codes (QR Codes).

Short Message Service (SMS) is a service for sending short messages up to 160 characters to mobile devices, like cellphones or smartphones. SMS and phone calls were probably the first technologies used to implement mobile ticketing solutions on public transport, and so there are quite examples of its implementation worldwide, such as Ring&Ride (Germany), Paybox (Austria), Proximus (Belgium), Mobipay (Spain), AvantixMetro (United Kingdom).

Wi-Fi, being a wireless technology that is used for local area networking of devices and internet access, is also a candidate for the communication protocol of mobile ticketing since several public transport companies already have Wi-Fi infrastructures adequately deployed in their stations and vehicles. Mobile telecommunications solutions, which first-generation (1G) appeared back at the end of the 1970's decade and its last-generation (5G) by 2019, is also a fine candidate to support

mobile ticketing solutions due to its low investment requirements from the Public Transport Operators' point of view. Ferreira, Nóvoa et al. (2014) propose an innovative ticketing solution based on the combination of the two previously presented technologies. The great virtue of the proposed solution is its compatibility with pre-existing infrastructures, being solely based on customers' mobile devices with an internet connection.

Near Field Communication (NFC) is a short-distance wireless technology that comes embedded in some mobile phones. NFC allows mobile phones to read an NFC tag or even other NFC devices. The NFC tag contains a passive NFC chip, which can be read by an active NFC device, designated as the reader. Amongst the main advantages of NFC, it is important to emphasize the fact that this technology has fast and automated connections, very fast set up times, and good user experiences (Pesonen and Hoster 2012). Ivan and Balag (2015) present their designing and implementation approach for a mobile ticketing system for urban transport based on NFC technology.

Bluetooth Low Energy (BLE) consists of a wireless technology that allows users to exchange data over a short distance by using radio transmissions, referring to an improvement of the standard Bluetooth. When compared to its precedent (Bluetooth), Bluetooth Low Energy's main advantages are the lower power consumption, the enhanced range, the lower bandwidth, the lower latency, and a more energy-efficient communication. Concerning the public transport context, either Martins (2017) and Ferreira, Dias et al. (2019) propose mobile ticketing solutions based on Bluetooth Low Energy.

Quick Response Codes (QR Codes) are constituted by small and symmetrical elements that are arranged in a rectangle, containing information both in the horizontal and vertical direction, and are frequently attached to a specific item to convey information about it. QR Codes can be scanned by using a mobile phone's camera, with the user being automatically directed to the URL that is encoded in those QR Codes. Finzgar and Trebar (2011) and Masabi (n.d.) propose mobile ticketing solutions, geared toward the public transport sector, based on the Quick Response Codes technology.

In summary, a variety of technologies may be used to support the implementation of public transport mobile ticketing services, and all of them have been proposed by many different authors. Each has its advantages and disadvantages, which are summarized in Table 1 - Relative comparison of the common mobile ticketing technologies (Ferreira, Dias et al. 2020).

Table 1 - Relative comparison of the common mobile ticketing technologies (Ferreira, Dias et al. 2020)

	SMS and Phone Calls	Wi-Fi and 3G/4G	NFC	BLE	QR Code
Type of payment	Remote	Remote	Proximity	Proximity	Proximity
Transmission distance (coverage)	>1000m	150 and >1000m	0,04m-0,1m	50m-70m	0,25m-2m
Transmission security technology	Low	Low	High	Low	Medium
Communication	One to one	One to one	One to one	One to many	One to one
Energy consumption	Low	Low	Very low	Medium	Very low
Environment conditions interference	Medium	Medium	Low	High	High
Security	Low	Medium	High	Low/Medium	Medium
Required investment from Service Provider	Minimal	Minimal	Significant: NFC-readers; software installation and integration	Significant: beacons; software installation and integration	Moderate: QR code scanners or printed QR Codes. Software installation and integration
Availability	High	High	Low	Medium	Medium
User interaction	High	No interaction (case of Be-in / Be-out systems)	Low	No interaction (case of Be-in / Be-out systems)	Medium
Check-in/check-out compatible	✓	✓	✓	✓	✓
Be-in/be-out compatible		✓		✓	
Advantages	<ul style="list-style-type: none"> - High availability - Familiar to every user - No or very low infrastructure investment 	<ul style="list-style-type: none"> - High availability - Data transmission with the backend in real-time - No or very low infrastructure investment 	<ul style="list-style-type: none"> - Secure (data is encrypted and stored in a secure element) - Low user interaction - Faster read-speed 	<ul style="list-style-type: none"> - Long-distance reception - No user interaction (case of Be-in/be-out systems) 	<ul style="list-style-type: none"> - Easy to create and print - Can be read by every smartphone with autofocus camera - Can be shown on any device's screen
Disadvantages	<ul style="list-style-type: none"> - Low security (no encryption) - No proof of delivery - Transaction costs (premium numbers) - Messages formats complicated, difficult to remember, hard to key in - High user interaction 	<ul style="list-style-type: none"> - Network connection problems (underground stations, crowded stations/vehicles) - Insecure public Wi-Fi networks 	<ul style="list-style-type: none"> - Lower availability - Not well-known - Only works well at very short distances - High infrastructure investment and maintenance costs 	<ul style="list-style-type: none"> - Low/medium security (data transfer performed at long distances) - Power source needed - High installation and maintenance costs - High environment conditions interference 	<ul style="list-style-type: none"> - High user interaction - High environment conditions interference - Less flexibility - High exposure to vandalism - QR Code reading process is not fast enough

2.1.3. Advantages and disadvantages of public transport mobile ticketing services

The main stakeholders of a public transport mobile ticketing service are both public transport operators and customers, meaning that if we want to study its advantages and disadvantages, we should take into account both points of view.

On the customers' side, Gudymenko (2015) lists the advantages of these solutions such as speed and convenience in the purchase and validation of tickets, optimization of the cost of the fare considering the customer's trip, the lack of risk of losing a public transport ticket, and the possibility to take advantage of discounts. However, we should not disregard the benefits of avoiding queues and the replacement of coins and banknotes to purchase the tickets (Ferreira, Dias et al. 2020).

The downside, in the customers' perspective, of public transport mobile ticketing services has to do with privacy issues such as the chance of being profiled by public transport operators, having ubiquitous customer identification, and the potential surveillance offered to public transport operators by these solutions (Gudymenko 2015).

Looking at the situation on the public transport operators, their main advantages when implementing a mobile ticketing service are the decrease in the systems' maintenance costs, the reduction on the payment handling costs, the mitigation of tickets' forgery, the possibility to attract more customers, mainly the youngster generations, and, consequently generate more revenue for themselves (Gudymenko 2015).

On the other hand, there are also some disadvantages for public transport operators when implementing mobile ticketing services, such as the lack of standardization in the sector as a whole, the investment required to create and deploy such a solution, and the need to ensure the interoperability between different service providers (Gudymenko 2015).

Table 2, which is adapted from the work of Gudymenko (2015), summarizes the main advantages and disadvantages of a mobile ticketing service for public transport, whether from the perspective of customers and public transport operators:

Table 2 - Advantages and disadvantages of mobile ticketing in the public transport sector (Gudymenko 2015)

	Advantages	Disadvantages
Customers	<ul style="list-style-type: none"> - Faster and more convenient verification of a ticket; - Saving on travel expenses (payment for the distance of the travel); - Profit from a flexible fare pricing; - Revocation of lost tickets; - Benefit from discounts. 	<ul style="list-style-type: none"> - Possibility of customer profiling; - Ubiquitous customer identification; - Privacy violation through the increased surveillance potential.
Public transport operators	<ul style="list-style-type: none"> - Decrease in the system maintenance costs; - Reduction of payment handling costs; - Mitigation of the ticket forgery problem; - Attract more customers and generate more revenue. 	<ul style="list-style-type: none"> - Lack of mature interoperable solutions and standardization in the sector as a whole; - The need to invest in the creation of a new infrastructure and its deployment; - To ensure the interoperability between different service providers.

2.1.4. Public transport mobile ticketing services worldwide

Mobile ticketing has been widely used throughout the world for several purposes, especially for public transport, with special prominence in Asia, since the implementation of such technological systems was quite easy and quick due to multiple reasons, such as:

- 1) The population's big density and the high demand potential for public transport services;
- 2) The characterization of the public transport networks by a strong market segmentation (private and public owned operators);
- 3) The public transport operators are frequently a part of a diversified bundle of services (public transport, communication, retail, travel);
- 4) The cooperation is partial rather than being organized in large transport associations;
- 5) The young urban Asian population is considered to be tech-savvy (Puhe, Edelman et al. 2014).

Nevertheless, and despite their significant prominence and popularity, Asian mobile ticketing systems are not the only ones that are considered to be exemplary. Some other systems,

used in London or the Netherlands, are also immensely popular, illustrating successful cases for distinct purposes, even though they do not seem to be transferable for other contexts and/or countries. Such lack of transferability is mainly related to the country's specificities, either related to its public transport network or its public transport operators' networks. For instance, the Oyster card in London was introduced and implemented to replace the magnetic stripe cards, and because the ticket gates were already available, hence reducing initial investments. Similarly, the nationwide OV-chipkaart scheme was introduced in the Netherlands due to the previous implementation of a hybrid system with both open and closed elements (Puhe, Edelmann et al. 2014).

Table 3 summarizes some of the main features of public transport mobile ticketing services worldwide, namely the name of the implemented scheme, its location, the used technology, the payment technology, its main applications, the number of users, and the possible integration in the public transport sector. Overall, the presented examples can be categorized according to different types of schemes, more precisely:

- 1) Schemes driven by public transport, allowing international users to use them. They do not necessarily have a direct link to the tourism sector, but they can be eventually used in such context;
- 2) Schemes directly linked to tourism, being often described as destination cards. Most of them entail free public transport usage, which is why they are mentioned in the present study;
- 3) Schemes designated as local authority cards, being remarkably interesting for both the public transport and the tourism sectors, since they aim to appeal to a specific target group/population (Puhe, Edelmann et al. 2014).

Table 3 – Use cases of mobile ticketing worldwide (Puhe, Edelman et al. 2014)

System	Location	Technology	Payment	Application	Number of users	Integration in transport
Oyster Card	London, UK	Contactless smart card	Stored value smart card	Public transport	43 million (2012)	Bus, underground, rail
Mi Muovo	Emilia Romagna region, Italy	Contactless smart card	Season tickets	Public transport	More than 200.000	Bus, trains, bike sharing, car sharing
Octopus Card	Hong Kong, China	RFID smart card	Prepaid smart card, NFC	Transport, tourism, retail shopping, eGovernment	More than 10 million (2007)	Bus, tram, ferries, taxis, railways, parking
T-Money	Seoul, South Korea	RFID smart card	Prepaid smart card	Public transport, retail	1.3 million (2010)	Bus, rail, ferry, taxi
EZ-Link	Seoul, South Korea	Singapore	Prepaid smart card, NFC	Transport, tourism, retail shopping, eGovernment	12 million (2012)	Rail, bus, taxi, parking, car sharing
Ventra	Chicago, USA	RFID smart card	Prepaid smart card	Public transport, retail	-	Mass rail transit, bus
Touch & Travel	Germany	NFC	NFC	Trains and public transport	-	Train, bus, tram
CityZi	Nice, France	NFC	NFC	Public transport ticketing	2.5 million (2013)	Bus, train, tram
iAmsterdam	Amsterdam, Netherlands	RFID	Prepaid smart card	Public transport, touristic sites	130.000 cards per year	Bus, tram, metro

BodenseeErlebniskarte	Austria, Germany, Liechtenstein, Switzerland	OCR	One-time payment	Tourism	25.000 per year	Touristic services, public transport
St. Petersburg City Card	Saint Petersburg, Russia	RFID	e-terminals or cash desks	Tourism, public transport	-	Metro, tram, bus
Southampton Smartcities Card	Southampton, UK	Dual interface card	Stored-value card	Public transport	80.000 (2012)	Bus

2.2. Technology Adoption

2.2.1. Technology Adoption Models

Considering the constant technological evolution and change, leading companies are always seeking to improve their technological applications to increase their benefits and profits. The acceptance and adoption of such technologies by consumers directly depends on several aspects, namely the availability of the technology, its convenience, and security, as well as the consumers' needs.

Hence, and due to these distinct aspects, several studies have been developed to fully understand the consumers' acceptance and adoption of new technologies, approaching different technology adoption models and theories (see Figure 5 - Technology Adoption Models Timeline).

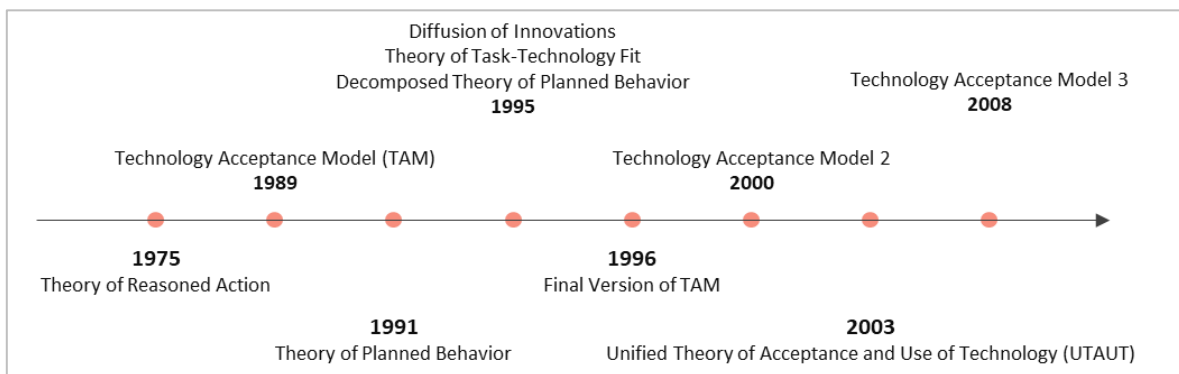


Figure 5 - Technology Adoption Models Timeline

The “Theory of Reasoned Action” (TRA) was developed by Fishbein and Ajzen (1975) and consists of one of the most popular theories to explain technology adoption by consumers. Overall, this theory is based on one specific factor, which determines the behavioral intention of the consumer’s attitudes towards that same behavior. According to the authors, the concept of attitude refers to the consumer’s evaluation of an object, the concept of belief consists in the link between the object and a specific attribute, and the concept of behavior refers to an intention or result. Hence, the consumers’ attitudes are affective, as well as based on a set of specific beliefs about the object of the behavior. Still, there is also a second factor involved in the consumers’ behavior, directly associated with the consumer’s subjective norms of what he/she perceives about the society’s attitude towards a specific behavior.

The “Technology Acceptance Model” (TAM) consists of an adaptation of the Theory of Reasoned Action (TRA), being particularly developed for modeling the consumers’ acceptance of technologies. According to Davis, Bagozzi et al. (1989), the main goal of the TAM is to explain the

determinants of computer acceptance, which lead to an explanation of the consumers' behaviors across a broader range of end-user technologies. The basic TAM includes and tests two beliefs in particular: The Perceived Usefulness (PU) and the Perceived Ease of Use (PEU). Essentially, the first consists of the potential user's subjective likelihood that the use of a specific technology will improve his/her action, while the second is related to the degree to which the potential user expects the technology to be quite effortless. Nonetheless, the consumer's belief regarding a specific technology can also be influenced by other factors, which are referred to as external variables of the TAM.

The "Theory of Planned Behavior" (TPB), also based on the consumers' behavior, was developed by Ajzen (1991) and refers to one specific factor that determines the behavioral intention of the consumer's attitudes towards that behavior. The first two factors are the same as those referred to in the Theory of Reasoned Action, while the third factor is related to the perceived control behavior, consisting of the control that is perceived by consumers as a limiting factor of their behavior.

"Diffusion of Innovations" was proposed by Rogers (1995) to explain the process through which an innovation is communicated through several channels over time and amongst the members of a specific social system, being designated as diffusion. Therefore, the Diffusion of Innovations theory states that both the innovation and the adoption happen after several stages, more precisely after understanding, persuading, deciding, implementing, and confirming. These different stages led to the S-shaped adoption curve of innovators, early adopters, early majority, late majority, and laggards, which was also proposed by Rogers (1995).

The "Theory of Task-technology Fit" (TTF) was developed by Goodhue and Thompson (1995) with the main goal of emphasizing the individual impact, which refers to the improved effectiveness, efficiency, and/or to a higher quality. According to these authors, the good fit between the task and the technology is related to the increase of the likelihood of usage and the performance impact, considering that the technology fulfills the task's needs and increases the users' willingness to use it. This specific model is adequate to investigate the actual usage of the technology, especially when the main goal is to test the new technology to obtain the users' feedback.

The "Decomposed Theory of Planned Behavior", introduced by Taylor and Todd (1995), refers to three main factors that highly influence the behavior intention and the actual behavior

adoption by consumers, more precisely to the attitude, to the subjective norms, and the perceived behavior control.

Venkatesh and Davis (1996) proposed the final version of the “Technology Acceptance Model” (TAM), more precisely after they both found out that both the perceived usefulness and the perceived ease of use have a direct influence on the consumers’ behavior intention, therefore eliminating the need for the attitude construct in this specific model.

The “Technology Acceptance Model 2” (TAM 2) was developed by Venkatesh and Davis (2000) with the main goal of providing more insights regarding the reasons why users found a given technology as useful at three different points in time, more precisely: 1) pre-implementation; 2) one-month post-implementation; 3) three-month post-implementation. Thus, the TAM 2 refers to a model that theorizes that the consumers’ mental assessments of the match between important objectives at work and the consequences of performing job tasks by using the technology serve as the basis of the formation of perceptions referring to the usefulness of the technology that is being adopted.

The “Unified Theory of Acceptance and Use of Technology” (UTAUT) was developed by Venkatesh, Morris et al. (2003) based on all of the previous models and theories. Essentially, the UTAUT has four main predictors in terms of the consumers’ behavioral intention, more precisely the performance expectancy, the effort expectancy, the social influence, and the facilitating conditions. Furthermore, the UTAUT model is also composed by five constructs when it comes to the performance expectancy, namely the perceived usefulness, the extrinsic motivation, the job-fit, the relative advantage, and the outcome expectations, while the notions of perceived ease of use and complexity are captured by the effort expectancy.

Lastly, the “Technology Acceptance Model 3” (TAM 3) was developed by Venkatesh and Bala (2008), who joined the TAM 2 and the model of determinants of perceived ease of use. This last model was based on four different types of factors, namely on the individual differences, the system/technology characteristics, the social influence, and the facilitating conditions, all of them considered to be very determinant in terms of the perceived usefulness and of the perceived ease of use. In sum, in TAM 3 the perceived ease of use to perceived usefulness, the computer anxiety to perceived ease of use, and the perceived ease of use to behavioral intention were all moderated by several experiences.

2.2.2. Mobile Ticketing Adoption in Public Transport

To fully understand mobile ticketing adoption in public transport eleven studies were analyzed, comprehending several investigations in different countries that aim to demonstrate how the general public accepts such new technologies in the public transport sector and what factors influence such adoption and usage. Table 4 summarizes the analyzed studies, presenting some information about them, namely their authors, year of publication, location, theories in which it is based, and factors that explain the use intention.

Table 4 – Summary of the analyzed studies about mobile ticketing adoption in public transport

Title and Authors	Location	Theories	Factors
Exploring consumer adoption of mobile payments - A qualitative study (Mallat 2007)	Helsinki, Finland	Diffusion of Innovations	Relative advantage; Compatibility; Complexity; Costs; Network externalities; Trust; Perceived security risks
An empirical investigation of mobile ticketing service adoption in public transport (Mallat, Rossi et al. 2008)	Helsinki, Finland	Technology Acceptance Model; Diffusion of Innovations	Ease of use; Usefulness; Attitude; Social influence; Compatibility; Cost; Prior Experience; Trust; Risk; Use context; Mobility;
The impact of use context on mobile services acceptance: The case of mobile ticketing (Mallat, Rossi et al. 2009)	Helsinki, Finland	Technology Acceptance Model; Diffusion of Innovations	Ease of Use; Perceived Usefulness; Compatibility; Mobility; Use context; Use intention

High speed rail passengers' mobile ticketing adoption (Cheng and Huang 2013)	Taiwan	Technology Acceptance Model	Personal innovativeness; Perceived risk; Perceived usefulness; Perceived ease of use
Empirical examination of the role of three sets of innovation attributes for determining adoption of IRCTC mobile ticketing service (Kapoor, Dwivedi et al. 2015)	India	Diffusion of Innovations	Behavioral intention; Voluntariness; Triability; Social approval; Riskiness; Relative advantage; Compatibility; Complexity; Cost; Image; Observability; Result demonstrability; Communicability
The Integrated Model on Mobile Payment Acceptance (IMMPA): An empirical application to public transport (Pietro, Mugion et al. 2015)	-	Diffusion of Innovations; Technology Acceptance Model; Unified Theory of Acceptance and Use of Technology	Usefulness; Attitude towards mobile services; Compatibility; Ease of use; Security; Intention to use; Users' behavior
Factor Influencing the Acceptance and Use of M-Payment in Thailand: A Case Study of AIS mPAY Rabbit (Kaitawarn 2015)	Thailand	Unified Theory of Acceptance and Use of Technology	Performance expectancy; Effort expectancy; Facilitating conditions; Social influence; Perceived convenience; Perceived sacrifice; Perceived value;

			Intention to use
User acceptance of e-government services: Examining an e-tax filing and payment system in Thailand (Bhuasiri, Zo et al. 2016)	Thailand	Unified Theory of Acceptance and Use of Technology	Performance expectancy; Effort expectancy; Social influence; Facilitating condition; Attitude toward using; Switching cost; Convenience; Privacy
Mobile payments adoption in public transport (Fontes, Costa et al. 2017)	Oporto, Portugal Beijing, China	-	-
Flight ticket booking app on mobile devices: Examining the determinants of individual intention to use (Suki and Suki 2017)	Federal Territory of Labuan, Malaysia	Technology Acceptance Model; The Theory of Planned Behavior	Perceived usefulness; Perceived value; Perceived ease of use; Perceived trust; Subjective norm; Airline image
Factors Influencing the Intention to Use the Common Ticketing System (Spider Card) in Thailand (Prayoonphan and Xu 2019)	Thailand	Unified Theory of Acceptance and Use of Technology	Performance expectancy; Effort expectancy; Facilitating conditions; Social influence; Perceived convenience; Perceived sacrifice; Perceived value; Intention to use

The study conducted by Mallat (2007) aimed to examine the factors that affect consumer adoption of mobile payments. The author's findings demonstrate that the relative advantage of mobile payments is determined by the enhanced availability of the mobile technology, the perceived independence of time and place, the ability to avoid queues, and the ability to

complement more traditional services, such as cash payments; that the situational factors do impact the consumers' decisions when it comes to adopting and using mobile payments; that complexity, compatibility, trust, network externalities, and cost factors are very important regarding the consumers' adoption of mobile payments; and that there is a partial adoption pattern among consumers since they use both mobile payments and traditional payment instruments daily.

In their study, Mallat, Rossi et al. (2008) explain the use intention of mobile commerce by looking at the mobile ticketing in the public transport sector. According to the obtained results, the authors concluded that the mobility and the contextual elements (such as the lack of cash, the unexpected need to use public transport, the expiration of a periodic travel card, and the hurry) play a very important role in the adoption of mobile services and that both of these factors must be closely integrated into the existing adoption models with the main goal of increasing their predictive power. Also, Mallat, Rossi et al. (2008) demonstrated that the effect of these two factors on the adoption of mobile services is plausible, considering the contextual and ubiquitous nature of the mobile services use in general.

In a more recent study, even though based on the same goals and specificities of the study that was previously conducted, Mallat, Rossi et al. (2009) developed and tested a mobile adoption model that addressed the features of mobile technologies and services, concluding that users consider two distinct types of benefits of mobile ticketing service adoption, namely the performance-related usefulness and the spatially and temporally improved service access that is enabled by mobile technology. Furthermore, they also claimed that the benefits were mediated by the use context and that the ease of use and the compatibility factors affect the use intention by consumers.

In turn, Cheng and Huang (2013) have demonstrated that the mobile ticketing adoption is influenced by the potential loss (perceived risk) and benefit (perceived ease of use and perceived usefulness) of the mobile ticketing service. Furthermore, these two authors proposed that the combination of the mental accounting theory and of the Technology Acceptance Model is very adequate to explain the customers' decisions regarding the adoption of such services. In more detail, the perceived usefulness, the perceived ease of use, and the perceived risk affect the consumers' mobile ticketing adoption.

Kapoor, Dwivedi et al. (2015) have suggested that, and other than complexity, the remaining attributes from the Diffusion of Innovations theory have a significant influence on the behavioral

intention of consumers in terms of adoption of mobile ticketing services, and that the riskiness significantly affects both the behavioral intention and the adoption of mobile ticketing services.

On the other hand, Pietro, Mugion et al. (2015) have proposed a new model, designated as the Integrated Model on Mobile Payment Acceptance (IMMPA), which was designed specifically for mobile payments in public transport. The main conclusions presented by these authors are the following ones: the intention to use a technology is affected by the usefulness, the ease of use, and the security of that technology; and the usefulness is influenced by the ease of use, the compatibility with the consumers' values and needs and their attitude towards mobile ticketing services.

The study conducted by Kaitawarn (2015) proved that both the convenience and attitude are considered to be the most important determinants regarding the adoption and use of mobile ticketing services. Still, the author also emphasized that the privacy of personal information and the switching costs significantly affect the consumers' intention to use such technologies.

In the following year, Bhuasiri, Zo et al. (2016) concluded that the performance expectancy, the facilitating conditions, the social influence, and the perceived credibility are all very significant factors in the adoption of mobile ticketing technologies, while the perceived risk and the effort expectancy do not influence the consumers' intention to adopt and use those same technologies.

Fontes, Costa et al. (2017) suggest that specific factors, such as travel frequency, average travel frequency, hurry, the traditional places used to buy tickets, and the typical type of ticket that is used, are considered to have a crucial role in the assessment of the ticketing systems. Overall, this study showed that there is a great acceptance in terms of the use of the mobile payment technologies in the public transport, that convenience and time saving are the main advantages of these technologies, and that privacy, interaction, and reliability are some of the major concerns when deciding for the adoption of mobile ticketing services.

Conducted in the same year, the study developed by Suki and Suki (2017) assesses the individual intention to use a flight ticket booking app on mobile devices. Essentially, the authors demonstrated that the perceived usefulness is the strongest determining factor in the consumers' intention to use mobile ticketing technologies, followed by the ease of use, which is directly associated with less mental efforts and less intricate operationalization of the technologies.

Finally, in the study conducted last year Prayoonphan and Xu (2019) intended to identify the determinant factors that truly impact the passengers' intention to use the Spider Card based on

the UTAUT model by integrating perceived convenience and perceived sacrifice as a part of the perceived value. Overall, the main conclusions of this study demonstrate that:

1. The perceived value, the facilitating conditions, and the performance expectancy are very significant determinants in the customers' intention to adopt and use the Spider Card;
2. The public transit passengers are more likely to use the Spider Card if they consider it to be more beneficial than other means;
3. The perceived value influence is more substantial than the UTAUT constructs, meaning that customers are more amenable to the Spider Card based on the degree of the value that they can afford.

2.3. Tourist use of public transport

Tourism is one of the sectors with the highest growth rate over the past years and its evolution is placing tough challenges to many cities worldwide since many of them were not initially planned to receive such amount of tourists. Those challenges range from residential pressure in the city centers, also known as tourism gentrification, to mobility issues like the overuse of road networks or public transport.

Until recently, the mobility of tourists at their destination has received little attention from researchers, contrary to the transport modes tourists use to travel from their point of origin to their destination. However, more than ever it is important to enhance the utilization of public transport by tourists at their destination, given the pressure that tourism is putting on transport infrastructures worldwide.

Kinsella and Caulfield (2011) realized that a city newcomer relies intensely on information when using public transport. Their study looks at the importance of providing information to Dublin's newcomers, and how the provision of appropriate information can improve their tourist experience. Unlike local users, the results of the study reveal that newcomers place higher importance on having information about the public transports of the city they are going to visit, rather than the quality or safety of such transports.

Malhado and Rothfuss (2013) took advantage of the 2014 FIFA World Cup to propose strategies that could be implemented to promote sustainable mobility in the city of Manaus during that mega-event. That research question forced them to study which facilitating conditions and barriers exist among car users on adopting public transport. They found out that lack of information

is one of the main factors restricting the use of public transport since tourists need details on schedules, stops, stations, and routes to conveniently use that transport mode.

In its review on the “tourist use of public transport at destination”, Le-Klähn (2014) looked to answer, among other questions, how public transport could be encouraged in tourism. He concludes that poor service delivery is many times a strong motif for passenger dissatisfaction, and to promote public transport adoption among tourists it is crucial to make it easy to use. That may be accomplished, among other factors, by sharing critical information such as network maps, or next stops, in multiple languages.

Le-Klähn, Gerike et al. (2014) looked to understand the reasons not only for a tourist using public transport at the destination but also to not using it. Their research, which was based on the city of Munich, concluded that the benefits of not having to drive are one of the reasons for visitors using the public transport network in that city. On another hand, lack of information is one of the reasons for tourists not using public transports in Munich.

In their study about tourist’s satisfaction with public transport in Munich, they concluded that typically the city visitors were satisfied with the transport system. However, six key aspects should be considered to improve the public transport system in the tourist’s point of view: information, ticket price, service frequency, ease of use, and comfort. Interestingly the pertinence of the information is in line with the researches previously presented.

Gutiérrez and Miravet (2016) leaned over the highly touristic area of Costa Daurada, which is 100 km south of Barcelona, to study the characteristics that most influence tourists’ choice for public transport in their destination. Contrary to what previous research concluded, which emphasizes the importance of providing information to tourists, their study reveals that the main factor influencing the adoption of public transports at the destination is the transport mode used to reach the Costa Daurada – if a tourist used their private car to reach the region we will certainly not use public transport, as opposed to one that arrived by plane, for example.

3. Methodology

As previously stated, the present research aims to study the adoption factors of a public transport mobile ticketing service for tourists and what features its potential costumers most value.

For that purpose, a mixed-methodology was followed, meaning that a combination of qualitative and quantitative methods was used. Qualitative data tends to be open-ended without predetermined responses while quantitative data usually includes closed-ended responses such as found on questionnaires or psychological instruments (Creswell 2014).

The methods used in our research range from a literature review, presented in the previous chapter, to semi-structured interviews, to a questionnaire that supported a descriptive statistical analysis, and a multivariate statistical analysis – structural equation modeling. Figure 6 - Research methodology diagram gives an overview of the sequence of methods adopted through the course of this research, and its results.

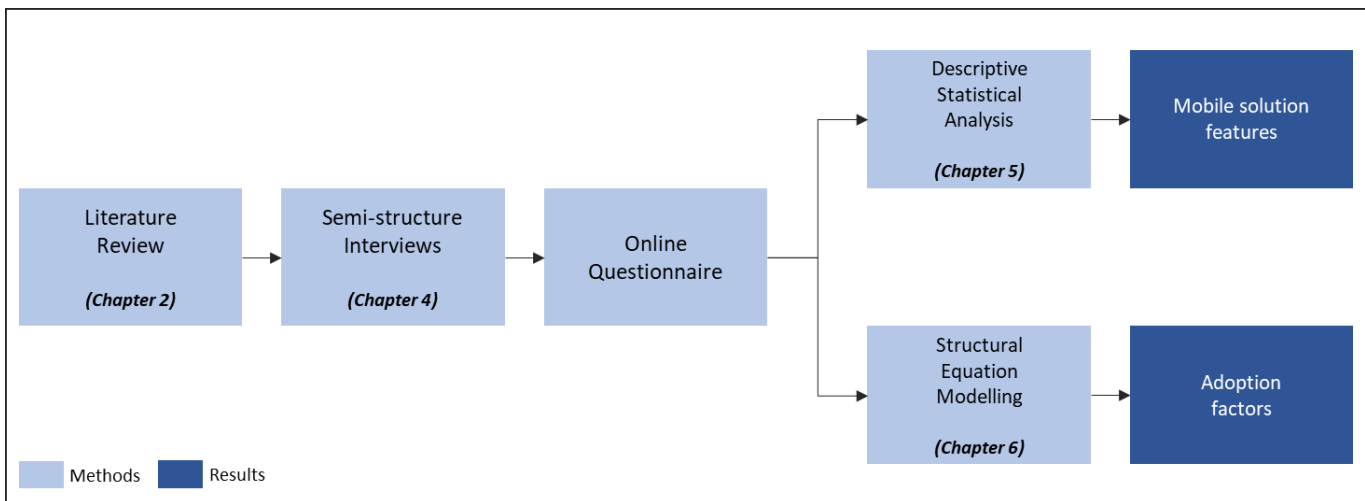


Figure 6 - Research methodology diagram

The literature review, which determines the starting point of the study, was based on the consultation of several articles, books, and documents regarding what is already known about public transport mobile ticketing, technology adoption models, and tourist use of public transport. The importance of this step cannot be neglected since it was the base stone for the knowledge we obtained on those topics, and that was applied throughout the whole research.

After the literature review, and considering that we started being acquainted with the topics previously referred, 5 semi-structured interviews were carried in the beginning of May 2020. The interviewees were chosen among our “Friends & Family” network, with particular emphasis on

people who travels frequently. In “Appendix 1 – Semi-structure interview script” we detail the script used to conduct the interview.

The semi-structured interviews objectives were to collect the first insights into the mobility experience during tourism, and to create a solid basis for the subsequent construction of a questionnaire. The topics explored with the interviewees ranged from describing past experiences using public transport to the discussion of how a mobile ticketing service could enhance that experience.

Despite the interviews were conducted amid the COVID-19 confinement, forcing us to make them via telephone, they proved to be extremely useful for the research since its objectives were accomplished. The contact we had with the interviewees, which we considered to be among the potential users of the public transport mobile ticketing service for tourists, were essential for the construction of a questionnaire, that would later be shared online.

A questionnaire was then applied to 351 participants aiming to collect data to support two distinct analyses: a descriptive statistical analysis, and a structural equation modeling. “Appendix 2 – Online questionnaire structure and questions” presents the questionnaire disclosed.

Google Forms was the tool used to create and gather the answers from the questionnaire. It was online between the 5th and the 18th of June 2020, and multiple methods were used to share its link, such as the University of Porto email, Facebook, WhatsApp and “friends & family”.

With the information obtained through the questionnaires, we started by applying descriptive statistics not only to describe the sample collected but also to statistically describe their opinion on the features that the public transport mobile ticketing service for tourists should have.

After completing the descriptive statistical analysis, we built a Structural Equation Model, which is composed of a Confirmatory Factor Analysis and by a Structural Model (Hair, Black et al. 2013), aiming to answer the second objective of the research – which factors influence the adoption of a public transport mobile ticketing service for tourists.

For that purpose, a set of 20 statements were included in the questionnaire so that respondents could assess them in the form of a Likert scale. Each statement was associated with a construct that we aimed to measure – “Ease of Use”, “Usefulness”, “Compatibility”, “Mobility” and “Use Intention”.

Once the existence of the constructs previously addressed had been tested, we formulated the following hypothesis to be accepted, or rejected, in the context of our research:

- **Hypothesis 1:** “Ease of Use” has a positive impact on “Usefulness”;
- **Hypothesis 2:** “Compatibility” has a positive impact on “Usefulness”;
- **Hypothesis 3:** “Usefulness” has a positive impact on “Use Intention”;
- **Hypothesis 4:** “Mobility” has a positive impact on “Use Intention”.

After testing the previous hypothesis, the two main objectives of the research were accomplished – find out what features a public transport mobile ticketing service for tourists should have, and what factors determine its intention to use – and as such our research was successfully completed.

The following sections detail the results of applying the various methods mentioned.

4. Semi-structured interviews

After conducting the literature review, and considering that we already had a good understanding on the most relevant topics for this research – public transport mobile-ticketing, technology adoption models, and tourist use of public transport – a set of semi-structured interviews were conducted to follow up on our work.

As previously explained, the objectives of the semi-structured interviews were to collect the first insights into the mobility experience during tourism, and to create a solid basis for the subsequent construction of a questionnaire about a public transport mobile ticketing service.

Despite having an exploratory character, during the semi-structured interviews we focused on understanding how frequently interviewees travel in tourism and how do they plan their trips. We also looked to hear about past experiences using public transport while in tourism, making them describe the whole experience from buying the ticket to reaching their destination. Then we described the concept behind our research – a public transport mobile ticketing service for tourists – and asked for their vision of such a product. Finally, and considering that the interviews were made amid the COVID-19 pandemic, we looked to understand their opinion on the effects of a global pandemic, particularly in the usage of public transports in tourism.

In the next subsections, we describe the opinions collected during the semi-structured interviews according to the following structure:

- Sociodemographic characterization and tourist habits
- Trip planning and collection of destination information
- Past experiences with public transport in tourism
- Public transport mobile ticketing service for tourists
- Tourism and public transport in the context of a global pandemic

4.1. Sociodemographic characterization and tourist habits

A total of 5 interviews were made between the 4th and 8th of May 2020. All of the interviewees have previously traveled in tourism, either in their home country or abroad, which makes their opinion valid in the context of the research being developed.

Two variables were classified as particularly important when choosing the sample for these interviews: the age and the frequency of tourism. Besides the relevance of their opinion for the research purposes, these two characteristics provide the reader with a good general idea regarding the interviewees' profile. The people chosen to perform the interviews were among our "Friends & Family" network.

The group of interviewees was composed of two females and three males, with their ages ranging from 29 to 63 years old. Considering the difficulties of interviewing people during the COVID-19 pandemic confinement, we focused our efforts on the set of people most valuable for the research: people that travel regularly.

Table 5 - Interviewees' travel frequency distribution

Frequency of Tourism	Number of Interviewees
Rarely (1 time in the last 5 years)	0
Occasionally (1 time in the last 2 years)	0
Frequently (Once a year)	3
Very frequently (at least 2 times per year)	2

As show in Table 5, the sample of interviewees is composed of people who travel for tourism at least once a year, which theoretically is the group of people more comfortable discussing a touristic topic such as the one being studied.

4.2. Trip planning and collection of destination information

After the sociodemographic and frequency of travel sections, the interviews addressed the topic of how the interviewees prepared their trips and how do they gather relevant information for their trips.

The majority of the interviewees stated that they like to plan their trips before boarding, their main concern being where to stay to sleep, what tourist attractions they will visit and in which restaurants they will eat.

Surprisingly, mobility – being mobility the means of transport available for them to use and what conditions exist for them to use those means of transport – was not a *top of the mind* topic for interviewees when planning their trip: some of them searched this topic before boarding, while others do not.

Although mobility is not a consensus topic for interviewees when planning their trips, at any moment, everyone faced the need to pursue this topic. For our research, two questions are particularly important: how they seek mobility in a destination and what information is important to them.

While the interviewees who researched mobility at a destination before boarding used tourist guides, tourist maps, and the internet to research, those who researched the topic when arriving at the destination used mainly Google Maps. There is probably a generation gap on this matter, as the interviewees who used Google Maps when they arrived were young Adults.

Regarding mobility's most important information, the interviewees' opinion was more consensual. Most of them indicated *transport network pricing model, network map, means of transport available, schedules, suggested routes, price of a trip, duration of a trip, frequency of transport, and tourist attractions location* as the most important information for them respecting mobility.

4.3. Past experiences with public transport in tourism

After discussing interviewees' planning routines and the way they collect information about their destination, the interview focused on the means of transport typically used by the interviewees while in tourism, and past experiences they had on using public transport while abroad.

The means of transport mostly used by the interviewees while in tourism are:

- Public Transport
- Taxi, uber, or other transport platforms
- Transfers
- Rented car

- Tourist Bus (“Hop-on, Hop-off”)

The most frequent mean of transport stated by the interviewees was “public transport”, and all of them remembered using public transport abroad: for our research, we were particularly interested in understanding the interviewees’ difficulties and enablers on those experiences.

Regarding the difficulties mentioned by the interviewees when using public transport while in tourism, understanding the transport network pricing model was the challenge most referred. The interviewees’ opinion is understandable, as each public transport operator defines its network pricing model, even within the same country (the San Francisco’s public transport network pricing model is different from the New York’s, for example).

Language barriers, ticket purchase process, and ticket validation processes are other difficulties referred by the interviewees when using public transports in tourism.

The existence of physical information boards and direction boards on the public transport network, and tickets targeted to tourists were the issues mentioned by interviewees when asked about facilitators in the use of public transport while abroad.

4.4. Public transport mobile ticketing service for tourists

After discussing interviewees’ past experiences with public transport while in tourism, we asked them to imagine a hypothetical public transport mobile ticketing service for tourists. We explained that such service would allow them to buy and validate public transport tickets, and also to gather crucial information regarding the public transport network. Additionally, we told the interviewees that the service would also help them enjoy the city they were visiting, by making it possible to buy and validate tourist attractions’ tickets, and to search for touristic information.

All interviewees found the solution useful considering that for each new city they visit, they have to study and understand a whole new public transport network. As such, they viewed the application as an abstraction layer for the multiplicity of public transport networks around the world, that is, public transport made simple.

The most mentioned features interviewees would value were the possibility of *buying public transport tickets, validating the tickets, and get key-information* regarding the public transport network.

Other features mentioned during the interviews concern the creation of a *personal profile that allows the reception of personalized information and obtain information regarding touristic attractions*.

Since that interviewees highlighted the importance of obtaining information about the public transport network and touristic attractions, we scrutinize exactly what they wanted to look for. We conclude that that information is coherent with the information they searched for when planning their trips and their mobility in the destination.

The transport network pricing model, network map, means of transport available, schedules, suggested routes, price of a trip, duration of a trip is the set of information respecting the public transport network. *Touristic attractions' location, schedule, prices, popularity, and description* is the set of information valued by the interviewees about touristic attractions.

4.5. Tourism and public transport in the context of a global pandemic

Considering that the interviews were made amid the COVID-19 pandemic, we took the opportunity to ask interviewees about its impacts on tourism and how an application previously discussed would help in dealing with such context.

None of the interviewees had any doubts that a global pandemic would have profound impacts on tourism and that the hypothetical tourism-oriented mobile ticketing application would be useful if it had real-time information about public transport network and touristic attraction capacity.

5. Features of a public transport mobile ticketing service for tourists

After interviewing a set of potential users of the public transport mobile ticketing service for tourists, we developed an online survey to detect which features such a solution should provide to its users.

In the following section, we will describe the sample of participants who responded to the survey, either socioeconomically, either regarding their touristic habits. Then, we will analyze the features of a mobile ticketing service to tourists they most value. Finally, we will understand what participants think about using public transports amid a global pandemic.

5.1. Sample characterization

A total of 351 participants were surveyed (see Table 6), 200 (57,0%) females and 151 (43,0%) males. The most prevalent category of age was ≤ 31 years old ($n=183$; 52,1%). Most of participants had higher education ($n=294$; 83,8%) and were workers ($n=294$; 83,8%). Almost all participants ($n=336$; 95,7%) have been using smartphones for more than 24 months. A very large part of the sample ($n=321$; 91,5%) had already made payments with mobile apps. Almost all had a driving license ($n=332$; 94,6%), but a more reduced proportion owned a car ($n=268$; 76,4%).

Table 6 - Sample characteristics

Sociodemographic characterization	n	%
Sex		
Female	200	57,0%
Male	151	43,0%
Age Group		
≤ 31	183	52,1%
31-40	80	22,8%
41-50	42	12,0%
51-60	38	10,8%
61-70	7	2,0%
≥ 70	1	0,3%
Education		
No education	1	0,3%
Secondary education	56	16,0%
High education	294	83,8%
Occupation		
Unemployed	6	1,7%

Student	96	27,4%
Working-student	5	1,4%
Worker	241	68,7%
Retired	3	0,9%
How long have you been using smartphones		
Don't have a smartphone	10	2,8%
< 6 months	1	0,3%
6-24 months	4	1,1%
>24 months	336	95,7%
Have you ever made a payment with a mobile app		
No	30	8,5%
Yes	321	91,5%
Driving license		
No	19	5,4%
Yes	332	94,6%
Do you own a car		
No	83	23,6%
Yes	268	76,4%

The frequency of tourism travels varied mostly between frequent (41,6%) or very frequent (44,2%). Most of the participants agree or totally agree that they like to contact the locals when visiting a tourism spot (see Figure 7).

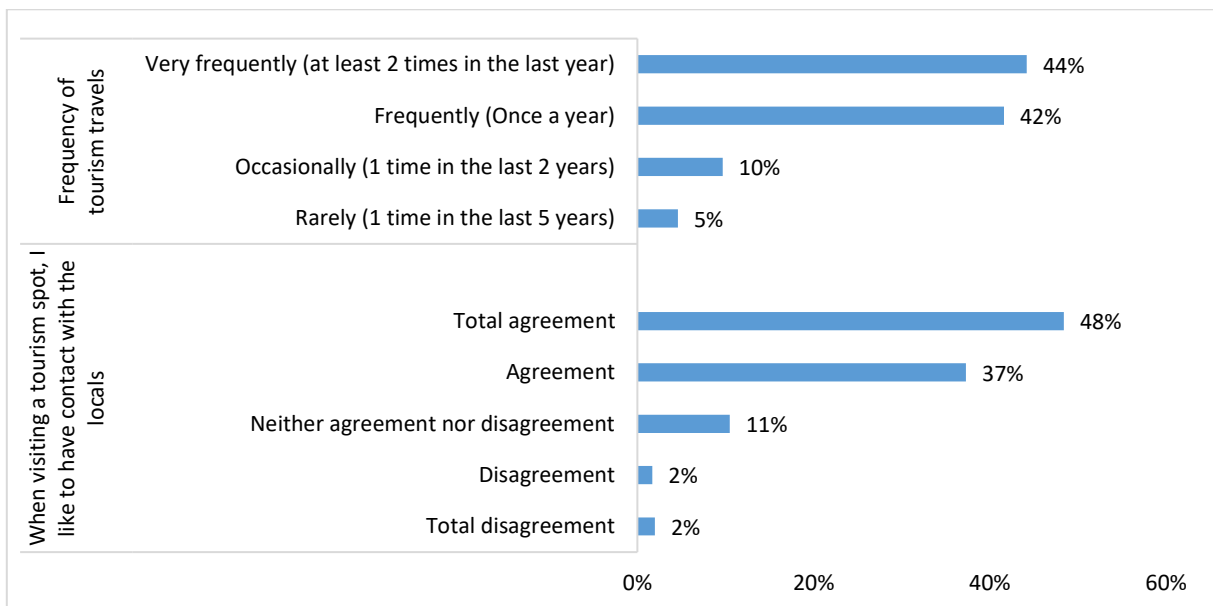


Figure 7 – Tourism frequency travels and contact with locals

Walking was the most frequent response of the participants when enquired about means of transport at the tourism destination (85,5%); public transport was the second most frequent response (67,2%). The remaining options are presented in Figure 8.

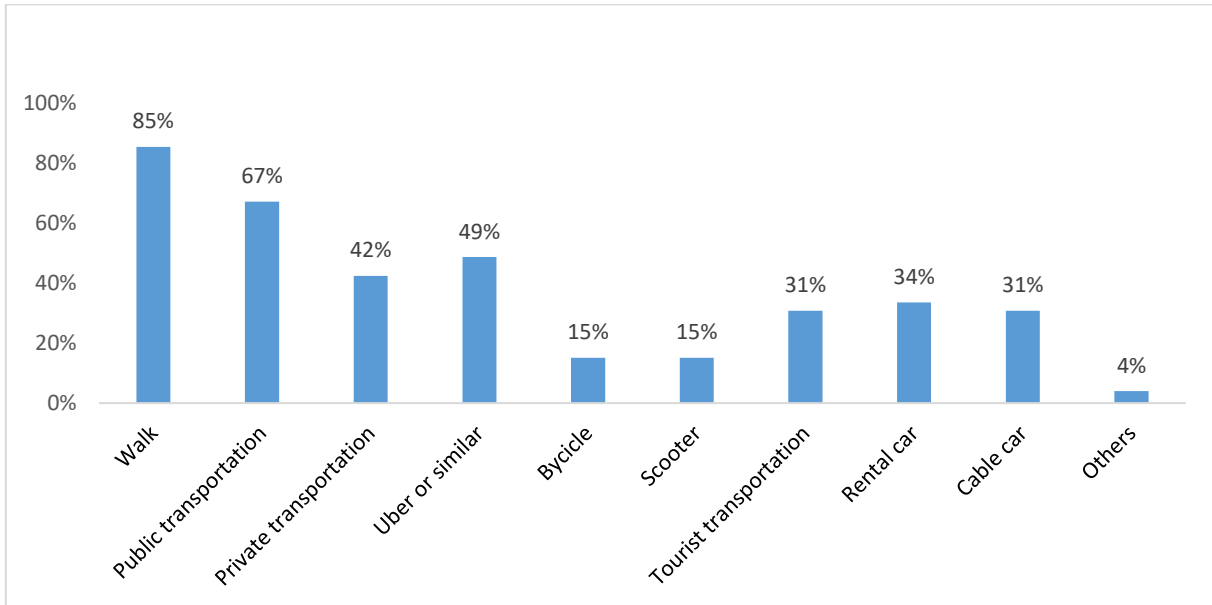


Figure 8 – Means of transport used at the tourism destination

Internet was the most common source of information for mobility at tourism destinations (59,8%) and tourist attractions (82,3%). Family and friends, touristic guides, and paper maps and roadmaps followed the internet as the most used means for getting information regarding tourism destination and its attractions. Apps did not reveal to be a frequently used source of information, with 27,6% prevalence for responses concerning mobility at tourism destinations and 25,4% for responses related to tourism attractions (see Figure 9).

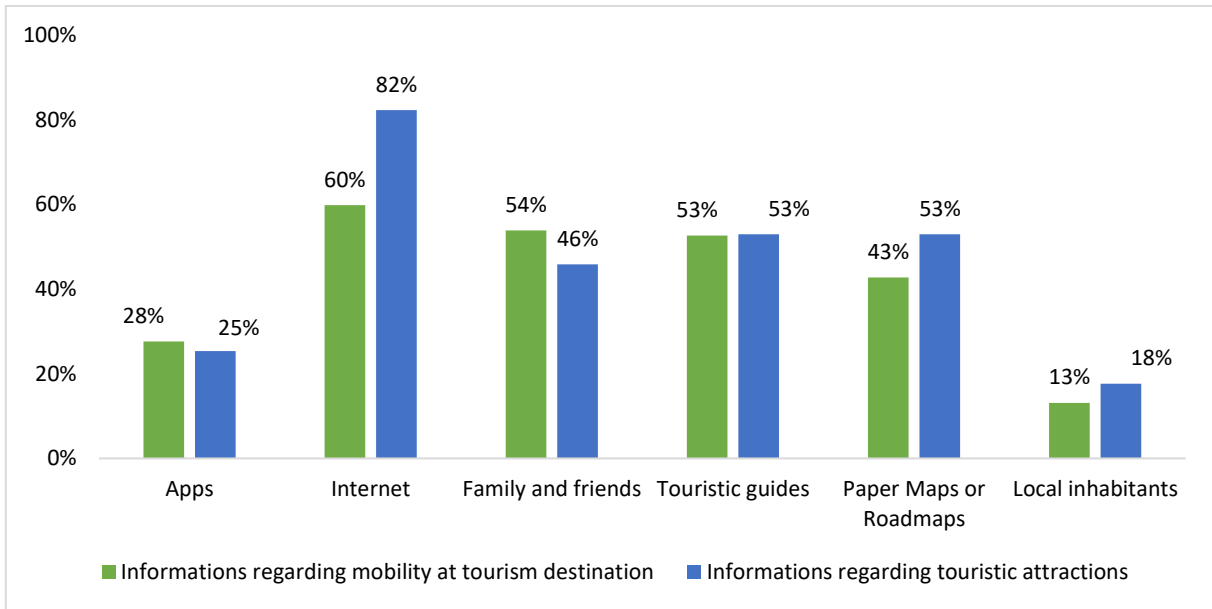


Figure 9 – Sources of touristic information

5.2. Functionalities of a mobile ticketing application for tourism

When answering questions regarding the functionalities of a mobile ticket solution for tourists, the distribution of responses showed a positive attitude towards the usefulness of mobile transport ticketing oriented to tourism (see Figure 10).

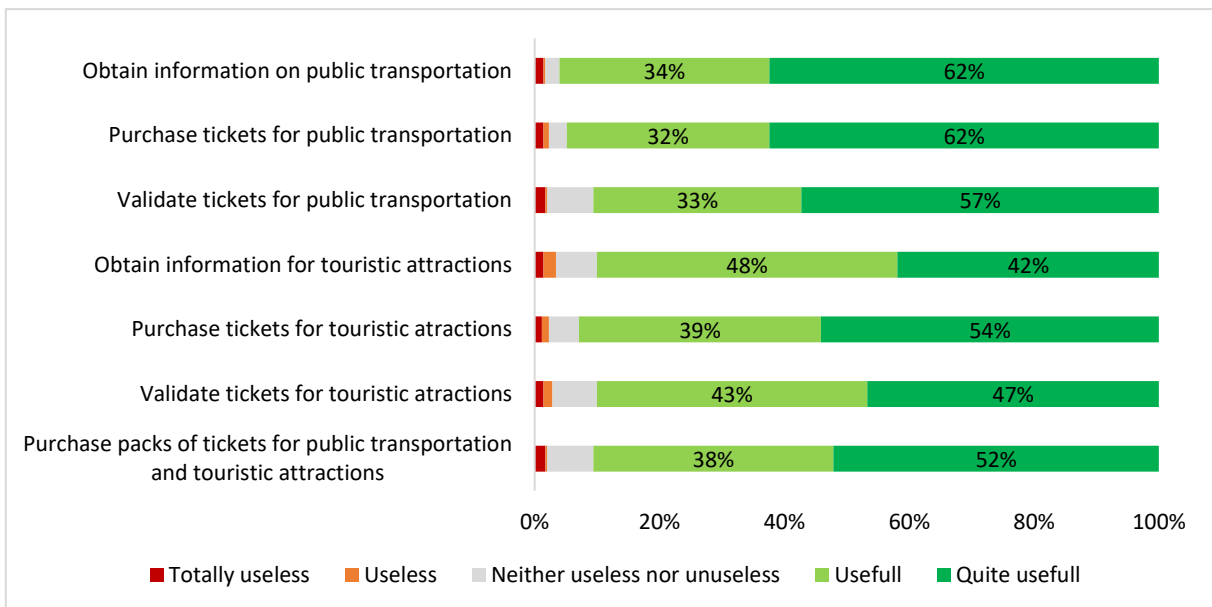


Figure 10 – Mobile ticketing application features' usefulness

Regarding the most relevant information that the hypothetical application should provide about public transports, participants were favorable to all the items showed in Figure 11. The exception was for “Conditions of use for pets”, in which “only” 65% of participants considered that information as “Quite Useful” or “Useful”.

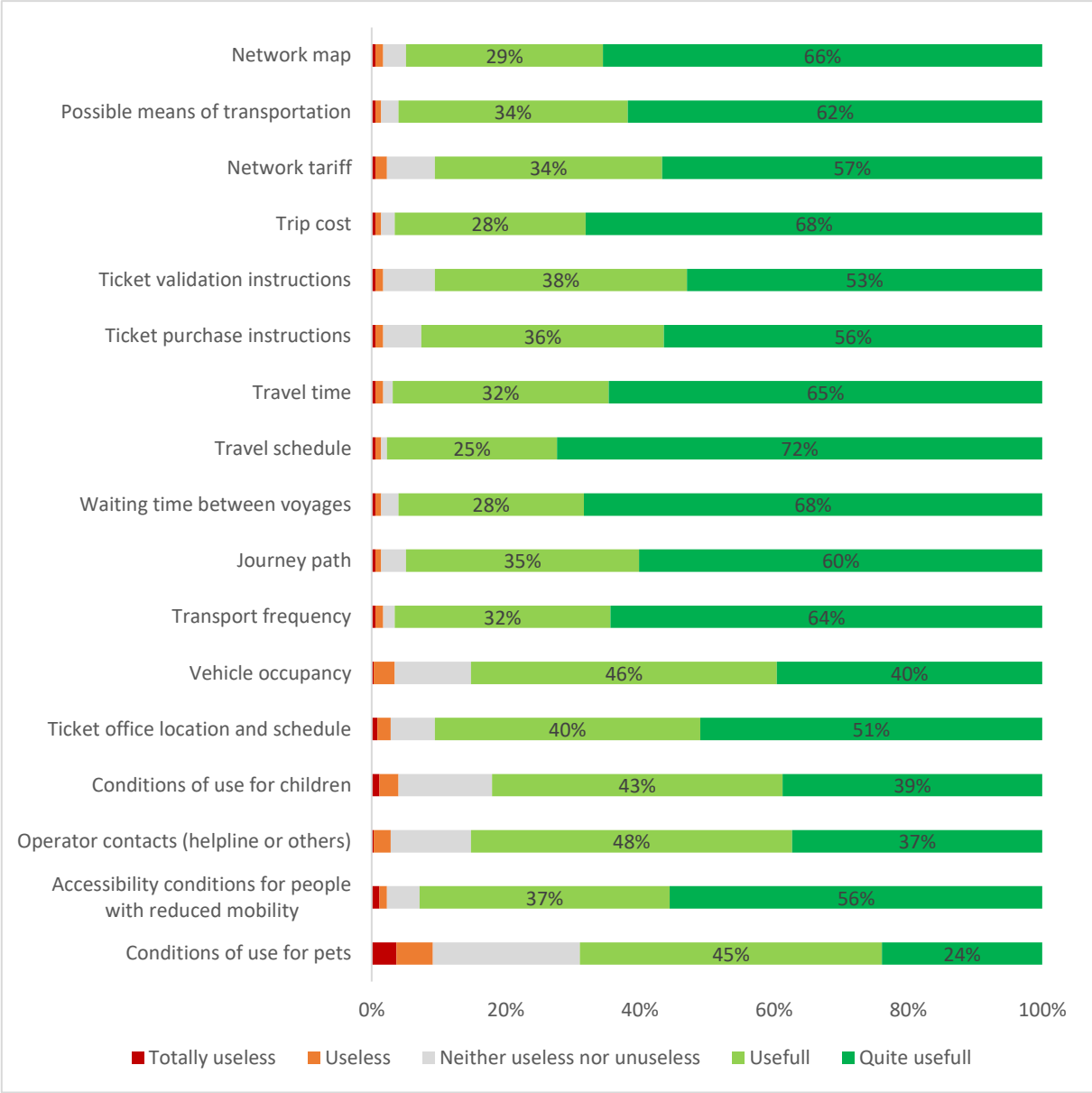


Figure 11 – Public transport’s information usefulness on a mobile ticketing app

Regarding tourist attractions, price, schedule and location were the most useful information to have on a mobile ticketing application oriented to tourism. Description of tourist attractions, photographs and popularity were also valued, but less than the first three indicators (see Figure 12).

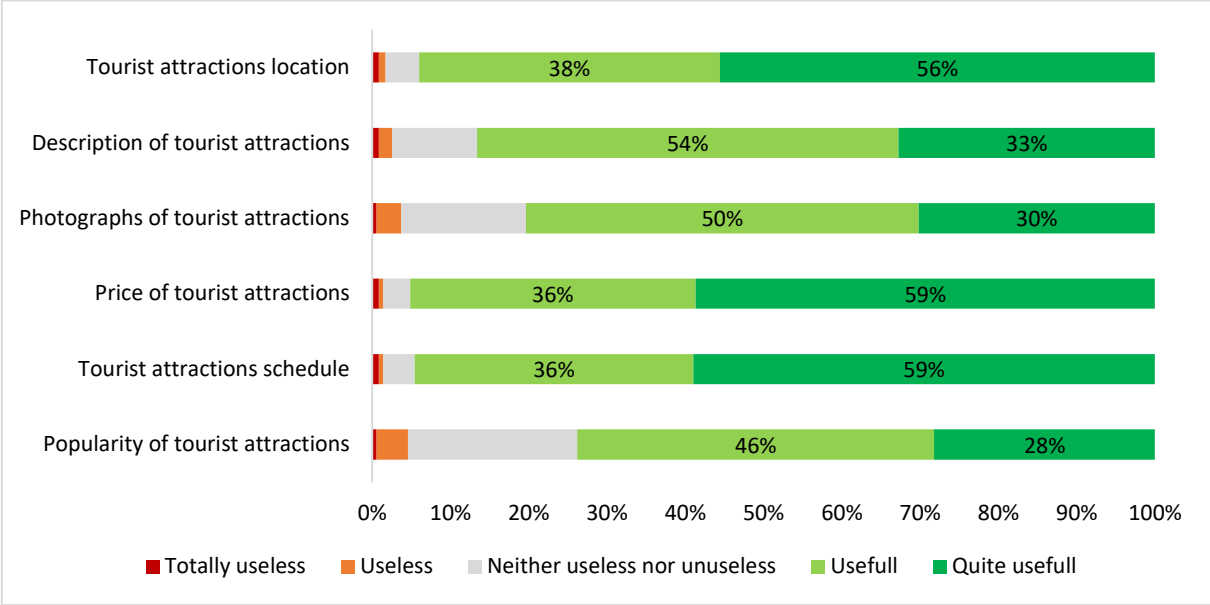


Figure 12 – Attractions’ information usefulness on a mobile ticketing app

5.3. Public transport in tourism during a global pandemic

Participants acknowledged the use of a public transport mobile ticketing service for tourists during a global pandemic context, namely regarding capacity, rules, alert and notifications and hospital locations; despite being also considered of importance, disinfection, location of hydroalcoholic dispensers and number of confirmed cases in the city were not among the principal acknowledged factors (see Figure 13).

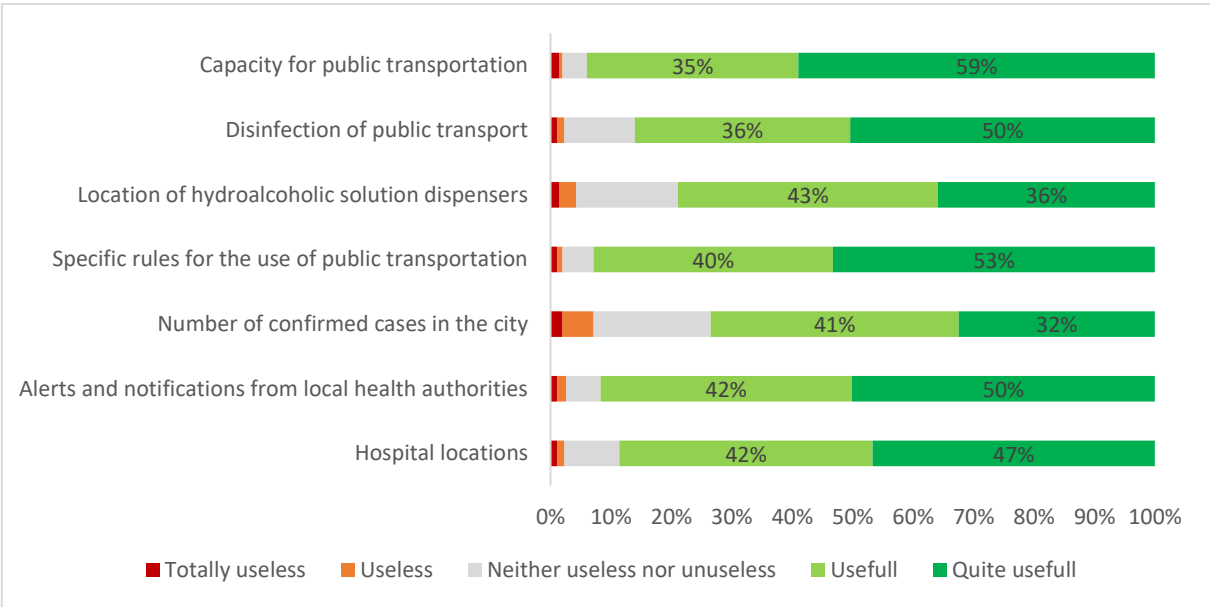


Figure 13 – Features for a mobile ticket application in a global pandemic context

6. Factor Analysis and Structural Equation Model

In the previous chapter we have addressed one of the objectives of our research: to identify which features the users of a public transport mobile ticketing service would value most. In this chapter, we will address the other goal of the study: to understand which factors positively influence the adoption of such a solution.

For that matter, we used a part of the data gathered in the surveys to apply a multivariate statistical analysis with SPSS, version 22 (IBM Corporation, 2013) and AMOS, version 22.

Confirmatory factor analysis (CFA) was implemented to find a robust factorial structure that fits our data. Then, Structural Equation Modelling (SEM) was accomplished to confirm the study hypothesis, based on theoretical premises. The confirmation of the hypothesis was conditioned by the assessment of the p-value associated with each path coefficient (β).

Exploratory factor analysis (EFA) and CFA are derived from the common factor model (Thurstone 1947), which assumes that each indicator in a set of observed variables is a linear function of one or more common factors. Factor analysis divides the variance of each indicator or observed variable into two parts: the common variance, related to the variance of latent(s) variable(s) (constructs), estimated by the shared variance with the other indicators related to it, and the unique variance which combines the specific variance attributed to each indicator with the random error variance (measurement error) (Brown and Moore 2012).

The main difference between EFA and CFA is that EFA is data-driven, i.e. no previous relations are established between observed and latent variables. The best model is the one that best fit the data, with no previous specifications. Hence, this is considered to be an exploratory technique. On the other hand, CFA establishes previous relations between observed and latent variables, attempting to reproduce with the most possible accuracy the population covariance matrix of the measured variables. In this way, CFA is theory-driven, using previous scientific background and other studies (Brown and Moore 2012). In this study, CFA was used as a tool for scale validation, one of its main purposes (Schreiber, Nora et al. 2006), by building and assessing the fit of a measurement model.

Structural Equation Modelling (SEM) is a combination of CFA and multiple regression (Schreiber, Nora et al. 2006), and was used to confirm this study hypothesis, by establishing dependence relations between latent variables.

Coefficient estimates (β) or loadings (λ) were estimated according to the maximum likelihood method after checking for items symmetry, between -2 and 2. This estimation method has proven to be robust even when this assumption is not met (Albright and Park 2009). Each coefficient measured the relative contribution of each indicator on the construct for the measurement model (CFA) and the effect size of each independent latent variable on the corresponding dependent latent variable for the structural model (SEM).

To assess the fit of the measurement and structural models we used the following absolute adjustment measures: chi-square (χ^2/df), root mean square error of approximation (RMSEA), the goodness of fit index (GFI), and the Tucker Lewis index (TLI). We also used parsimony-adjusted that compensate for the complexity of the models (Jackson, Gillaspay et al. 2009, Schmitt 2011), namely the comparative fit index (CFI). Specifically, for CFA, loadings (λ) were assessed as a measure of association of each observed variable with its latent variable, considering $\lambda > 0,50$ (Schmitt 2011). Following Jackson, Gillaspay et al. (2009) suggestion we also observed average variance extracted (AVE) and composite reliability (CR) for each latent variable to ensure model validity, considering $AVE > 0,50$ and $CR > 0,70$.

Table 7 - Fit measurements criteria, adapted from Schumacker and Lomax (2016)

Fit measure	Criterion
Chi-squared/ degrees of freedom (χ^2/df)	$\chi^2/df < 3$
Tucker-Lewis Index (TLI)	TLI > 0,90
Comparative fit index (CFI)	CFI > 0,90
Goodness of fit index (GFI)	GFI > 0,90
Root mean square error of approximation (RMSEA)	RMSEA < 0,07

6.1. Confirmatory Factor Analysis

From the literature review, more specifically technology adoption models, we extracted factors that may influence the adoption of information systems. For our research, we chose the following factors: “ease of use”, “usefulness”, “compatibility”, and “mobility”. “Ease of use” is the degree to which a person believes that using a particular system would be free from effort, while “usefulness” is the degree to which a person believes that using a particular system would enhance his job performance (Davis, Bagozzi et al. 1989). “Compatibility” is the degree to which the adoption of a new system is perceived as consistent with the existing values, past experiences, and needs of potential adopters (Pietro, Mugion et al. 2015). Finally, “mobility” is the ability to access services ubiquitously, on the move, and through wireless networks (Mallat, Rossi et al. 2008).

As shown in Table 8, a set of 20 statements were included in the questionnaire (that gathered 351 answers) so that respondents could assess a group of factors in the form of a Likert scale. According to that set of 20 statements a Confirmatory Factor Analysis was used to validate an instrument to measure the factors affecting the adoption of a public transport mobile ticketing service for tourists.

Table 8 - Confirmatory Factor Analysis constructs

Construct	Statement #	Statement
Ease of Use	1	Easy to learn to use this app
Ease of Use	2	Easy to purchase tickets with this app
Ease of Use	3	Easy to validate tickets with this app
Usefulness	1	This app can expedite the process of ticket purchase and validation
Usefulness	2	This app eases the process of ticket purchase and validation
Usefulness	3	I consider being more effective to buy tickets with the smartphone
Compatibility	1	I consider that buying tickets with the smartphone is compatible with other operations
Compatibility	2	I consider the smartphone to be a suitable device to purchase tickets
Compatibility	3	I consider that electronic tickets are compatible with my habits
Compatibility	4	I consider that electronic tickets are compatible with my touristic habits
Mobility	1	I consider that is possible to purchase tickets with this app at any time
Mobility	2	I consider that is possible to purchase tickets with this app at any place
Mobility	3	I consider that purchasing tickets with this app reduce waiting queues
Mobility	4	I consider that using this makes eliminates the need of carrying money to purchase tickets
Use Intention	1	I hope to use this app in case of lack of knowledge of the transport network
Use Intention	2	I hope to use this app in case of lack of knowledge of the tourism attractions of the destination
Use Intention	3	I hope to use this app in case of lack of knowledge of the process of purchase and validation of tickets of the destination
Use Intention	4	I hope to use this app in case the transport only have an available language, that I'm not familiar with
Use Intention	5	I hope to use this app in case the touristic attractions only have information on a language that I'm not familiar with
Use Intention	6	I consider this app to improve my touristic experience

As shown in Figure 14, all loadings were $\lambda > 0,50$ and statistically significant at $p < 0,001$ level. Correlations between latent variables varied between $\rho = 0,72$ and $\rho = 0,92$, considered very high. Fit results accomplished all the established criteria, namely $\chi^2/df = 2,624$ (< 3), $GFI = 0,902$ ($> 0,90$), $CFI = 0,965$ ($> 0,90$), $TLI = 0,956$ ($> 0,90$) and $RMSEA = 0,068$ ($< 0,070$).

We followed the suggestion of AMOS modification indexes for establishing correlations between errors that were theoretically supported.

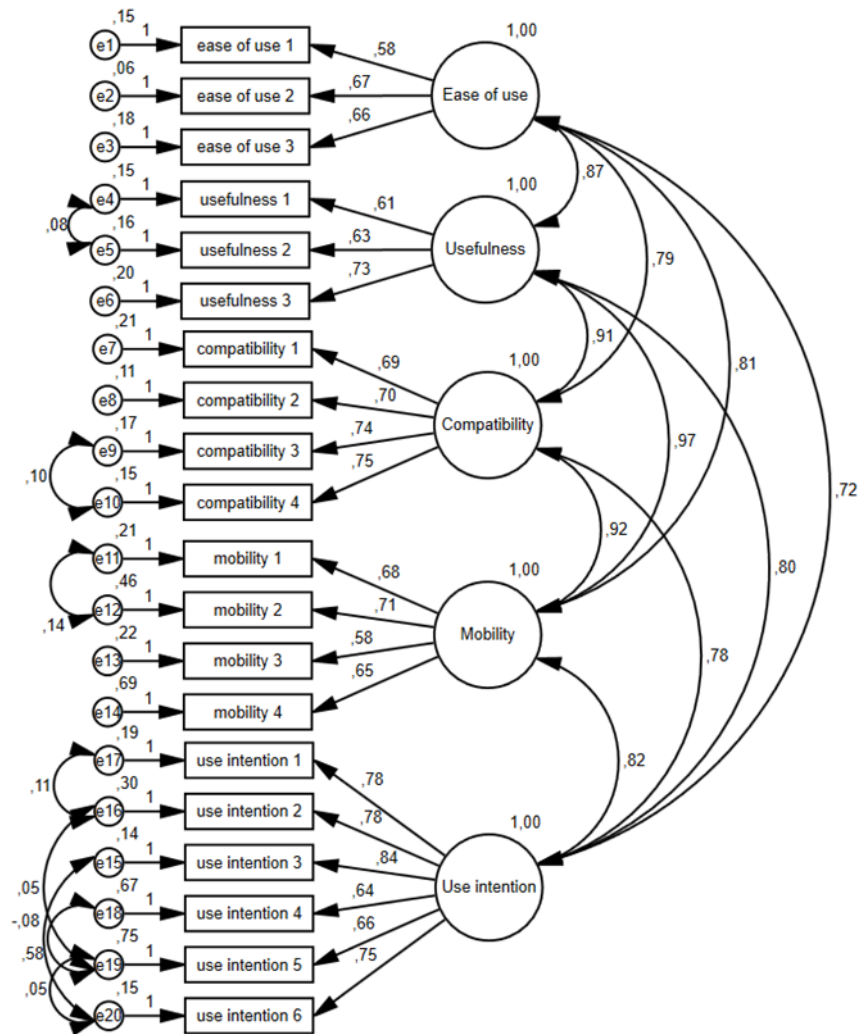


Figure 14 – CFA factors affecting the adoption of a mobile ticketing application

$\chi^2/df=2,624$, GFI=0,902, CFI=0,965, TLI=0,956 and RMSEA=0,068

Finally, we also assessed AVE and CR, with both measures above 0,50 and 0,70, respectively, confirming the validity of the proposed structure (Table 9 - AVE and CR).

Table 9 - AVE and CR

Construct	AVE	CR
Mobility	0,547	0,827
Ease of use	0,759	0,904
Usefulness	0,716	0,883
Compatibility	0,766	0,929
Use intention	0,634	0,910

6.2. Structural Equation Model

Once the existence of the factors (constructs) was confirmed through the Confirmatory Factor Analysis, a structural model was used to confirm the study hypothesis as shown in Figure 15 - Structural model.

Fit results accomplished all the established criteria, namely $\chi^2/df=2,738$ (<3), $GFI=0,90$ ($>0,90$), $CFI=0,962$ ($>0,90$), $TLI=0,953$ ($>0,90$) and $RMSEA=0,070$ ($<0,070$).

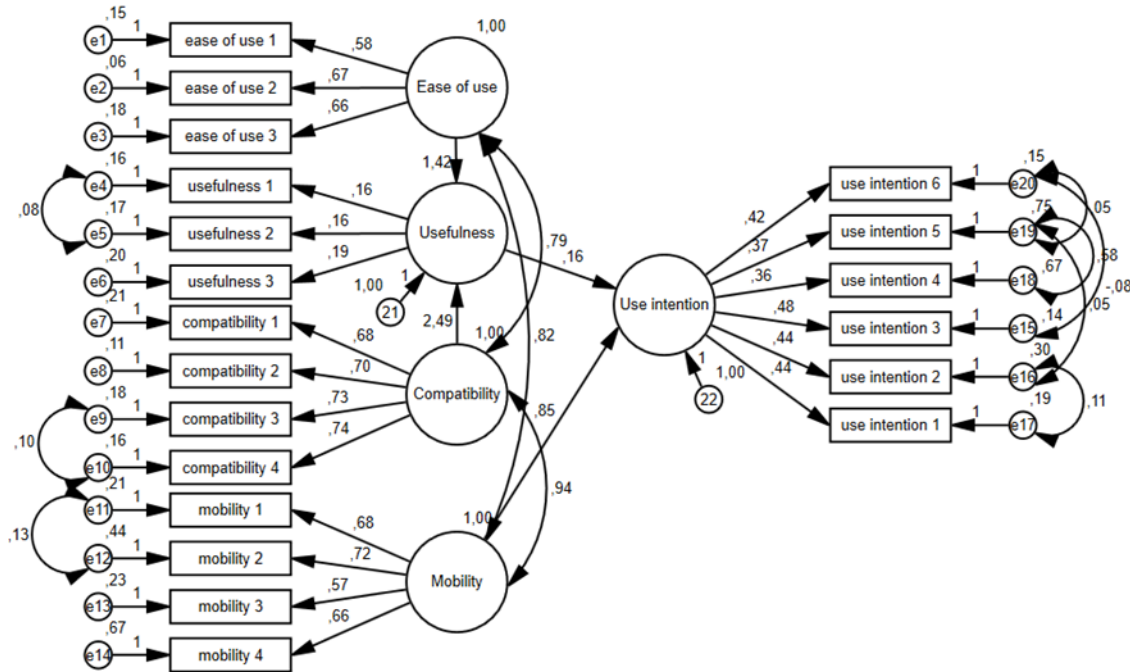


Figure 15 - Structural model

$\chi^2/df=2,738$, $GFI=0,895$, $CFI=0,962$, $TLI=0,953$ and $RMSEA=0,070$

As shown in Table 10, all hypotheses were confirmed for this study: “Usefulness” is simultaneously and positively impacted by “Ease of Use” ($\beta=1,42$; $p<,001$), confirming Hypothesis 1, and by “Compatibility” ($\beta=2,49$; $p<,001$), confirming Hypothesis 2. On another hand, “Use Intention” is positively impacted by “Usefulness” ($\beta=0,17$; $p=,036$), confirming Hypothesis 3, and by “Mobility” ($\beta=0,85$; $p=,009$), confirming Hypothesis 4.

Therefore, it can be concluded that usefulness of the service is positively impacted by its ease of use and compatibility, and usefulness and mobility explain the intention to use such a service in the context of tourism.

Table 10 - Hypothesis results

Hypothesis	Description	Estimate (β)	SE	p-value	Result
H1	Ease of use → Usefulness	1,42	0,34	$p < ,001^*$	Confirmed ✓
H2	Compatibility → Usefulness	2,49	0,55	$p < ,001^*$	Confirmed ✓
H3	Usefulness → Use intention	0,17	0,08	$p = ,036^*$	Confirmed ✓
H4	Mobility → Use intention	0,85	0,32	$p = ,009^*$	Confirmed ✓

* statistically significant

7. Conclusion, research limitations, and future work

7.1. Conclusion

We faced this research as an opportunity to explore the application of public transport mobile ticketing in a touristic context, which has been little studied so far. More specifically, the main objectives of the present study were to understand, for a public transport mobile ticketing service for tourists: (i) what factors may explain its adoption; (ii) if that solution was to be developed, what features should be offered to its users.

To achieve the goals of our study, we designed a research methodology composed of a mix of qualitative and quantitative methods. We believed in the importance of reaching, as early as possible, people who travelled frequently and so, after completing the literature review, we interviewed a set of people to explore their experiences as tourists using public transports.

The interviews conducted were helpful to assess the potential relevance of a public transport mobile ticketing service. The feeling we got from the contact with the interviewees was that such a service would have been helpful at any given time on their experiences as tourists.

Following the interviews, we developed an online questionnaire that allowed us to collect data from more than 300 people. We used the collected data to develop two distinct analyses: a descriptive statistical analysis of the features of the public transport mobile ticketing service; and structural modelling to study the adoption factors of that service.

The descriptive statistical analysis demonstrates that the features that potential users of such service value most would be obtaining information about the public transport network of the destination, buying the public transports tickets, and validating those tickets.

The importance of obtaining information through the idealized service is coherent with the existing literature about the adoption of public transport by tourists. Those studies invariably reinforce the importance of information for tourists for them to use and privilege public transport at the expense of private transports.

Regarding the structural modelling developed to discover the adoption factors of the public transport mobile ticketing service, the results are coherent with the literature on the topic. First of all, it is proved that the constructs of “Ease of Use”, “Usefulness”, “Compatibility”, and “Mobility” all exist in the context of mobile ticketing technology adoption. Secondly, the results show that if a

technology is easy to use and compatible with the way people previously work, it necessarily becomes much more useful. Additionally, and looking in concrete to a public transport mobile ticketing service, that usefulness allied to its ubiquitous usage, largely explain the adoption of such technology.

Finally, we also believe that the results of our research are of interest of companies that create services geared toward mobile ticketing as it becomes clear that such solutions solve a problem that many people face worldwide, which means that the probability of people using their services is higher. Additionally, the methodology followed in our research is also valuable for those companies, as it allows them to explore and understand the factors that explain the adoption of the services that they create.

7.2. Research limitation and future work

Although we have achieved the objectives set for this research, we are also aware of the limitations that it may have.

First of all, the non-existence of a prototype of the service that we imagined, and that we communicated to the stakeholders of this research, may have limited the capacity of either the interviewees or the respondents of the questionnaire to evaluate such service.

Secondly, the relatively small number of interviews made, and the fact that they were made via telephone due to COVID-19 confinement, may have shortened our view on the preparation of the questionnaire.

After concluding our study, we have the conviction that there is space for a mobile service like the one we envisioned over the present work.

Considering that the development of such a service was outside the scope of this research, we believe that the natural continuity of our research would be the development of a prototype of the public transport mobile ticketing service for tourists.

The proposal of the prototype would be whole new research by itself, but the development of the prototype would open a range of other possible studies on the scientific gap that we initially identified: the application of mobile ticketing on public transports in a tourism context.

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Appendix

Appendix 1 – Semi-structure interview script

Topic	Question(s)
Demographic Information	Gender; Age
Tourist Habits	How frequently do you travel? Which means of transport do you use upon reaching your destination?
Tourism Mobility	Please describe an experience you had using public transports when abroad. Which factors eased that experience? Which factors inhibited that experience?
Ticketing system in tourism	Please describe the process of acquisition and validation of tickets in the experience you previously referred to. Which factors eased the acquisition and validation of the tickets? Which factors inhibited the acquisition and validation of the tickets?
Mobile ticketing application	Please imagine a public transport mobile ticketing service for tourists, that would allow you to buy and validate tickets for public transport and tourist attractions. Additionally, it would allow you to obtain useful information as a tourist: How would such service ease the use of public transports when abroad? Which features should the service have?
Global pandemic context	To which extent a global pandemic context such as the one we are living nowadays can interfere in the adoption of public transports when abroad? How can a mobile ticketing application help on dealing with a global pandemic context? Which additional features should be implemented on the application that we previously discussed?
Conclusion	Do you have any additional comments or questions?

Appendix 2 – Online questionnaire structure and questions

Sociodemographic characterization

Gender *(Possible answers: male; female)*

Age group *(Possible answers: less than 30; between 31 and 40; between 41 and 50; between 51 and 60; between 61 and 70; more than 71)*

Education *(Possible answers: no education; basic education; higher education; university education)*

Occupation *(Possible answers: student; worker; unemployed; retired)*

How long have you been using smartphones? *(Possible answers: I don't have smartphone; less than 6 months; between 6 months and 2 years; more than 2 years)*

Have you ever made a payment with a mobile app? *(Possible answers: Yes; No)*

Do you have a driving license? *(Possible answers: Yes; No)*

Do you own a car? *(Possible answers: Yes; No)*

Characterization of tourist habits

How often do you travel for tourism? *(Possible answers: Rarely; Occasionally; Frequently; Very frequently)*

Assess, for your agreement, the following statement:

(Possible answers: totally disagree; disagree; neither agree or disagree; agree; totally agree)

When I visit a tourist spot, I like to have contact with the locals

What means of transport do you use to move around the destination?

(Possible answers: walking; smooth modes; private transports; car renting; public transports; touristic transports)

How do you obtain this information when you are traveling on tourism?

(Possible answers: friends and family; local inhabitants; tourist guides; app's; internet)

If you wish, you can indicate which app's you use to obtain information on mobility in tourism

Factors affecting the adoption of a mobile ticketing application

Assess, for your agreement, each of the following statements:

(Possible answers: totally disagree; disagree; neither agree or disagree; agree; totally agree)

I think it would be easy to learn how to use this application

I think it would be easy to buy tickets through this application

I think it would be easy to validate tickets through this application

I think this application could make the ticket purchase and validation process faster

I think this application could make the ticket purchase and validation process easier

I think it is more effective to buy tickets via mobile phone

I believe that purchasing and validating tickets is compatible with other uses that I use with a mobile phone

I think the mobile phone is an appropriate device for purchasing tickets
I believe that electronic tickets are compatible with my habits
I believe that e-tickets are compatible with the way I tour
I believe that I could buy tickets through this application at any time
I think I could buy tickets through this application anywhere
I believe that buying tickets through this application would reduce the queues
I believe that using this application you would no longer need to have money to buy tickets
I hope to use this application if I don't know the public transport network of the city where I'm doing tourism
I hope to use this application if I don't know the tourist attractions of the city where I'm doing tourism
I hope to use this application if you are unfamiliar with the process of buying and validating tickets in the city where I am doing tourism
I hope to use this application if public transport only has information in a language I do not speak
I hope to use this application if tourist attractions only have information in a language I do not speak
I believe that this application would improve my tourist experience
Can you please indicate what other factors influence your adoption of a mobile ticketing application?

Functionalities of a mobile ticketing application for public transport oriented to tourism

Evaluate, concerning its usefulness, the following functionalities of a mobile transport ticketing application-oriented to tourism:

(Possible answers: very useless; useless; neither useful nor useless; useful; very useful)

Get information on public transport
Purchasing public transport tickets
Validate public transport tickets
Get information about tourist attractions
Purchasing tickets for tourist attractions
Validate tickets for tourist attractions
Purchasing packs of public transport tickets and tourist attractions

Can you please indicate what other features you find useful?

Evaluate, regarding its usefulness in a mobile ticket application for public transport oriented to tourism, the following information about public transport:

Network map
Means of transport available
Network tariff
Trip cost
Ticket validation instructions

Ticket purchase instructions
Travel time
Schedules
Waiting time until the next trip
Journey path
Transport frequency
Vehicle occupation
Ticket office location and schedule
Conditions of use for children
Operator contacts (helpline or others)
Accessibility conditions for people with reduced mobility
Conditions of use for pets

Can you please indicate what other information on public transport do you consider relevant?

Evaluate, regarding its usefulness in a mobile ticketing application for public transport oriented to tourism, the following information about tourist attractions:

Tourist attractions location
Description of tourist attractions
Photos of tourist attractions
Tourist attractions price
Tourist attractions schedule
The popularity of tourist attractions

Can you please indicate what other information about tourist attractions do you consider relevant?

Public transport in a tourist context during a global pandemic

Assess the following information on public transport for its usefulness in the context of a global pandemic:

(Possible answers: very useless; useless; neither useful nor useless; useful; very useful)

The capacity of public transport
Disinfection of public transport
Location of hydroalcoholic solution dispensers
Specific rules for the use of public transport
Number of confirmed cases in the city
Alerts and notifications from local health authorities
Hospital locations

Evaluate the following statement:

(Possible answers: totally disagree; disagree; neither agree or disagree; agree; totally agree)

When traveling, a mobile ticketing application can help me be better protected from the risks associated with a global pandemic

Do you want to indicate how the mobile application would help you to protect yourself?
