FACULDADE DE ENGENHARIA DA UNIVERSIDADE DO PORTO

Design and Development of a Mobile Based Solution for Tourists

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Mestrado Integrado em Engenharia Informática e Computação

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July 21, 2021

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Abstract

Over the last few years, the tourism sector has been growing rapidly, placing pressure on cities worldwide that were not initially planned to receive such an amount of tourists. This sector represents a vital growth driver for countries considering the critical role it plays in economic development. Seeing as public transports are already the leading choice of transport for tourists at their destination, promoting sustainable public transport use becomes not only logical but urging.

The daily usage of smartphones is increasing, making them an object people carry everywhere. As a result, the seamless integration of the smartphone in a tourist's journey becomes feasible. The current market for tourist-oriented applications focuses mostly on tourism-related suggestions, acting as tourist guides. However, previous literature identifies using public transport as one of the biggest struggles tourists face due to poor organization and lack of clear information.

Mobile solutions targeting public transport have been around for a while, focusing on route planning and mobile ticketing. More recently, the concept of Mobility as a Service (MaaS) emerged, combining various transport modes and complementary services in a single platform. Nevertheless, these solutions focus on the needs of the local traveler, which has existing knowledge about the public transport network, gaining a significant advantage over tourists.

This dissertation introduces Tourism as a Service (TaaS), which takes inspiration from MaaS and applies it to tourism. It integrates useful services to tourists into a single service, including ticketing, route planning, and information on public transport and tourist activities. This solution is agnostic and adaptable to different transport networks. Furthermore, we present a prototype of a TaaS mobile application.

We followed the User-Centered Design methodology, an iterative process that places the user in the center of the design, requiring constant feedback. Initially, focus groups were held (n=11) where participants shared their previous experiences to gather more insight into their needs and goals as tourists. Then, a questionnaire was applied to a larger sample (n=254) in order to better understand the target audience and prioritize requirements. After the requirements elicitation, the prototyping began. There were two iterations of designing, corresponding to medium and high-fidelity prototypes, respectively. With each iteration, the prototypes were subjected to usability testing (n=9, n=13). These consisted of (i) a task assessment where users performed certain tasks on the prototype, (ii) an adaption of the System usability scale, and (iii) open feedback. The results obtained were positive, and improvements were made based on the feedback. The validation with the target audience confirmed the positive impact of this solution, along with the willingness and excitement to use it.

We believe this solution to be useful in helping cities attract tourists by improving their transportation experience. Thus, generating a positive impact for tourist-dependent industries, and minimizing pollution in the industry.

Keywords: tourism, public transportation, mobile ticketing, tourist guide, smartphone, UCD

Resumo

Nos últimos anos, o sector do turismo tem vindo a crescer rapidamente, exercendo pressão sobre cidades que inicialmente não planearam receber esta quantidade de turistas. Este sector gera um crescimento vital para os países, tendo um papel crítico no seu desenvolvimento económico. Sendo que os transportes públicos são a principal escolha de transporte para turistas, promover a utilização sustentável dos transportes públicos torna-se, não só lógico, mas também urgente.

A utilização diária de smartphones está a aumentar, tornando-os um objecto que as pessoas transportam para todo o lado. Como resultado, a integração de smartphones na viagem de um turista torna-se viável. O mercado actual para aplicações orientadas a turistas centra-se principalmente em sugestões relacionadas com o turismo, actuando como guias turísticos. No entanto, literatura anterior identifica a utilização dos transportes públicos como um dos maiores desafios entrentados por turistas, devido à má organização e falta de informação clara.

Soluções móveis para transportes públicos já existem há algum tempo, centrando-se em *route planning*, e *mobile ticketing*. Mais recentemente, o conceito de *Mobility as a Service* (MaaS) surgiu, combinando vários modos de transporte e serviços complementares, numa única plataforma. Estas soluções centram-se nas necessidades do viajante local, que possui conhecimentos existentes sobre a rede de transportes públicos, ganhando uma vantagem significativa sobre os turistas.

Esta dissertação introduz *Tourism as a Service* (TaaS), baseado em MaaS. Integra serviços úteis aos turistas numa única plataforma, incluindo *ticketing*, *route planning*, e informação sobre transportes públicos e actividades turísticas. A solução é agnóstica e adaptável a diferentes redes de transporte. Além disso, apresentamos um protótipo de uma aplicação móvel baseada em TaaS.

Foi seguida a metodologia *User-Centered Design*, um processo iterativo que coloca o utilizador no centro do design, exigindo feedback constante. Inicialmente, realizaram-se grupos de foco (n=11) nos quais os participantes partilharam experiências anteriores de forma a recolher mais informação sobre as suas necessidades e objectivos como turistas. De seguida, foi aplicado um questionário a uma amostra maior (n=254), a fim de compreender qual o público alvo e estabelecer prioridades. Após a elicitação dos requisitos, começou a fase de prototipagem. Houve duas iterações , correspondentes a protótipos de média e alta fidelidade, respectivamente. A cada iteração, os protótipos foram sujeitos a testes de usabilidade (n=9, n=13). Estes consistiram em: (i) avaliação de tarefas, nas quais os utilizadores completavam tarefas no protótipo, (ii) adaptação da escala da *System Usability Scale*, e (iii) feedback aberto. Os resultados obtidos foram positivos, e, com base no feedback, foram feitas melhorias. A validação com o público-alvo confirmou o impacto positivo desta solução, juntamente com o interessa em utilizá-la.

Consideramos a solução útil em ajudar cidades a atrair turistas, melhorando a sua experiência com transportes. Consequentemente, gera um impacto positivo para as indústrias dependentes do turismo, e minimiza a poluição causada pela indústria.

Keywords: turismo, transportes públicos, mobile ticketing, guia turistico, smartphone, UCD

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Beatriz Mendes

"The only time I set the bar low is for limbo"

Michael Scott

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Abbreviations

PTO	Public Transport Officer
RFID	Radio-Frequency Identification
NFC	Near-Field Communication
QR	Quick-Response
UCD	User-Centered Design
UX	User Experience
UI	User Interface
MaaS	Mobility as a Service
TaaS	Tourism as a Service

Chapter 1

Introduction

This chapter introduces the scope of this dissertation. Section 1.1 describes the context surrounding the topic of this dissertation, namely tourism, public transport, and mobile ticketing. Section 1.2 explains the motivation behind this work along with the primary goals expected. Finally, section 1.5 details the structure the rest of the document will follow.

1.1 Context

The tourism sector is facing a fast growth[1], *cf.* *Figure* 1.1, placing pressure on cities worldwide considering some were not initially planned to receive such an amount of tourists. The challenges posed range from tourism gentrification — residential pressure in the city centers [4] — to mobility issues such as the overuse of road or public transport networks.

On the other hand, the tourism sector plays a crucial role in countries' economic development, as tourist spending affects a broad category of areas, such as lodging, restaurant, culture, and shopping [4]. Thus, the need to nurture and encourage incoming tourism.

Mobility is a crucial comfort factor for tourists visiting urban areas, and the selected transport modes influence their movement patterns [36]. In light of this, cities with better public transport systems tend to be more attractive from tourists' points of view [27].

[1] The growth considered disregards the year of 2020 and the unprecedented health emergency that posed restrictions on mostly air travel.

Seeing as transport services are the primary source of CO2 emissions in tourism [36], It is important to foster the use of public transport by tourists at their destination.

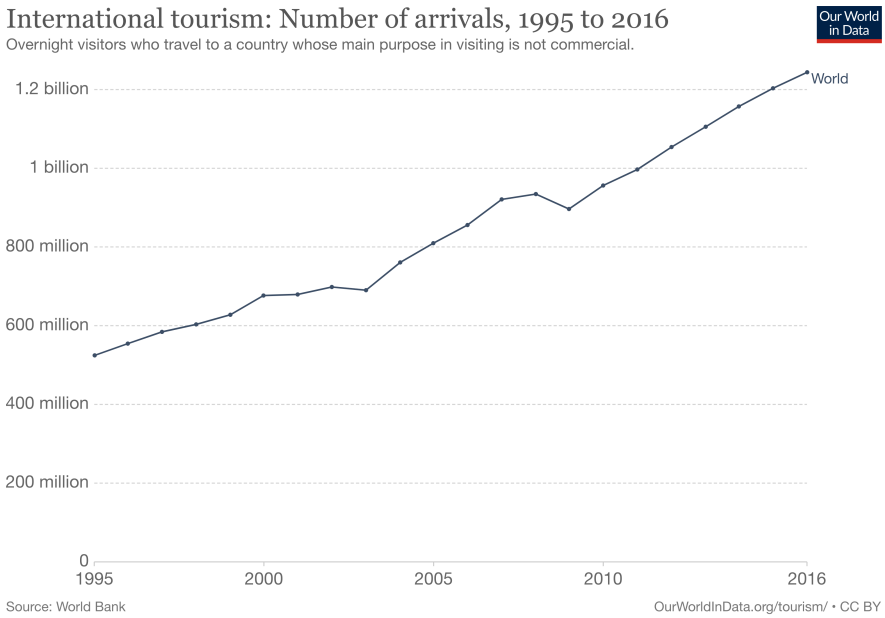


Figure 1.1: Tourism evolution in the world [1965-2016] (Our World in Data [45])

Although rural tourism has been increasing as of late, according to the United Nations Tourism World Barometer (UNTWO), bigger cities still have an edge as tourists' leading destinations. Urban areas tend to make more use of public transport to get around, thus evolving their public transport networks.

As daily mobile usage is on the rise and expected to continue increasing in the following years *cf. Figure* 1.2, mobile users continue looking for solutions that can ease their daily struggles. With the development of information and communication technologies, solutions that aim to facilitate the use of public transport have been emerging. The main focus of these has been on real-time arrivals, route planning, and, more recently, mobile ticketing options.

Mobile ticketing solutions free customers from difficult purchase decisions by allowing easier access to services [16]. In general, mobile ticketing presents several advantages when compared to traditional ticketing systems, both from the customer's and service provider's perspectives.

1.2 Motivation

Tourist-oriented solutions have focused primarily on tourist activities, acting as a tourist guide. However, since tourists rely heavily on public transport, turning them into a more attractive option can help cities attract more tourism, thus positively impacting their economy. Additionally, it might trigger a deviation from private transport usage to public transport, promoting sustainable mobility by decreasing the pollution caused by the sector.

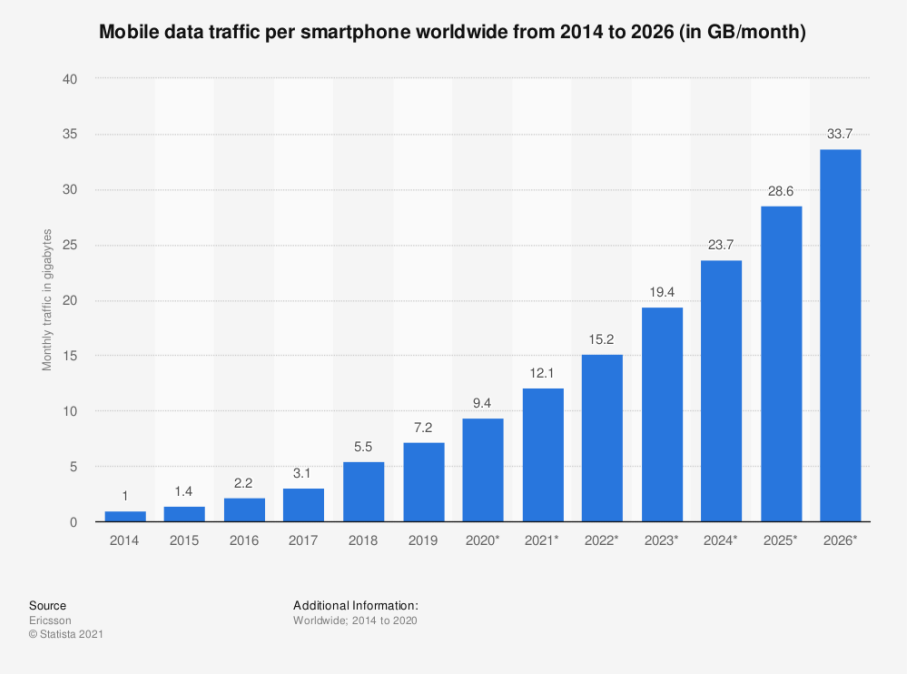


Figure 1.2: Monthly data traffic usage [2014-2026] (Statistica [41])

Currently, the local passenger is the main focus of solutions that aim to facilitate public transport usage — passenger which tends to have a pre-existing overview of how their local public transport system works. On top of that, tourists' mobility patterns at their destinations have not received much attention from researchers.

Thus, a new innovative solution must arise integrating the diverse tools sought out by tourists in the public transport and tourism sectors.

1.3 Goals

The ultimate goal of this dissertation is to design a tourist-oriented mobile solution that acts as a lifeline for tourists moving around in their destination, facilitating their visiting experience as a whole. It is possible to translate this concept into a two-part goal. The first and most relevant is regarding public transport — making it possible to travel using public transport relying mostly on their mobile devices. The second part is related to touristic leisure — focusing on the places they will be visiting or experiencing, namely museums, landmarks, restaurants, among others.

This idea of merging features and services available in one mobile application stimulates the emergence of a new concept, namely Tourism as a Service (TaaS). This concept describes a single service that is able to satisfy the tourists' various needs on demand.

Besides the characteristics mentioned above, the solution should be able to satisfy the following conditions:

- be easy, practical, and pleasant to use;

- add value to the user;
- be accessible to as many people as possible.

These guidelines are important to motivate the public to adopt it into their daily lives as tourists, bringing them satisfaction without much effort. The end goal of the work proposed is to make using public transport more attractive so it can: (i) stimulate the current usage of public transport, and (ii) make travelers shift from private to public transport.

1.4 Methodological Approach

In order to achieve the goals set, this work will focus on better defining the goals and needs of tourists, further exploring and conceptualizing Tourism as a Service. This will be done by conducting user research focused on this topic, and creating a static prototype that acts as a proof-of-concept for TaaS.

1.5 Document Structure

This chapter introduced the scope of this dissertation, describing the context and motivation behind it and goals to achieve during the development process. The remaining document is divided into four additional chapters, organized as follows:

- Chapter 2, **Literature Review**, includes related work in the following areas: tourism and tourism-related mobile services, public transport-oriented solutions, and human-computer interaction.
- Chapter 3, **Problem Statement**, formally defines the problem, the proposed solution, and the methodology adopted to achieve it.
- Chapter 4, **Requirements Elicitation**, describes the elicitation process, analysis, and the resulting requirements.
- Chapter 5, ***PocketCity* Prototype**, presents a solution aiming to solve the problem described in this dissertation, along with the process involved to reach it.
- Chapter 6, **Ussability Testing**, demonstrates the validation process and analysis of the results obtained.
- Chapter 7, **Conclusion**, presents a summary and reflection of the work developed, including possible limitations and future work.

Chapter 2

Literature Review

This chapter introduces literature on areas directly or indirectly related to this dissertation's theme, namely tourism, mobile ticketing, public transport, and concepts related to designing and technology acceptance. Section 2.1 explores research on tourists' mobility preferences and existing mobile solutions designed for tourists. Section 2.2 explores mobile services that facilitate the use of public transport, namely route planning and mobile ticketing. Section 2.3 describes technology adoption models and how they have been used to study the adoption of mobile-ticketing services. Finally, section 2.4 explores some concepts and methodologies of Human-Computer Interaction to be used to design the new solution.

2.1 Tourism

The World Tourism Organization defines tourism as 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. (...) Tourism has to do with their [tourists] activities, some of which involve tourism expenditure."*

Leisure tourism, more specifically, can be centered around beaches and resorts, or in the case of urban tourism, more about experiencing the city and its attractions. The latter implies significantly more traveling between the places of interest. In light of this, this section will focus on tourists' mobility patterns and mobile tourist guides.

2.1.1 Tourism and Public Transport

One of the biggest challenges tourists face is mobility. Understanding their mobility habits is an important step in designing a solution that not only satisfies the current users of public transport but can divert attention from private transport, supporting sustainable mobility.

Accessibility can make or break a destination [46], and it can take many shapes, one being in regards to public transport. Accessibility in public transport can be achieved by installing the necessary infrastructure, *e.g.*, ramps for people with locomotor disabilities, but also by making the process of acquiring the tickets and getting the necessary information easy for all users.

According to Puhe *et al*. 2014 [42], after reaching their destination, many tourists chose public transport to move throughout the visiting area, and only a minority hire private transport. This is mostly the case for urban tourism. Cultural tourism is an increasingly form of tourism, including trips to exhibitions, performances, festivals, and other cultural attractions.

In 2011, Kinsella *et al*. [33] studied the opinions of both newcomers and visitors regarding the public transportation system in Dublin. The authors realized the significant impact of useful information on how the public transport network in bettering their experience. Furthermore, research revealed visitors often seek public transport information while planning a journey. The authors conclude that poor service delivery is often a strong motif for passenger dissatisfaction and that 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 *et al*. 2014 [36] performs a study on what makes tourists use or not use public transport. The reasons in favor are drive-free benefits, avoiding traffic, and the possibility of car unavailability. On the other hand, the factors discouraging public transport use are inconvenience, limitations, lack of information, and preference. Variables that also influence the decision are the length of stay, purpose, age group, usual frequency of public transport use at the place, and valid driving license ownership.

Oliveira *et al*. 2020 [38] researches the factors and features of a potential tourist-oriented mobile ticketing solution. The results show that the most desired features are information on the public transport network, buying and validating options for public transport tickets.

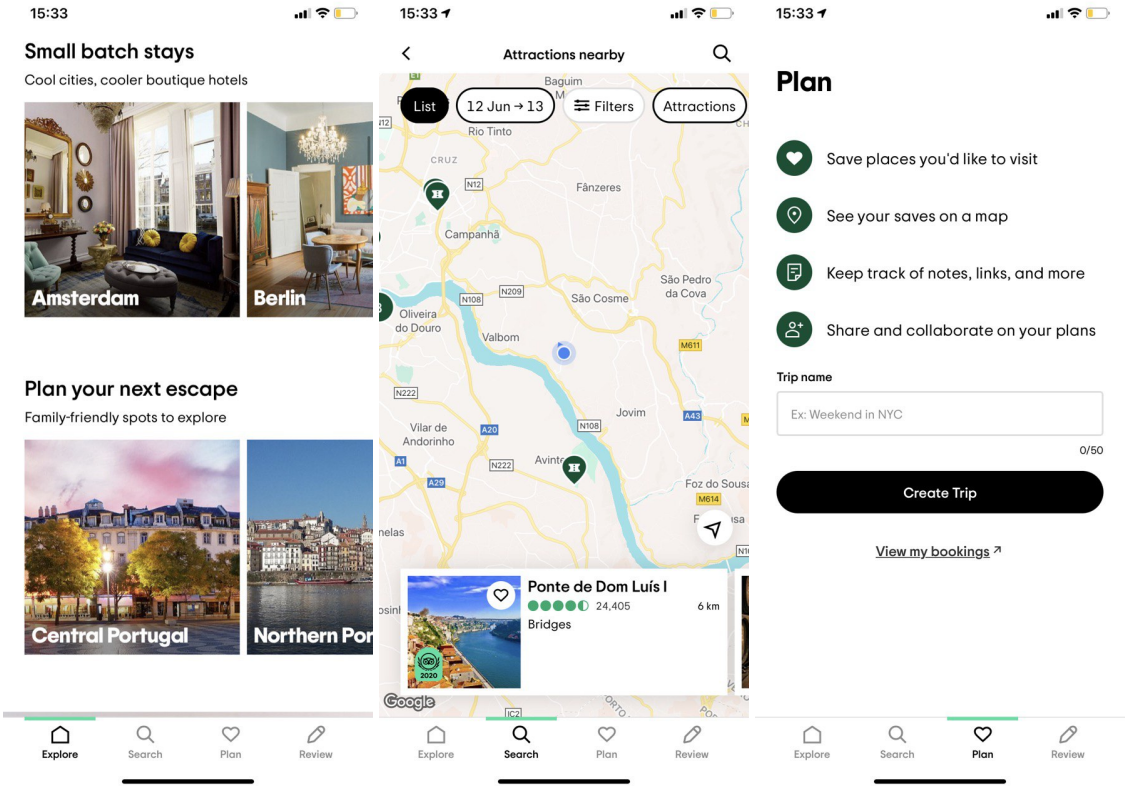
2.1.2 Mobile Tourist Guides

Tourism-oriented mobile applications may assist tourists in the preparatory phase or during the trip. Since the goal is to achieve a solution that acts as a lifeline for tourists on a daily basis, this section will be focusing on providing assistance during the trip itself.

Mobile tourist assistants tend to provide two services, namely, suggestions and booking of tourist-related activities.

The problem with traditional paper-based tourist guides is that they may become challenging to navigate. Most mobile tourist assistants nowadays are location-aware. This means that they can

offer suggestions based on the user's current and past locations, allowing for a more personalized experience.



(a) Explore (b) Nearby Attractions (c) Plan a trip

Figure 2.1: *Tripadvisor* interfaces

One of the most popular tourist-related mobile applications nowadays is *Tripadvisor*, *cf. Figure* 2.1. It offers suggestions by many specifications (*e.g.*, proximity, reviews, ratings) on accommodation, restaurants, attractions, and activities. It also offers some trip planning features, such as allowing users to save locations in a specific trip folder.

Another good example of a mobile trip assistant is *Culture Trip*. It offers all the features *Tripadvisor* does, as well as the ability to book the accommodation and certain activities within the application. Design-wise, they are extremely similar, keeping a modern-looking minimalist interface.

While offering personalized suggestions, these applications and other similar options still are very different from an in-person experience with a tour guide. Some proposals have emerged over the years suggesting more context-aware mobile tour guides. For example, Echtibi *et al.*, 2009 [14] proposes a context-aware tourist advisor that offers suggestions based on a context model. This model comprises the location, the user profile, the current date, event-related information, and user interaction. It continuously evaluates the user's context to provide them with information.

2.2 Public Transport and Mobile Solutions

Considering public transport as the primary means of transport of tourists [42], it is important to go over existing solutions that have integration with this sector. This section goes over two types of mobile solutions, namely, route planners and mobile ticketing applications in the context of public transport.

2.2.1 Route Planners

A route, journey, or trip planner is a smart travel tool that provides real-time travel plan information to the passenger for a given origin and destination, including the types of transport to take, arrival and departure times, and fares.

A good trip planner attracts people to public transport by providing an easier way to obtain information on travel routes according to their specific needs. This helps to mitigate the environmental impact of the transport sector by reducing the use of private transport and CO2 emissions. Additionally, it reduces the use of paper maps and timetables [55].

In 2016, the Manchester School of Architecture [9] presented a thorough analysis of journey planners. A few high-level features that journey planners should include were identified:

- **Multi-modality** — integration of multiple modes of transport;
- **Navigation** — keeping track of the user's position and provide navigation guidance accordingly;
- **Real-time information** — updated line closures, arrival and departures time. It also implies having built-in GPS navigation that allows warnings on traffic conditions, re-routing, and re-calculating of arrival times;
- **Crowdsourcing data** — users contribute information to the system. It allows valuable data to be collected, such as accidents, delays, and discrepancies between the information provided and reality;
- **Personalization** — tailoring the experience to the user based on their previous behavior. Some examples are the possibility of saving certain locations as shortcuts.

The study also identified core features that have to power to improve the usability of the application:

- **Maps and points of interests (POI)** — ability to retrieve a location from a user and translate it to longitude and latitude coordinates, or retrieve with location information;
- **Geocoding** — upon inserting a postal code or address, the user is able to choose the desired location from a list of partial matching options;

- **Time of travel** — informs users about the time a trip will take or the remaining time of a current trip;
- **Customization** — allows the user to specify requirements related to their needs or preferences for travel;
- **Results display** — for a certain origin and destination set, various journey options are presents.

		Features	Usability	Popularity
1	MAPS.ME - Map & GPS Navigation	8	16	2
2	Voyager: Route Planner	12	17	9
3	My TfGM	3	13	16
4	Maps - Navigation & Transit (Google)	1	7	1
5	MapQuest GPS Navigation & Maps	11	14	7
6	Citymapper	3	2	4
7	Transit Directions by Moovit	4	6	5
8	Transit: Real-Time Transit App	7	4	8
9	TRAFI - Public transport app	5	6	6
10	TripGo:Transit,Maps,Directions	2	1	14
11	HERE WeGo - City Navigation	2	9	3
12	Journey Planner (TFI)	7	8	10
13	Offi . Journey Planner	11	12	4
14	Maps, Navigation & Directions	11	18	5
15	Traveline GB	8	3	12
16	London Journey Planner	9	5	11
17	TRACKR FREE: Bus & Train Times	8	9	15
18	Tripotnik - Sustainable travel	6	11	17
19	Merseytravel	10	10	13
20	MOVESMART (Certh-iti)	6	15	18

Table 2.1: Ranking of trip planning applications (Adapted from Manchester School of Architecture [9])

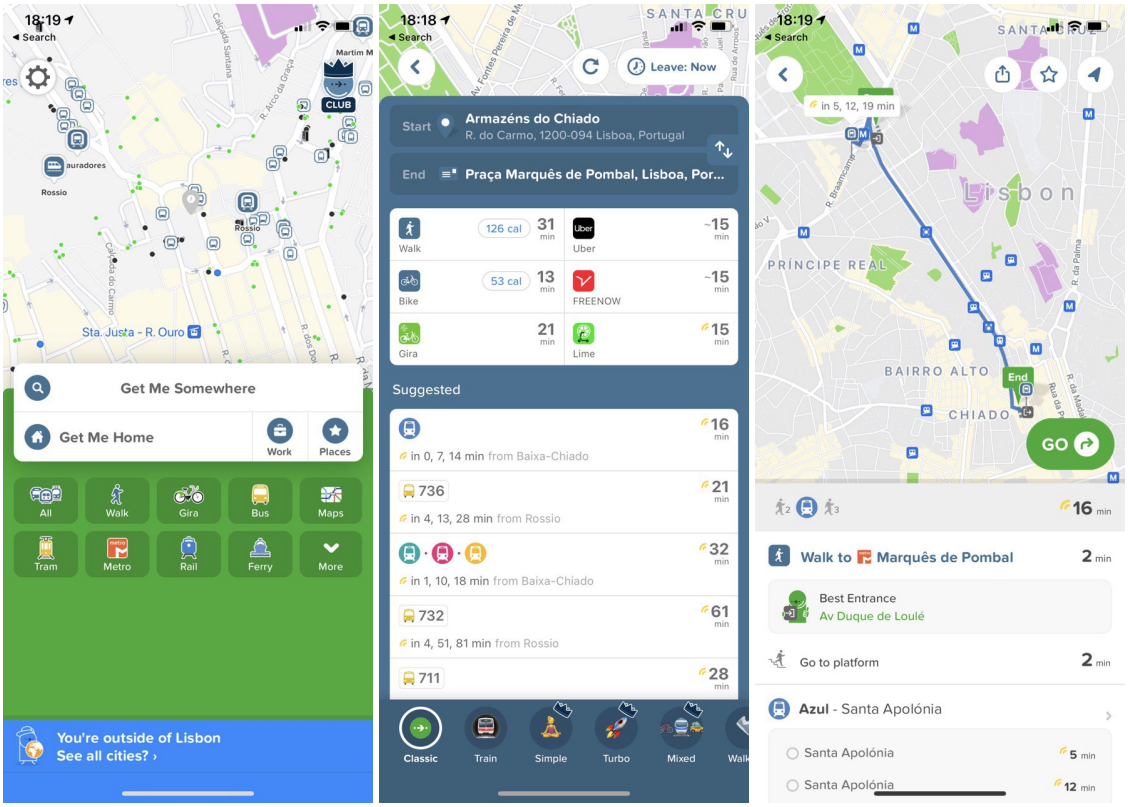
Table 2.1 presents the summarized rankings of various journey planning applications resulting from the analysis done by the Manchester School of Architecture [9]. It rates the high-level features, usability, and popularity, with 1 being the highest score possible (corresponding to green) and 20 the worst (corresponding to red). Note that the scores presented are the product of the normalization of the metrics analyzed.

The high-level feature evaluation was based on the features and transport modes supported.

The usability evaluation was based on the satisfaction of users, the effectiveness and efficiency of the application. The study highlighted a few qualities that tend to improve usability. In regards to the **ease of data input** there should be auto-completion; reduced textual input; platform convention for UI elements; feedback to validate input. In regards to the **customization of preferences**, the options should be clearly visible or obey the platform convention. Finally, the **display of route**

options should appear in natural and logical order, and additional information should be relevant to the user's needs.

The popularity evaluation was based on the number of estimated installs per day, user ratings, and reviews. The study concluded that there was a direct relationship between the popularity of the applications and the existence of car navigation.



(a) Homepage (b) Route Search Results (c) Route details

Figure 2.2: *CityMapper* interfaces

Overall, the highest-ranking application out of the analyzed is *CityMapper (6)*, *cf. Figure* 2.2. *CityMapper*'s mission is to help people getting around cities while reducing congestion and pollution. As of today, it is available in a large pool of metropolitan European cities. For its design, it makes use of vibrant colors and symbols in order to create an easy and pleasant to use interface.

2.2.2 Mobile Ticketing

Paper tickets were the first form of tickets to appear, and they are still heavily used. They are the simplest ticket form due to their low cost and compatibility with other forms of payments. Nevertheless, they are susceptible to fraud and inconvenience. As time went by, news forms of ticketing appeared, such as **magnetic stripe cards** and **contactless cards**.

There are diverse definitions for **mobile ticketing** or m-ticketing. The more strict definitions solely consider the ticket acquisition process: the initiation, authorization, and confirmation of a

payment for a ticket [32]. The more relaxed definitions consider it as the usage of a mobile device to old an e-ticket, allowing for extra services to be integrated *e.g.*, ticket validation Puhe2014.

There several ways to address payments in e-ticketing depending on the complexity and intent of the system. The most adopted payment strategies in public transport e-ticketing systems, but not exclusively, can be summed up to five models [29].

- **Pre-paid value model -** the ticket is issued by the PTO. The value stored may be in terms of money, rides, or time). Currently, it is the most common form of automated ticketing.
- **Enhanced payment card -** relies on contactless debit/credit cards and payment applications, usually provided by an intermediary. The user presents the device to a reader, and the payment transaction is processed based on the fare structure. Essentially, it is a *pay-as-you-go* model.
- **Post-paid model -** relies on smart cards or payment applications. The customer is charged afterward according to their usage. These models tend to minimize customers ' costs.
- **Combined/enhanced collaborative models -** incorporating multiple applications (*e.g.*, transit and payment) in smart cards or phones. The transit portion may be pre or post-paid, while the payment portion usually works like a credit/debit card.
- **Embedded secure element/(U)SIM -** involves an intermediary, usually, a trusted service manager (*e.g.*, , financial institution), a mobile network operator, or handset manufacturer defines the business rules. It can be applied to any of the models mentioned above.

2.2.2.1 Advantages and Disadvantages

The **passenger** benefits from a significant increase in usability, ticket acquisition, and validation efficiency by avoiding queues, replacing coins and banknotes. It makes the overall experience more convenient and straightforward [16]. Other significant advantages are cost minimization, individualized are schemes that allow for special offers based on consumer use, and elimination of the risk of losing tickets [26].

The main disadvantage is the privacy concerns surrounding the system, namely customer profiling, ubiquitous customer identification, and privacy violation through the increased surveillance potential [26].

Regarding **PTOs**, m-ticketing can be beneficial due to decreased maintenance and payment handling costs, and ticket forgery mitigation. Most importantly, it makes it possible to generate more revenue by attracting more customers, mainly younger generations [26].

On the other hand, there might be a lack of standardization in the sector, having to ensure interoperability between service providers as well as requiring significant investment to implement such systems [26].

2.2.2.2 Communication Technology

Mobile ticketing implies using technology that allows the user's mobile device to communicate with the service provider.

Short Message Service (SMS) and phone calls were one of the first forms of mobile ticketing to appear, seeing as it is simple and easy to use. Its main downsides are the lack of encryption and proof of delivery, along with the unpleasant user experience. In this case, the user usually pays for the requested services in addition to their next phone bill. Some implementation examples are *Ring&Ride* in Germany, *Paybox* in Austria, *Proximus* in Belgium, *Mobipay* in Spain, and *AvantixMetro* in the United Kingdom [38].

Wi-Fi does not require much infrastructure, seeing as it is highly available. Most establishments provide a public signal, although they present a security liability. Additionally, transport companies are already making efforts to make Wi-Fi available in buses and trains. The use of cellular data (3G, 4G, 5G), which is increasing, achieves the same goal minus the security liability. On the other hand, it is more costly to the user. Both are subject to network connectivity issues. Wi-Fior Cellular data are usually used coupled with other technologies, *e.g.*, GPS, which is the case in the public transport ticketing solution proposed by Ferreira *et al.* , 2014 [17]. It focuses on designing a system mainly based on customers' mobile devices and compatible with the existing infrastructures.

Quick Response Codes (QR Codes) are matrix bar-codes containing information that can be scanned by dedicated readers and most smartphone cameras used nowadays. It can be used in one of two ways:

1. QR code is in the user's mobile device and scanned by the service providers to verify ticket purchase or validity;

2. QR code is presented by the service providers and scanned by the user to execute the payment [16].

Regardless of the scenario, relative proximity is required. An example of the integration of QR-codes in a mobile ticketing service is the proposal of Finzgar *et al.*, 2011 [18]. The passenger scans a QR code that identifies his location for check-in/check-out purposes in this proposal. The ticket is also stored in the form of a QR-code and used for validation as per the first scenario mentioned above.

Radio-Frequency Identification (RFID) systems are composed by a reader with an antenna and a transponder *aka* tag. It is suited for asset and location tracking.

Near Field Communication (NFC) is a short-range wireless communication protocol based on RFID. It allows for secure transactions. The main difference between NFC and RFID is that an NFC-enabled device can act as both reader and tag. A good implementation example is EasyRide in Switzerland [28]. The vast majority of smartphones nowadays are equipped with NFC technology. However, Apple poses a lot of use limitations to the NFC capabilities on their devices. Generally speaking, the NFC equipped device is approached by a reader, and the payment details

are safely transferred. Most mobile ticketing systems in public transport nowadays are NFC-based ones. Some examples to highlight are *Oyster Card* in the UK, Touch&Travel in Denmark, *CityZi* in France, and *Anda* in Portugal. To this day, Apple Inc. only exposes NFC for payments processed with Apple Pay. This poses a strong limitation in NFC-based digital wallets since the percentage of iPhone users is significant.

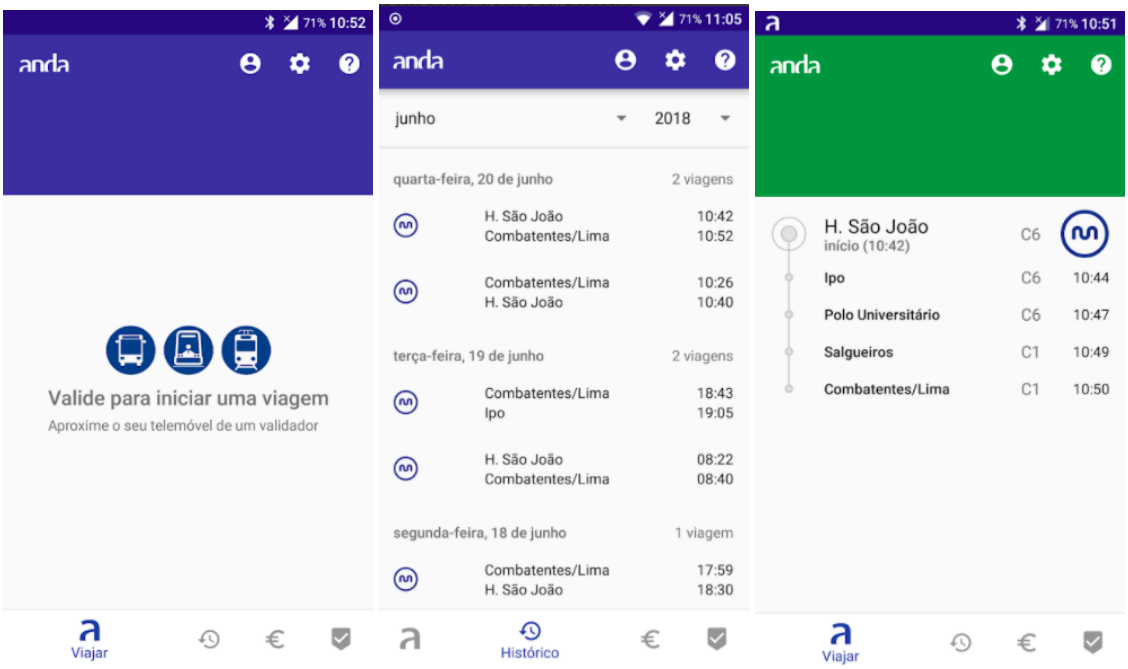
BLE Bluetooth Low Energy (BLE) is a low-power, short-range wireless communication technology. Much like NFC, it's present in most smartphones being used now. The concept of its application to mobile ticketing is still quite recent. The general idea is that BLE-equipped devices act as beacons, broadcasting information. Recent proposals based on BLE have been proposed by Martins *et al.*,2017 [39], and Ferreira *et al.*,2019 [15].

In the following section, a critical analysis is made based on, among others, some of the examples pointed out for each technology.

2.2.2.3 Mobile Ticketing Solutions Worldwide

The concept of applying mobile ticketing to public transport is not new. Solutions that execute that concept have been appearing for a few years worldwide.

Based on the work of Puhe *et al.*, 2014 [42] and Ferreira *et al.*2020 [16], a compilation of mobile ticketing solutions being used around the world was made. Table 2.2 summarizes those solutions regarding technology, system architecture, and current application to the tourism sector.



(a) Homepage (b) Route Search Results (c) Real-time arrivals

Figure 2.3: *Anda* interfaces

Of the solutions presented, 7 present integration with the tourism sector, in which 4 have to possibility to use as a payment method for tourist-related attractions —- *Oyster Card*, *Octupus*

	Technology	System	Application To Tourism
Oyster Card, London (UK)	RFID, NFC	Pre-paid smart card	Visitor Oyster card: use as form of payment for attractions
Mi Muovo, Emilia Romagna (I)	RFID	Season tickets	-
Octopus Card, Hong Kong (CN)	RFID, NFC	Pre-paid smart card; NFC-enabled Android phones	Destination card: use as form of payment for attractions
T-Money, Seoul (KR)	RFID	Pre-paid smart card	Seoul City Pass: use as form of payment for attractions
EZ Link, Singapore	RFID, NFC	Pre-paid smart card; NFC-enabled Android phones	Destination card: use as form of payment for attractions
Touch & Travel (D)	NFC	NFC-enabled smartphones or sim cards	-
CityZi, Nice (F)	NFC	NFC-enabled smartphones or sim cards	Information on touristic sites via NFC tags
I amsterdam City Card, Amsterdam (NL)	RFID	Pre-paid smart card	Information on touristic sites; Discount/ /free entry to museums and touristic sites
Saint Petersburg City Card, Saint Petersburg (RU)	RFID	One-time pass with integrated e-purse for public transport	Free entry/discounts to Museums, shopping entertainment, restaurants
SBB App EasyRide Protocol (SW)	RFID	Mobile App with payment card associated	-
Anda, Porto (PT)	NFC, Bluetooth	Mobile App with payment card associated	-

Table 2.2: Summary of mobile-ticketing services around the world

Card, *T-Money*, and *EZ Link* — and 3 offer information and/or discounts in tourist-related attractions — *CityZi*, *I amsterdam City*, and Saint *Petersburg Card*. However, these solutions are mostly based on smart cards and digital wallets, which offer very limited features.

The most complex examples presented are the *Anda* and *SBB* mobile applications. The latter allows additional trip planning features between stops/stations, real-time schedules, and travel history. However, the *SBB* application has more complex route planning features as well as more customization within the application.

2.2.2.4 Mobility as a Service

"If Netflix's business model were applied to urban transportation, how might that change the way city dwellers get around? " - Delloite, 2017 [25].

The answer to this question is offered by Mobility as a Service (MaaS), a relatively recent concept in the transport sector. MaaS offers a tailored mobility package that combines various transport modes [30]. It also tends to offer complementary services, such as trip planning, reservation, and payments. All this is done through a single platform.

In this scheme, the service providers provide an easy, reliable, flexible, price-worthy, and sustainable way for everyday travel, hence why MaaS needs to be user-centric [23]. From a user's perspective, it should be easy to plan, book, and pay for travel, integrating various transport modes. Ideally, this should happen seamlessly and effortlessly.

Table 2.3 presents an overview of a few mobile applications that implement MaaS, namely *Whim* from Finland, *UbiGo* from *Sweeden*, *Moovel* from Germany, and *Smile* from Austria. Although there are certainly more than just these four applications, these were specifically chosen to fairly represent the concept.

Within the MaaS mobile applications considered, there is a certain diversity of services offered. However, some patterns can be detected, such as the transport modes included and the basic features available (real-time information, trip planning, booking, and ticketing). Some go further and offer extra services, such as synchronization with personal agenda and trip disruption warnings.

MaaaS provides seamless integration of the two transport solutions seen in the previous sections — route planning and mobile ticketing. Nevertheless, MaaS is designed around everyday travels, as previously mentioned. Furthermore, the missing piece in the context of this dissertation is an integration with the tourism sector.

2.3 Technology Acceptance

2.3.1 Technology Adoption Models

With the constant technological developments, new technology-based products appear on the market every day. However, few end up becoming seeded into the audience's habits and routines, prompting companies and organizations to effectively measure the acceptance of certain technology by their consumers. Acceptance can be viewed as a positive and proactive decision to use an innovation [47]. It can not be translated into a single property. It depends on a variety of factors such as availability, usability, security, among others.

	Whim app (Helsinki, FI)	UbiGo (Gothenburg, SE)	Moovel (DE)	SMILE (Viena, AT)
Transport modes and services	Public Transport Bike sharing Car Sharing Car rental Taxi Regional rail	Public Transport Bike sharing Car Sharing Car rental Taxi	Public Transport Bike sharing Car Sharing Ferry Regional rail	Public Transport Bike sharing Car Sharing Taxi Parking garages Charging stations Regional Trains and Ferry
Tariff option	3 monthly packages or pay-per-use	Monthly tariff	Pay-per-use	Pay-per-use
Features	- Real time info - Trip planning - Booking & ticketing - Payment - Invoincing	- Trip planning - Booking & ticketing - Payment - Invoincing - 24hour customer service line	- Real time info - Trip planning - Booking & ticketing - Payment - Invoincing	- Real time info - Trip planning - Booking & ticketing - Payment - Invoincing - Service Alerts
Personalisation	- Calendar synchronization - Personal info sharing - Social interaction	N/A	- Store favourite routes - Personalized notifications on disruptions	- Optimized trip plan to user's profile
Customization	- Cancelation - Change of subscription - Top-up	- Mobility budget with top-up and roll over	- Link with social media accounts - Booking cancellation	- Enable mode filtering based on cost, time, and CO2 footprint

Table 2.3: MaaS mobile applications

Understanding the factors that influence the acceptance of a product by its users is a significant advantage since these factors can be taken into account during the design process.

In order to address the adoption of new technologies, researchers have conceptualized a variety of models and frameworks. Figure 2.4 illustrates a portion of the theories and models embraced, demonstrating the inheritance that occurs.

Out of these models, a few considered to be the most popular will be singled out to provide some insight into their thesis.

In 1989, Davis *et al.* [11] proposed one of the most widely cited models in the field of technology acceptance, the Technology Acceptance Model (TAM) [53], which is an adaptation of the

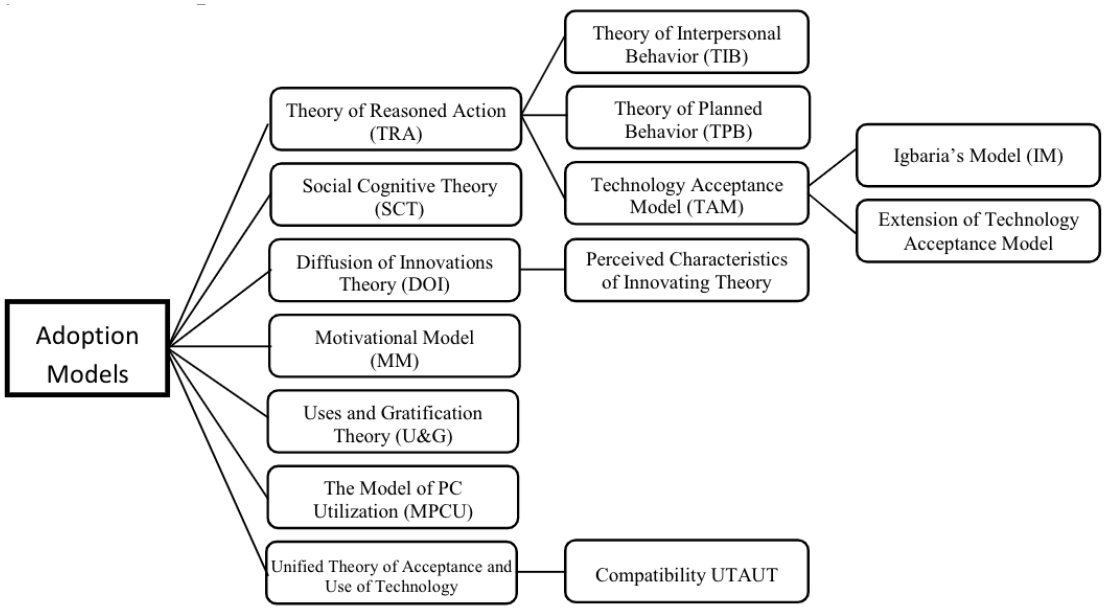


Figure 2.4: Technology adoption models (Taherdoost *et al.* [47])

Theory of Reasoned Action TRA. Interestingly, it was initially conceptualized for modeling computer acceptance, yet it enlightened user's behavior in a range of computing technologies. Davis breaks down users' motivation into two concepts *i.e.*, Perceived Usefulness and Perceived Ease of Use. Perceived Usefulness is the degree to which a user expects the system enhances a certain task. Perceived Ease-of-Use relates to the effort degree a user believes the system to be. Considering that this model, contrary to its predecessor, disregards the social norms, external variables might need to be added to provide more accurate predictions [47].

Diffusion of Innovations (DOI), proposed by Rogers *et al.* [43], served as a foundation for further research on innovation acceptance and adoption. [34]. It aims to explain *"the process by which an innovation is communicated through certain channels over time among the members of social systems"* (Rogers *et al.* [43]). DOI defends that innovation and adoption occur at various stages, namely, understanding, persuading, deciding, implementing, and confirming.

Unified Theory of Acceptance and Use of Technology was the result of Venkatesh *et al.* [50] comparing previous models and theories. Four predictors of the acceptance were identified, *i.e.*, performance expectancy and effort expectancy, social influence, and facilitating conditions.

2.3.1.1 Mobile Ticketing Adoption in Public Transport

There is literature that studies the application of these technology adoption models to mobile ticketing technologies in public transport.

In 2008, Mallat *et al.* [37] studied how perceptive consumers were to adopt the mobile ticketing scheme in the transport sector, having as a basis the TAM model and DOI theory. The results indicate that mobile ticketing in this sector is context-dependent, making it an area developers must take advantage of. Some examples of contextual factors lacking out of cash or facing a long

queue to acquire a traditional ticket. The authors concluded that the adoption of mobile services in public transport is feasible.

In 2013, Cheng *et al*. [8] studied the acceptance of QR-code-based mobile ticketing by high-speed rail passengers. The results were based on the combination of TAM with the Mental Accounting Theory developed by Richard H. Thaler in 1999. According to this theory, the main influencing factors are the benefits, *i.e*., perceived usefulness, perceived ease of use, and perceived use, as well as the potential loss, *i.e*., perceived risk. Prior experience and usual attitude towards innovation are also connected to a positive adoption by users.

The Integrated Model on Mobile Payment In 2015, Pietrp *et al*. [13] proposes a completely new model, the Integrated Model on Mobile Payment Acceptance (IMMPA), based on existing models, namely, TAM, DOI, and UTAUT. It is designed specifically for Mobile Payment Acceptance in the context of public transport by mixing variables from the existing models as well as adding new ones tailored to the specific context. IMMPA relied on five predictors: usefulness, ease of use, security, compatibility, and attitude towards mobile services. The latter takes into account general requirements for these services, such as completeness of information, information on time and delays, speed of use, intuitiveness of user interface, and path customization.

	Model	Considered Factors
Mallat *et al*., 2008	TAM DOI	[weak] Ease of use [weak] Usefulness [strong] Context [strong] Social influence [very strong] Compatibility [very strong] Prior Experience Attitude Trust Risk
Cheng *et al*., 2013	TAM	[very strong] Perceived Risk [strong] Prior Experience Perceived Usefulness Perceived Ease of Use Tendency Towards Innovation
Pietro *et al*., 2015	TAM DOI UTAUT	Usefulness Ease of Use Compatibility Security Attitude Towards Mobile Services

Table 2.4: Factors considered in mobile ticketing adoption in public transport

Although not specifically based on any of the models mentioned above, the 2017 study by Fontes *et al*. [20] is quite useful in understanding which factors mobile ticketing service to be

well accepted and adopted by the community. The results were based on a survey distributed in a medium-sized metropolitan area as Porto, Portugal, and a big metropolitan area as Beijing, China. Overall, the Beijing population showed a bigger use intention of such a system. Traditional factors, such as age, gender, qualification, and prior experience, were considered as well as travel frequency, hurry, and typical ticket usage.

Finally, the work of Oliveira *et al*. 2020 [38] precedes this dissertation in establishing the receptiveness of tourists for a tourist-oriented mobile ticketing solution. He concludes that ease of use, usefulness, compatibility, and mobility definitely impact the adoption by consumers.

In recent years, the TAM model was augmented to include a hedonic component of enjoyment. The work of Cyr *et al*. 2006 [10] examines this augmented model to discover that visual design aesthetic positively impacts the ease of use, usefulness, and enjoyment of the system. Although it might not directly lead to trust and loyalty, it is a contributing factor that motivates the user to stay within the platform [19].

Researchers have developed various models, each with their own specific theories, and different studies on mobile ticketing solutions expose different sets of determining factors in technology acceptance. Nonetheless, all can agree on a subset of factors that include ease of use, usefulness, risk, and usual attitude towards mobile services. These are important aspects to keep in mind when designing mobile solutions in order to maximize their adoption by the public. The system needs to be easy to use, and its users need to recognize its value.

2.4 Human-Computer Interaction

Traditional methods of Human-Computer Interaction (HCI) like the technology adoption models discussed are mainly cognitive-oriented, having little regard for the user's emotional experiences [24]. In this section, we will describe more recent interwoven concepts of HCI, namely usability, UX/UI design, and user-centered design.

2.4.1 Usability

Usability represents the quality of the interaction, the efficiency and effectiveness of the system in terms of parameters such as the time taken to perform tasks, the number of mistakes made in doing so, among others [6].

The ISO 9241 standard on Ergonomics of Human System Interaction defines usability as: *"The extent to which a product (...) can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use"* [21].

There are several evaluation methods that can be conducted to empirically measure the usability of a system, *cf. Figure*2.5

In the context of a mobile ticketing application, the evaluations conducted by experts or by users are more adequate [54].

Usability testing is a method that relies on observation rather than participation with the goal of understanding what challenges users are having with the system [35]. Mediators observe users

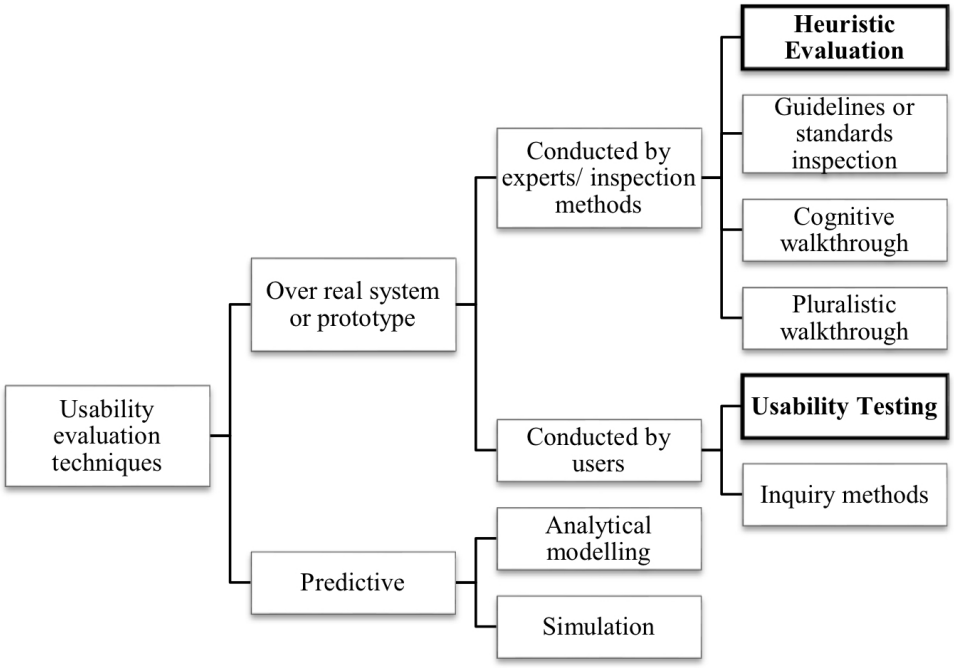


Figure 2.5: Classification of usability evaluation methods (Amorim *et al*. [12])

interacting with a version of the products (prototype or real system) and register the specifics of how the proposed task was carried out, such as how long the user took, how many detours did the user make, and if the task was performed successfully in the end. Ultimately, it's expected to empirically collect data to compare and bridge the gap between the prototype and the user's mental model [44].

Heuristic evaluation is an inspection technique conducted by experts by using a heuristic checklist. The term *expert* is used to contrast the term *user*. It refers to an individual with some previous knowledge of usability, not necessarily usability experts [54, 12].

Nielsen *et al*. 1994 [40] suggests ten general usability heuristics for interaction design, *i.e*., :

1. Visibility of system status;
2. Match between system and the real world;
3. User control and freedom;
4. Consistency and standards;
5. Error prevention;
6. Recognition rather than recall;
7. Flexibility and efficiency of use;
8. Aesthetic and minimalist design;
9. Help users recognize, diagnose, and recover from errors;
10. Help and documentation.

Alternatively, these heuristics can be used as guidelines whilst designing in order to achieve good usability.

The System Usability Scale is a Likert Scale created by John Brooke in 1986 as a 'quick and dirty' low-cost form of usability evaluation [7]. It includes 10 statements that users are asked to rate from 1 to 5, based on their level of agreement, which are later translated into a usability score.

Amorim *et al*. 2018 [12] studies the usability of the application *Anda* by performing usability tests along with heuristic evaluation. The latter, which proved to be the most decisive, included a heuristic checklist based on the initial Nielsen *et al*.heuristics stated above and the added security and pleasurable and respectful Interaction aspects. The checklist proved to be useful and validated by the users.

For a platform to be usable, it needs to be accessible first. Although accessibility is an extensive concept with its own guidelines and evaluation methods, putting it simply, it is the concept of usability addressed for all. ISO 9241-171 (2008b) defines accessibility as: *"the usability of a product (...) by people with the widest range of capabilities"* [22]. The Web Content Accessibility Guidelines (WCAG) [52] define accessible design guidelines to deliver content to a wider range of people with special conditions, including physical disabilities such as blindness and deafness as well as learning and cognitive limitations.

2.4.2 UX/UI design

UX/UI design is a relatively recent area of design that focuses on building an aesthetically pleasing interface (UI) that incorporates the best possible user experience (UX), thus increasing usability and ease of use present in the traditional models.

UX refers to any and all interactions a user has with a product [31]. Nowadays, it has the power to dictate the adoption or rejection of a product [24].

Designing for small, hand-held mobile devices requires is a big challenge due to the small screen size, low resolution, and different input methods. Adipat *et al*. 2005 [3] defines the biggest challenges for mobile users as information overload, limited memory of devices, and navigation loss. To combat this and other issues, a framework is proposed for the effective design of mobile interfaces that focus on four components: information presentation, data entry methods, mobile users, and context. With regards to information presentation, the authors highlight the importance of visualization, adaptive interfaces, multi-modal displays. In regards to the user, their preferences and, cognitive load, and disabilities are important to have in mind.

UI design is subject to trends and preferences, thus it is important to establish base guidelines that persist through all the changes. Two of the biggest players designing for the mobile market developed their own internal design guidelines to maintain the integrity and consistency of their products. Apple Inc. follows six main principles: aesthetic integrity, consistency, direct manipulation, feedback, metaphors, and user control [5]. Google developed their own *design language* and opened it for any designer to take advantage of, Material UI.

2.4.3 User-Centered Design

The search for improving UX originated a collection of approaches prioritizing the needs of the user, being user-centered design a common one [31].

User-centered design (UCD) is an iterative design process that, as the name indicates, puts users in the center of the design process, focusing on their needs, goals, and overall satisfaction [48]. UCD design is driven by addressing user experience in hopes of explicitly understanding users and environments and is refined with user-centered evaluation [49].

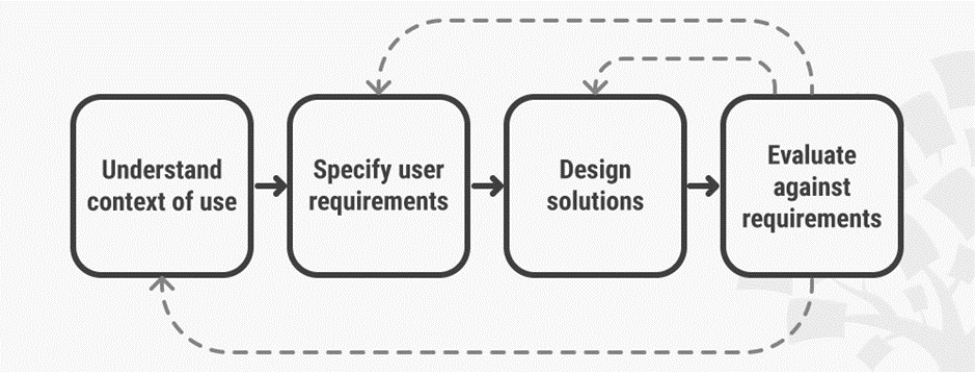


Figure 2.6: User Centered Design Methodology [48]

Generally speaking, UCD iterations consist of four general steps: defining the context of use; defining the requirements; designing solutions; evaluating designs. This process can be repeated until the designers are satisfied with the results [48, 49].

The UCD methodology has a similar lifecycle to the software development process but with longer iterations. UCD approaches may vary in the application by adaptation to specific project needs and integration with software development methods, such as waterfall or agile [49].

2.5 Summary

This chapter went over some important concepts related to the work of this dissertation and relevant existing work.

Section 2.1 described tourists' behavior and mobility patterns and presented a few of the currently existing solutions aimed at tourists, namely mobile tourist guides. Despite the challenges, most tourists still opt for public transport. The surge of mobile tourist guides has presented users with a convenient way to replace paper-based guides.

Section 2.2 described two concepts that are able to facilitate using public transport, namely route planners and mobile ticketing, as well as existing solutions that implement them. Route planners are not a new concept, and there are multiple services implementing them successfully. Mobile ticketing appeared later, and its usage in public transport has been increasing. The most popular communication technologies used in today's ticketing services are NFC and QR-codes.

What can be concluded from the first two sections is that the services tourists need on a daily basis are spread out through many different platforms, creating the need for an all-in-one solution that satisfies the daily goals of a tourist.

Section 2.3 goes over technology acceptance models and their application to public transport. There is a subset of determining acceptance factors that most researchers agree upon, including ease of use, usefulness, risk, and usual attitude towards mobile services.

Finally, section 2.4 describes concepts of Human-Computer interaction fundamental to the design of systems, such as usability, UX/UI design, and User-Centered Design.

Chapter 3

Methodology

This chapter formally states the intention of this work, the problem it is attempting to solve and the approach adopted to reach the proposed solution. Section 3.1 presents the current issues and the goals this work is trying to achieve. Section 3.2 describes the general overview of the proposed solution. Section 3.3 describes how the development of the solution is going to be approached. Finally, section 3.4 summarizes the topics mentioned in this chapter.

3.1 Issues and Goals

The previous chapter provided some insight into the experience of tourists while visiting a destination and reviewed existing solutions directed at tourists and mobility in tourism. Some of the biggest challenges faced by tourists are:

- lack of clear information about the local public transport network, *e.g.*, fares, maps, next stops;
- dispersion of solutions. Tourists are forced to go to different mobile applications for every individual action.

As previously concluded, most solutions to ease the use of public transport focus mainly on the local passenger as a customer, failing to meet some needs of visitors who do not have a preconceived knowledge of the network.

The goal is to create a solution that acts as a lifeline for tourists, allowing them to fulfill their daily needs in one single place.

3.2 Solution

To approach the unaddressed needs of tourists, this dissertation introduces the concept of Tourism as a Service (Taas), inspired by the concept of Mobility as Service (MaaS). In the previous chapter, it was mentioned that MaaS offers integration between various transport services into a standalone service, providing a more convenient and sustainable way to travel. We decided to apply this same line of thought to tourism, resulting in the integration of tourists' daily needs and goals into a single service accessible on demand.

Furthermore, this dissertations presents a prototype of a tourist-oriented mobile application based on TaaS. From the literature reviewed, it was established that the services most sought out by tourists, and therefore of more importance in this solution, have to do with route planning, mobile ticketing, and informational services in regards to public transport and tourism-related activities.

Although the communication technology used for ticketing affects how the application flows, it should not impose significant investment or extra maintenance costs. As mentioned in chapter 2, a good solution is one that either relies solely on the user's mobile device or it takes advantage of the public transport infrastructure already in use. This infrastructure varies from city to city, and sometimes transport mode. This means that the ideal solution would be adaptable to its environment. This issue is outside of the scope of this thesis, and therefore, the focus is on creating an agnostic solution that could be easily tweaked to fit different types of ticketing according to the location. Having said that, it is important to prioritize a pre-paid ticketing model versus post-paid since tourists stay for a limited amount of time and tend to plan their trip costs ahead and look into ticket deals.

3.3 Methodology

To achieve the proposed solution, a user-centric methodology was followed, namely user-centered design (UCD) with two iterations, *cf. Figure* 3.1.

3.3.1 Focus Groups

The initial and literature review allowed us to form an idea of functional and non-functional user requirements. In order to further understand tourists' challenges and goals, focus groups with potential users were held.

Focus groups allow individuals to share their opinions and past experiences on a certain topic. As opposed to regular interviews, this type of inquiry has the advantage of allowing participants to discuss their different points of view with one another, contributing to a richer result.

There were 3 focus group sessions with a total of 11 participants, who qualified as potential users of the mobile application in the context of tourism. The sessions were divided into two parts: the first consisted of filling out a small form with their socio-demographic information, and some

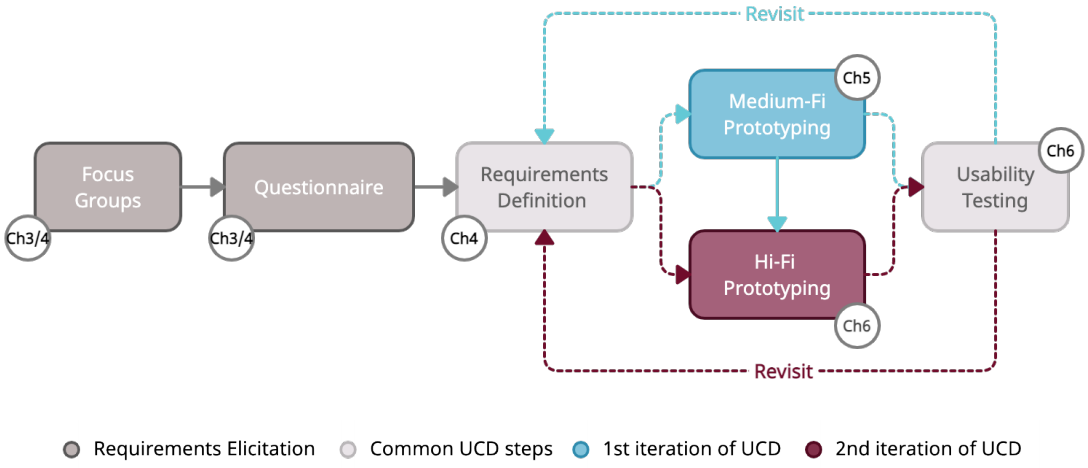


Figure 3.1: Methodology Adopted

behaviors as tourists, for sample characterization, *see Appendix A.1*; the second consisted of semi-structured interviews. The form was created in the shape of a *Google Forms*, and the discussion was carried out in a video-conference, using *Google Meets*. The audio of these sessions was recorded in order to allow transcription.

The semi-structured interviews loosely followed a script, *see Appendix A.2*, that encouraged the participants to share their past experiences while doing tourism, both positive and negative, with the goal of translating these experiences into useful features.

The sessions followed a four-part structure. Initially, a short introduction was made introducing the moderator and exposing the goal of the session. Secondly, a set of guidelines and rules were divulged about how the session would work. The third step represented the main portion of the session, lasting for around 45-55 minutes. The participants were asked to briefly introduce themselves and then discuss a set of exploratory questions, as follows:

1. Do you usually use mobile applications aimed at public transport?

While doing tourism:

1. In what situations do you use public transport?
2. Do you usually plan your trip in terms of mobility at the destination?
3. What are the biggest challenges you face in terms of mobility?
4. In what way do you rely on your mobile phone to plan/manage the trip?
5. What features would make you install a mobile application that aims to help tourists get around in the destination?
6. Would you use an application as the one discussed previously?

Finally, the sessions were concluded and the participants thanked for their participation.

The audio of the sessions was roughly transcribed, leaving out unimportant deviations from the topic. The transcription thoroughly analyzed and translated into a few requirements.

3.3.2 Questionnaire

With more structured requirements formed from the previous steps, a questionnaire in the shape of *Google Forms* was created, *see Appendix B.1*.

It is difficult to conduct focus groups with many individuals, which restricts the diversity of opinions collected. This questionnaire was created in order to confirm and prioritize the ideas collected from the focus group, by applying them to a larger and more diverse sample, with the goal of getting better insight into the public's opinions.

The questionnaire was shared in social networks, by dynamic email in the University of Porto community, with international students from the Erasmus+ community, friends, and family. It was filled by a population of 254 individuals.

The questionnaire was divided into 4 sections. The first being an informational section briefly explaining the context and intent of this study in question. The remaining sections collected information on the following topics: (i) socio-demographics; (ii) tourist behavior; and (iii) interest in application features. In this last section, the participants were asked to prioritize the initial requirements according to personal preference. This step allowed the definition of well-defined features, as well as understanding who the target audience is.

3.3.3 Prototyping

The design process began with the requirements established, starting with a medium-fidelity prototype. These prototypes focus on the visual organization and content shared, and not on the aesthetic of the design. After being subject to usability testing, the prototype was slightly altered based on the feedback offered.

A second iteration began by designing high-fidelity prototypes, a realistic version of the final application. This step involves designing a set of instructions that assure consistency throughout the system, such as typography and color palette definition. This prototype was subjected to user evaluation, once again.

The prototypes were created through *Figma*. *Figma* is a free online collaborative design tool that provides illustration and prototyping capabilities, as well as code generation.

3.3.4 Usability Testing

For the proposed solution, validation is an essential part of the design process, feeding each iteration, as opposed to one single evaluation moment.

This validation was done through usability testing. The testing was held asynchronously and remotely with the assistance of *Google Forms*, and *Maze*, an online remote usability testing tool.

Seeing as there were two design iterations, there also two evaluation moments. According to Virzi, 1992 [51], the performance of usability tests with at least 5 participants is, in most cases, sufficient to identify 80% of the usability problems of an interface. In this case, the first testing session had a total of 9 participants, and the second had 13 participants (including the 9 present in the first session, and 4 new participants).

The selection of volunteers performed a set of defined tasks on the prototype shared. The relevant metrics were collected, *i.e.*, time taken, success or failure, and the amount of deviations from the desired path. In the end, they were asked to rate the overall application in terms of ease of use, ease of finding information, visual design, navigation flow, using an adaptation of the System Usability Scale. The participants also had the opportunity to leave open feedback.

3.4 Summary

This chapter formally states the problem this dissertation is trying to solve, along with the methodology adopted to approach this.

The main issues identified in Section 3.1 were the lack of clear information about public transport and the dispersion of solutions available. Therefore, the main goal of this work is to create a solution that acts as a lifeline for tourists.

Section 3.2 presents the solution proposed by this dissertation, a tourist-oriented mobile application. This mobile application aims to tackle the unaddressed issues in tourist mobility and serve as a lifeline for tourists while visiting their chosen destinations.

Finally, Section 3.3 thoroughly presents the methodology adopted. This work followed a double iteration UCD approach with repeated feedback from users, in order to achieve a high-fidelity prototype of the application. This process was divided into three phases: (i) requirements elicitation, (ii) prototyping, and (iii) evaluating. The requirements were defined based on the literature reviewed, the focus groups held, and the questionnaire shared with a large pool of potential users. There were two prototypes created, the first being a medium-fidelity prototype, and the second a high-fidelity prototype based on user feedback. Finally, the evaluation was done through usability testing.

Chapter 4

Requirements Elicitation

This chapter goes over the requirements elicitation process and the conclusions reached. Section 4.1 starts off this chapter, briefly restating some of the aspects found in the literature review. Section 4.2 describes how the focus groups were done and the conclusions reached. Section 4.3 exposes the results of the questionnaire applied. Section 4.4 describes the application modules. Finally, section 4.5 summarizes the topics mentioned in this chapter.

4.1 Introduction

The literature review process resulted in a good understanding of the relevant research topics, including an initial set of beliefs regarding the users' needs and challenges.

One of the biggest factors contributing to the inconvenience of using public transport is the lack of information. This includes clear information on the transport network, schedules, and fare prices available in multiple languages, There was also a proven desire for tourist-oriented ticketing services for public transport tickets.

Nonetheless, these are still vague ideas that needed to be explored with potential users to understand what would actually make a difference in their experiences as tourists.

4.2 Focus Groups

In order to further understand tourists' challenges and goals, focus groups with potential users were held. The focus group sessions were divided into two parts: the first consisted of filling out form A.1 for sample characterization purposes; the second consisted of semi-structured interviews.

4.2.1 Sample Characterization

The focus groups were divided into 3 sessions with a total of 11 participants. It was important to choose participants from different backgrounds, as seen in Table 4.1, and that travel for tourism with some frequency. Of the 11 participants, 8 claim to travel for tourism up to three times a year, and the rest once a year.

Regarding their comfort using online payments, 4 of the participants agreed, 5 strongly agreed and 3 remained neutral.

All participants admitted to using Google Maps for route planning, 5 of which with a lot of frequency, and 4 with some frequency.

While doing national tourism, participants travel mostly by personal transportation, *i.e.*, cars or motorbikes, and by foot. However, for international tourism, participants rely mainly on the subway, buses, trains, in addition to traveling on foot.

	Options	Percentage	No participants
Gender	Female	54.4%	n=6
	Male	45.5%	n=5
Age Group	18-24	72.7%	n=8
	25-34	9.1%	n=1
	>50	18.2%	n=2
Marital Status	Single	81.8%	n=9
	Married	18.2%	n=2
Children	0	81.8%	n=9
	1	9.1%	n=1
	>1	9.1%	n=1
Education Level	Secondary	9.1%	n=1
	Bachelor's Degree	81.8%	n=9
	Master's Degree	9.1%	n=1

Table 4.1: Focus groups — socio-demographic sample characterization

4.2.2 Semi-structured interviews

As previously mentioned, the semi-structured interviews loosely followed a script that encouraged the participants to share their past experiences regarding tourism.

Participants agreed that understanding the local public transport network and its ticketing system is challenging at times, due to the complexity of the language in which the resources are presented.

All participants admitted to relying primarily on route planners for planning their routes, checking real-time arrivals and departures, and consulting the various possible routes to where they intend to go. Some also use these services to consult fare prices when available, even though these applications usually only show the price of standalone tickets.

They attributed value in seeing their journey progress, *i.e.*, receiving updates on how many stops are left until the destination is reached.

When in foreign locations, participants shared difficulty in finding trustworthy, updated, and reliable information sources. This is due to the fact that many of the services are designed for the locals and are only available are in the countries' main language. Bad usability was another negative factor that was brought up in the solutions tried before.

Regarding the possibility of purchasing transport tickets, ten of the eleven participants showed interest, especially when calculated for each route specifically. On the other hand, simply offering important on the transport network, the different types of tickets, and where to acquire them would have a positive impact on their experience, especially if also available offline.

The extension of these informational and ticketing features to incorporate airport shuttle services and tourist activities got a positive response.

Overall, the participants demonstrated great interest in a mobile application designed for tourists, integrating ticketing and route planning with public transport and tourist activities.

4.3 Questionnaire

Questionnaire B.1 was done with the goal of confirming the beliefs resulting from the focus groups with a larger population, as well as understanding who the target audience is.

4.3.1 Sample Characterization

The questionnaire reached 254 people. Once again, an effort was made to incorporate the opinions of individuals from different backgrounds, as seen in Table 4.2. It is important to note that, despite this effort, the participating demographic of this inquiry is biased towards the [18-24] age group. This time around, we also included people from different nationalities, around 20.5%.

Regarding the type of tourism, the majority does mostly national tourism (48.2%), as seen in Figure 4.1. However, the percentage of individuals doing national and international tourism in similar frequency is very similar (45.7%).

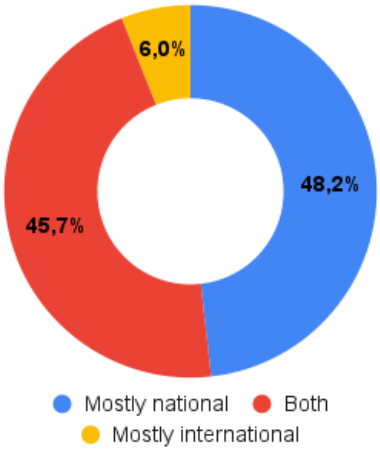


Figure 4.1: Type of tourism

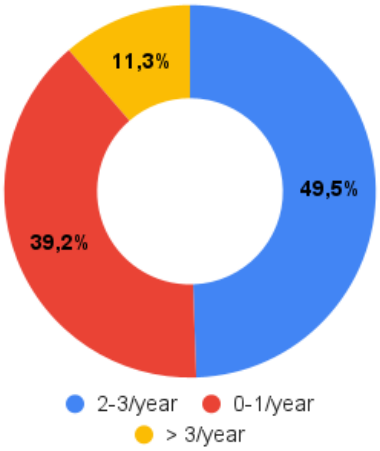


Figure 4.2: Frequency of tourism

As can be been in Figure 4.1, the participants usually travel once up to three times a year, with a minority of 11.3%travelling more than thrice a year.

In this pool of potential users, the tendency is to use a combination of public and private transport in their destination (40.6%), as seen in Figure 4.3 (a). The remaining population opted for either mostly public transport or mostly private transport, with an insignificant difference of around 1.4% (n=4). Figure 4.3 (b) shows the distribution of public and private transport usage by age group. It can be observed that, within older age groups, the tendency goes more towards private transport. However, since this study includes significantly more individuals from the [18-24] age group, comparison between this group with the remaining is limited.

People tend to travel more with family, then friends, partners and alone, in this particular order. Figure 4.4 shows this distribution divided by age group. There can be observed a small shift in this order in the [35,50[range, where individuals travel more frequently with their partners than their friends.

4.3.2 Discussion

The previous section depicts the target audience of this work. Although a significant percentage admitted to using public transport, the participants using private transport still represents a big portion. This reinforces the idea that the solution in question needs to, not only satisfy the needs of the current users of public transport but also attempt to encourage the remaining population. With this being more common in older generations, this can be achieved by designing a solution that can attract them by making it easy to use and accessible.

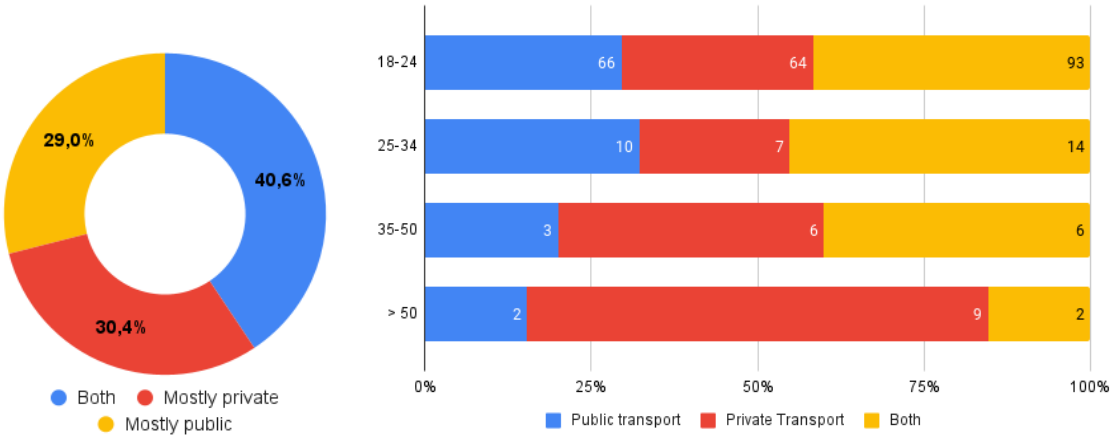
The result of the ratings of the potential features is represented in Table 4.3 by descending order of priority. These represent complex, high-level features that can be divided into more specified requirements. With the color green are the most wanted features with a score above or equal to 4.5. With orange are the features rated between 4 and 4.5. Lastly, with red are the features in rating lower than 4.

	Options	Percentage	No participants
Gender	Female	59,8%	n=152
	Male	40.2%	n=102
Age Group	<18	0.4%	n=1
	18-24	78.8%	n=223
	25-34	11%	n=31
	34-50	5.3%	n=15
	>50	4.6%	n=13
Marital Status	Single	88.7%	n=251
	Married	8.8%	n=25
	Non-marital partnership	1.4%	n=4
	Divorced	1.1%	n=3
Children	0	91.2%	n=258
	1	2.8%	n=8
	>1	6%	n=17
Education Level	Secondary	31.4%	n=89
	Bachelor's Degree	38.9%	n=110
	Master's Degree	27.9%	n=79
	PhD	1.8%	n=5
Nationality	Portugal	79.5%	n=225
	Other European countries	16.3%	n=46
	Africa	0.7%	n=2
	South America	3.5%	n=10

Table 4.2: Questionnaire — socio-demographic sample characterization

Overall, all features spiked interest from the participants. However, for the purpose of narrowing the scope to the most desired featured, we decided to consider only the ones rated above 4, the first twelve.

4.4 Mobile Application Modules



(a) Absolute percentages (b) Distribution by age group

Figure 4.3: Type of transport used in tourism

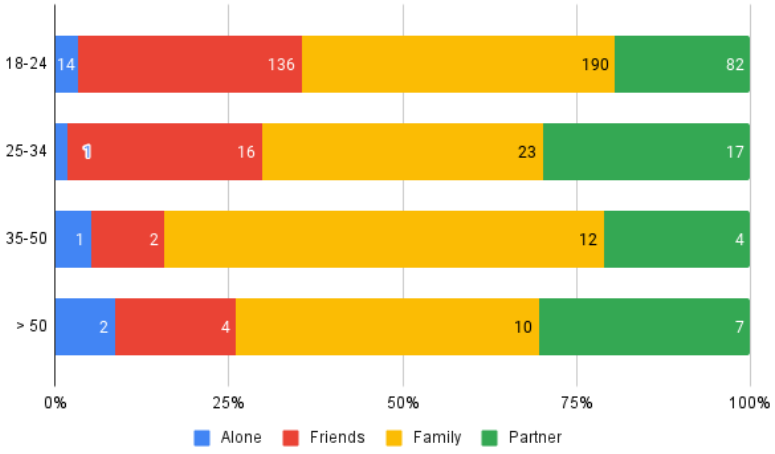


Figure 4.4: Nature of companionship while doing tourism

The mobile application is divided into three modules: (i) route planning, (ii) mobile ticketing, and (iii) information on public transport and tourist activities.

4.4.1 Route Planning

The route planning features are much like the ones described in Chapter 2. They offer users support in getting from *point A* to *point B* — related to features 1, 4, 9, 6, and 8.

The user can choose the best-suited route from multiple options according to their goals, *i.e.*, duration, price, or vehicle changes. This module offers directions and real-time navigation, showing each transport mode needed, their real-time arrival and departure times, and possible line or vehicle changes.

	High-level features	Score
1	Public transport real time arrival information	4,7
2	Information on public transport fares (e.g., types of tickets, prices, deals)	4,7
3	General information on how each transport mode works (e.g., how/where to board)	4,5
4	Integrate the many transport modes and companies	4,4
5	Information on where to buy and validate travel tickets	4,4
6	Mobile tickets and route planner integration — buy and validate the best travel tickets corresponding to the route planned	4,3
7	Information on airport transfer options and tickets	4,3
8	Buy and validate airport transfer tickets through the mobile application	4,2
9	Follow journey step by step — see the current station/stop and the remaining ones; see vehicle or line changes	4,1
10	Information on touristic sites (e.g., opening hours, how/where to buy tickets)	4,1
11	Suggestion of touristic sites to visit and alerts on points of interest throughout a journey (e.g., notifications of what you are passing by while on the bus)	4,1
12	Information on services useful to tourists (e.g, lockers to store bags temporarily, gas stations, parking lots)	4.0
13	Suggestion of popular routes taken by tourists	3.9
14	Creating a custom route given a series of interest points given by the user, including necessary tickets and information on the public transport needed	3,8

Table 4.3: Potential features ordered by user preference

4.4.2 Mobile Ticketing

This module is responsible for the purchasing and activation of tickets for public transport or tourist activities. — related to featured 6, and 8.

The user is able to consult the type of tickets available, including special deals, check their purchased tickets, and activate or re-purchase them.

This module is also intertwined with the route planning module, suggesting the best-suited tickets for a specific route.

4.4.3 Tourist Guide

The tourist guide features are the ones that are able to replace the traditional paper-based guides.

Similarly to the solutions described in Chapter 2, this includes suggestions on tourist activities by proximity, relevance, or other factors — related to features 10 and 11. Additionally, useful

services commonly sought by tourists are included, such as locker services to store luggage, ATMs, among others — related to feature 12.

On the other hand, it also goes beyond that and incorporates general information on public transport, *i.e.*, how the network is divided, the ticketing schemes in place, the price of tickets, the proper way to ride each transport mode, timetables — related to features 3, 5, and 7).

4.5 Summary

This chapter went over the requirements elicitation process followed in order to define the requirements of the proposed application.

With the initial ideas gathered from the literature review, focus groups were held with 11 individuals from diverse backgrounds. A big negative aspect identified in regards to using public transport was the lack of clear and reliable information sources. The participants demonstrated interest in mobile ticketing for public transport.

A questionnaire was sent to 254 people from diverse backgrounds, with pre-established requirements which the users were asked to rate according to their preferences. This step defined the high-level features desired in this application. It also allowed concluded that the current users of public transport in tourism are mostly younger generations.

The application can be divided into three intertwined modules: a tourist guide, a route planner, and a mobile ticketing module.

Chapter 5

PocketCity Protoype

This chapter goes over the interfaces proposed for the solution discussed previously. Section 5.1 introduces this chapter and gives context to what is presented in the following sections. Section 5.2 attributes credit to the tools used to create the interfaces. Section 5.3 presents key elements present in the prototypes. Section 5.4 presents and describes the interfaces developed. Finally, 5.5 summarizes the contents discussed in this chapter.

5.1 Introduction

In the previous chapter, it was reached a conclusion in the requirements of the mobile application. It incorporates three main services: mobile ticketing, route planner, and tourist guide features. This chapter goes over the translation process of these concepts into mobile interfaces, and formally presents "*PocketCity* - the go-to travel buddy for tourists".

As previously mentioned, the intent of this solution is to be adaptable to many mobile ticketing technologies, therefore not focusing on any specific one. Nevertheless, QR-codes were used, as an example, to describe a ticketing scheme.

The prototyping process consisted of two design iterations The first resulted in a medium-fidelity prototype that focuses only on the content and organization. The second resulted in a high-fidelity version that also pays attention to color, typography, and aesthetics. Both were subject to redesigning based on the feedback of potential users.

5.2 Tools

The prototypes presented in the following sections of the chapter were created through *Figma*. *Figma* is a free online collaborative design tool that provides illustration and prototyping capabilities, as well as code generation.

The interfaces make frequent use of icons to visually represent an idea that is being transmitted in a way that is intuitive and easy for the user. The icons used are from two free open-source icon libraries made for UI designers and developers, namely *Font Awesome* [2] and *Feather* [1].

5.3 Elements and Components

The aesthetic of the *PocketCity* interfaces was kept minimalist and modern.

The colors chosen to represent the application were neutral colors, white and greys, and two highlight colors, black and dark teal, to convey clickable elements. A rounded theme is carried through the interfaces, using rounded input fields and buttons.

The logo used for the application is a simple draft acting as a placeholder for the concept of the application.

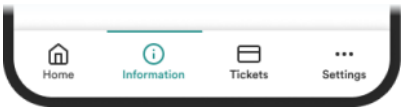


Figure 5.1: Bottom navigation bar

The application's screen navigation flow is centered at the bottom navigation bar, allowing access to the four main screens: Home, Information, Tickets, and Settings, *cf. Figure* 5.1. These will be further discussed in the following section.

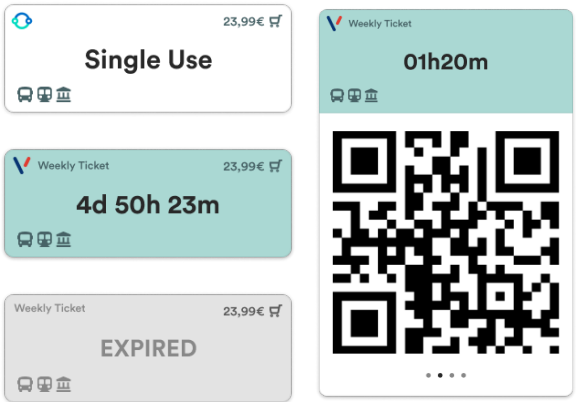


Figure 5.2: Tickets

Another important component used repeatedly throughout the prototype is the ticket. The ticket appears minimized or expanded, *cf. Figure* 5.2. It can have three states: inactive (represented by white background), active (represented by teal background), and expired (represented by faded

colors). They indicate the transport company, the type of ticket, the time left (if active), and the transport modes included in the ticket.

5.4 Screens

This section presents the different stages prototypes, showing and explaining certain changes. The changes described were made as a consequence of feedback given from potential users, resulting from the first round of usability testing, which will be discussed deeper in the next chapter.

5.4.1 Onboarding

The onboarding is the guide-through process of introducing your application to the users. The onboarding process reinforces the context of the application and highlights benefits and features.

The screens presented in Figure 5.3 represent the onboarding process for *PocketCity*. These were only included in the second prototyping iteration as a product of suggestions offered by potential users. These are important for a user to get acquainted with the application and get an insight into its purpose. The user can skip this step if desired.

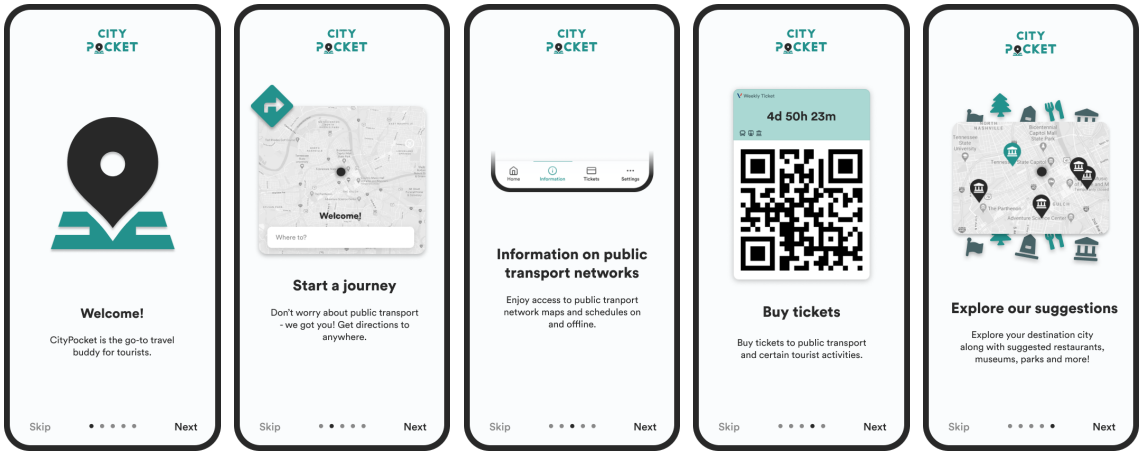
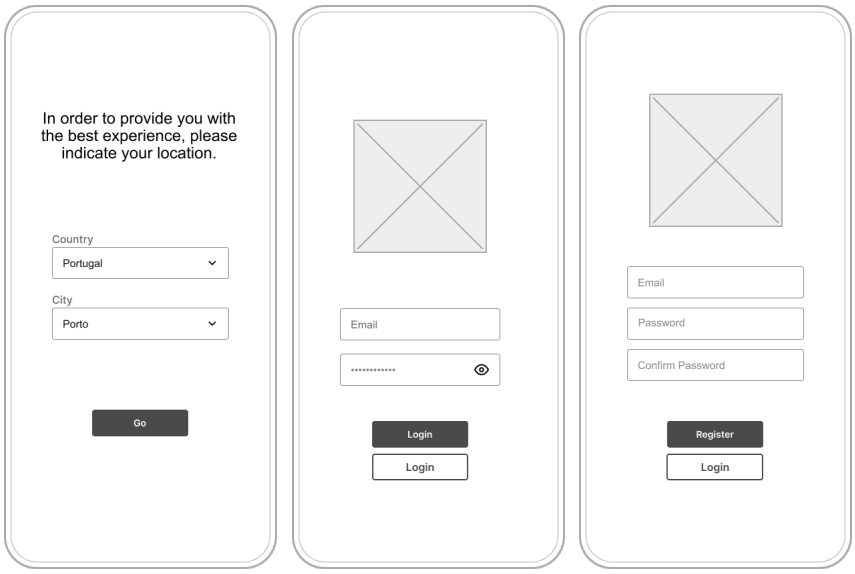


Figure 5.3: Onboarding process

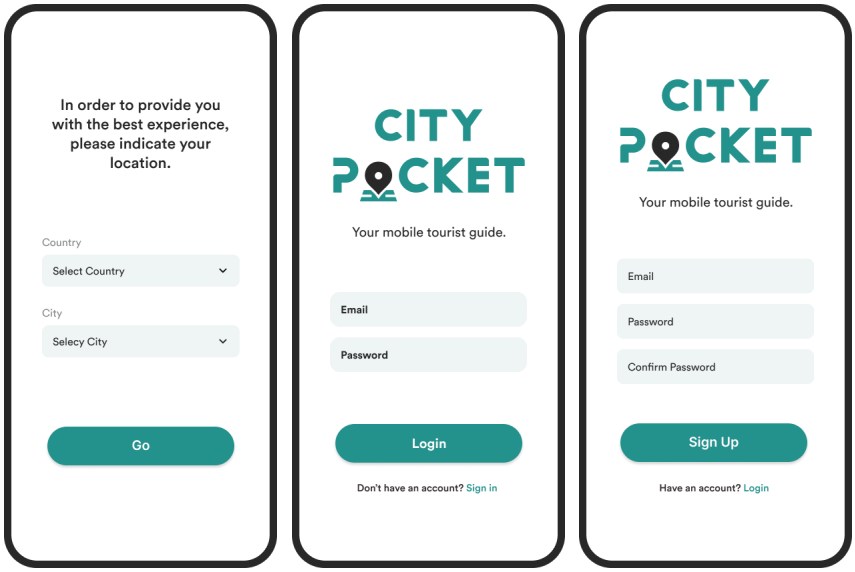
5.4.2 Login / Register

After going through the onboarding screens, the user must choose the desired location they will be or are visiting. Since the mobile ticketing portion of the application should be reviewed case by case and might require certain partnerships with local entities, this choice allows the application to adapt as needed.

The login and registering process is quite simple and familiar, by simply asking the user to enter their credentials (email and password), *cf. Figure* 5.4.



(a) Medium-fidelity



(b) High-fidelity

Figure 5.4: Login and register

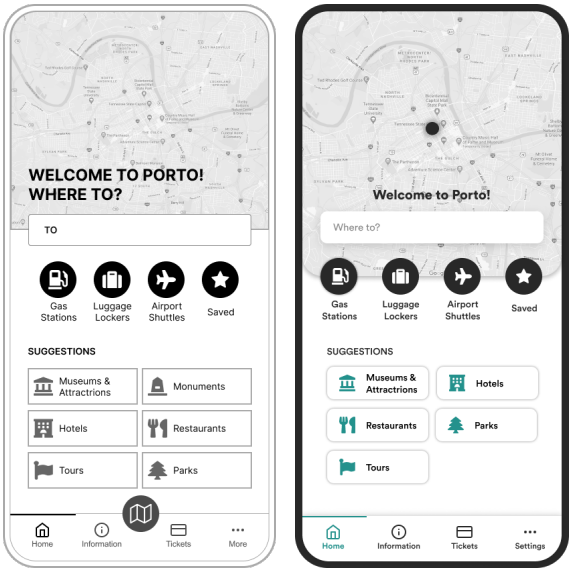
5.4.3 Home

After successfully logging in, the user is redirected to the Home screen, *cf. Figure* 5.5. This is the main screen, being the default when the application is open. It is through this page that the user can access the tourist suggestions and navigation features.

This page contains a map centered on the current location of the user with an input field where the user can enter where they wish to go. This leads to the navigation screens, presented later in section 5.4.8. In the medium-fidelity prototype, this was also possible through the middle button in the navigation bar. However, it was removed to simplify the interface as a result of user feedback.

Below that, there are presented a few shortcuts of places or services useful to tourists, namely, gas stations, luggage lockers, airport shuttles, and saved locations. When clicked, a full-sized map is shown with the nearest locations of the action selected.

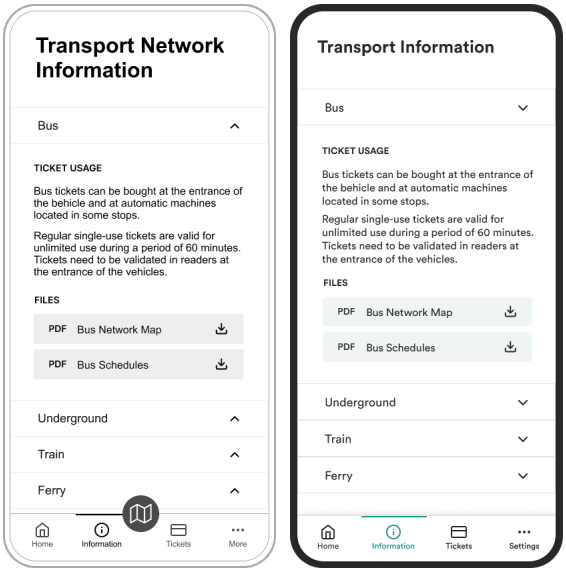
Lastly, it displays categories of tourist-related activities that, when clicked, generates a similar effect as the shortcuts, as displayed in section 5.4.7.



(a) Medium-fidelity (b) High-fidelity

Figure 5.5: Home

5.4.4 Information



(a) Medium-fidelity (b) High-fidelity

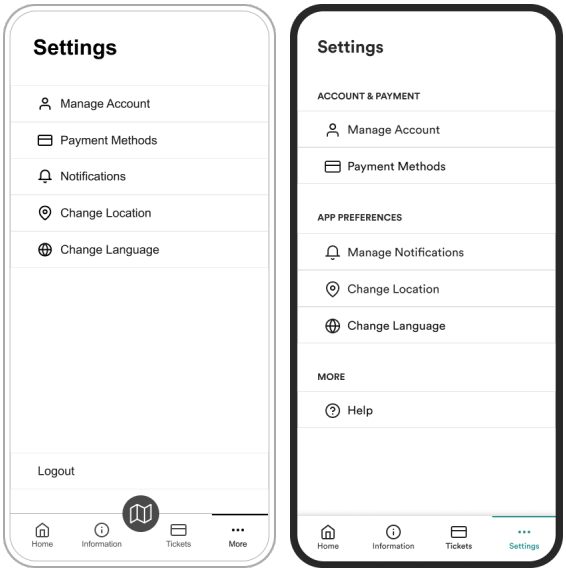
Figure 5.6: Information on the transport network

The Information screen contains all the crucial information one would need to use public transport comfortably, *cf.* *Figure* 5.6. It explains how to use each transport mode, how and where tickets can be purchased and validated (outside of the application), and offers network maps and timetables that can be downloaded. This is just the beginning of what could be shared, a lot more useful information can be added. This information would be available on and offline.

5.4.5 Settings

The Settings screen is quite simple, *cf.* *Figure* 5.7. As the name indicates, it allows the user the change settings related to the account and payment methods and the application preferences. This is where the location set at the beginning can be changed, as well as the preferred language.

It also offers a place where the user can find help for certain aspects of how the application functions.



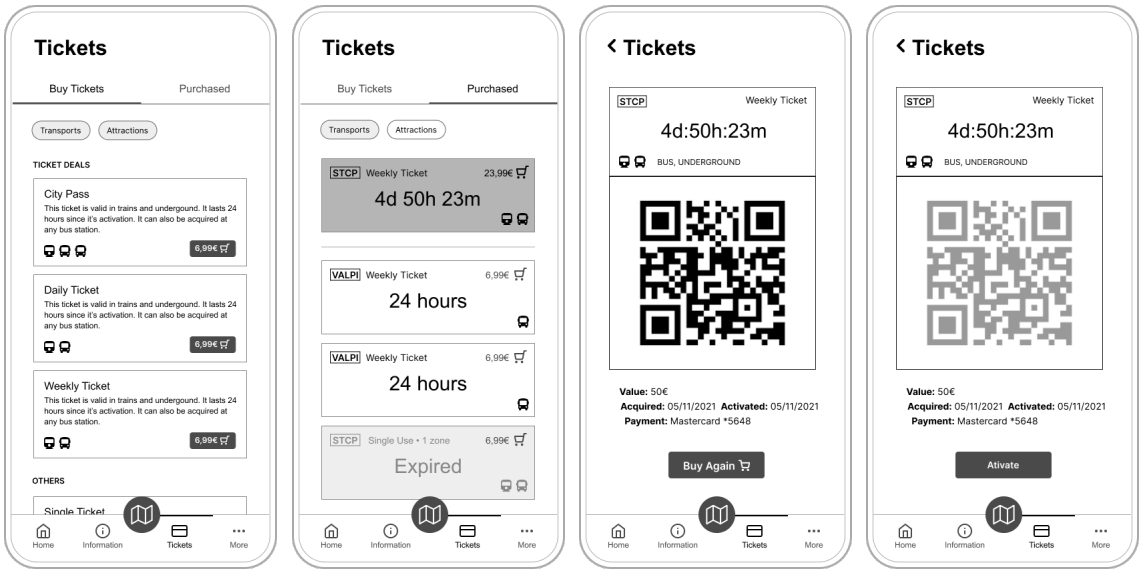
(a) Medium-fidelity (b) High-fidelity

Figure 5.7: Settings

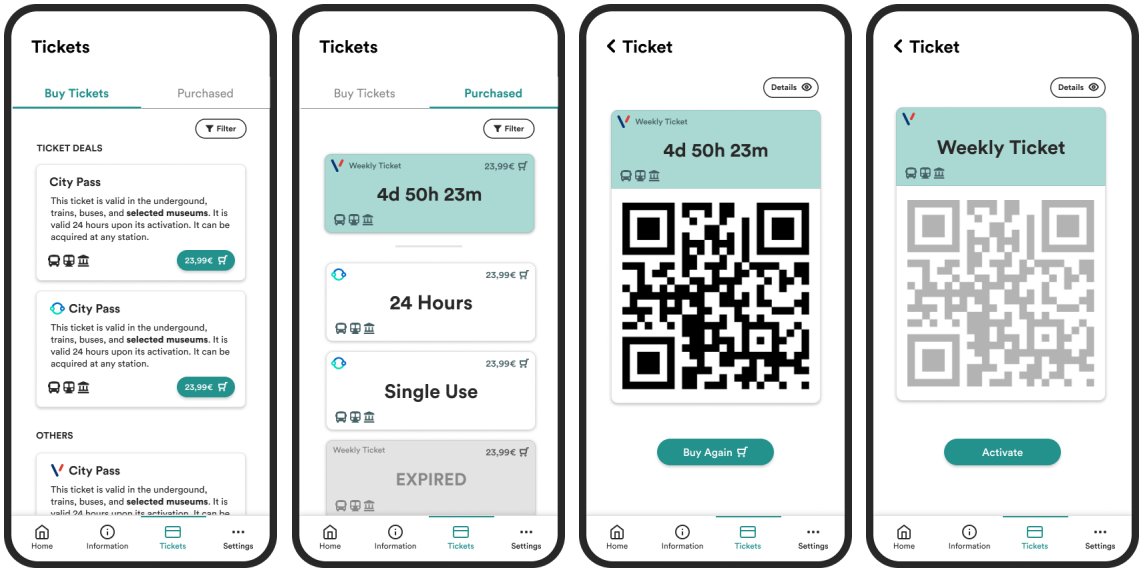
5.4.6 Tickets

The Tickets screen is the starting point for actions to do with ticketing, *cf.* *Figure* 5.8. This interface is divided into two sections, 'Buy Tickets' and 'Purchased', that are alternatively shown according to the tab selected.

The first tab presents the diverse ticket options which the user can filter by price, the context of use, among others. For each option, there is a description, the transport modes in which it can be used, and the price of the ticket. Through the price button, the user can purchase the chosen ticket.



(a) Medium-fidelity



(b) High-fidelity

Figure 5.8: Tickets

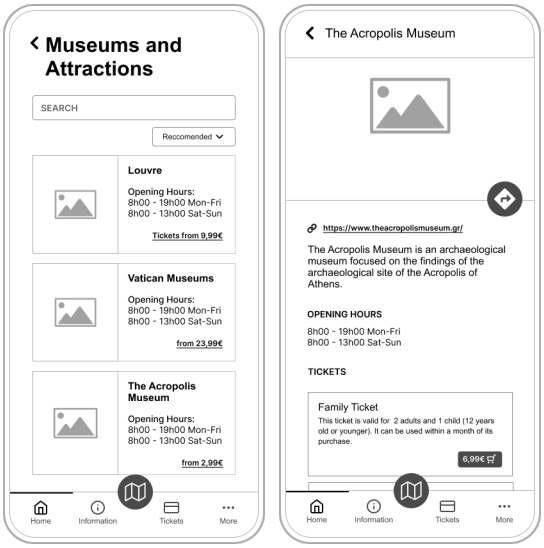
The second tab displays the minimized version of the already purchased tickets. Similarly to the previous tab, these can also be filtered as desired. By clicking each ticket, the full version of the ticket is displayed, and the user can activate or repurchase it.

5.4.7 Suggestions

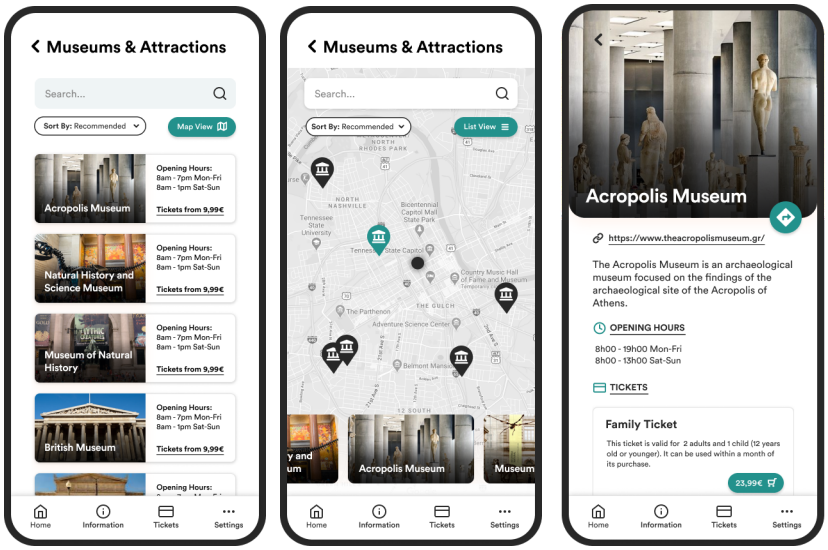
The suggestion screens are the result of clicking on the activities suggested in the Home screen, *cf. Figure* 5.9.

A list of suggestions related to the selected activity is displayed and can be sorted and filtered by certain criteria. Notice that in the high-fidelity prototype, it is also possible to see these in a map with the distance to the user's current location represented. This was another addition made as a product of the feedback received from potential users.

Each suggestion has its own dedicated screen with details such as a brief description, a URL to their website, and its opening hours. From this screen, it is also possible to buy tickets for the activity, if applicable, and get directions to it.



(a) Medium-fidelity



(b) High-fidelity

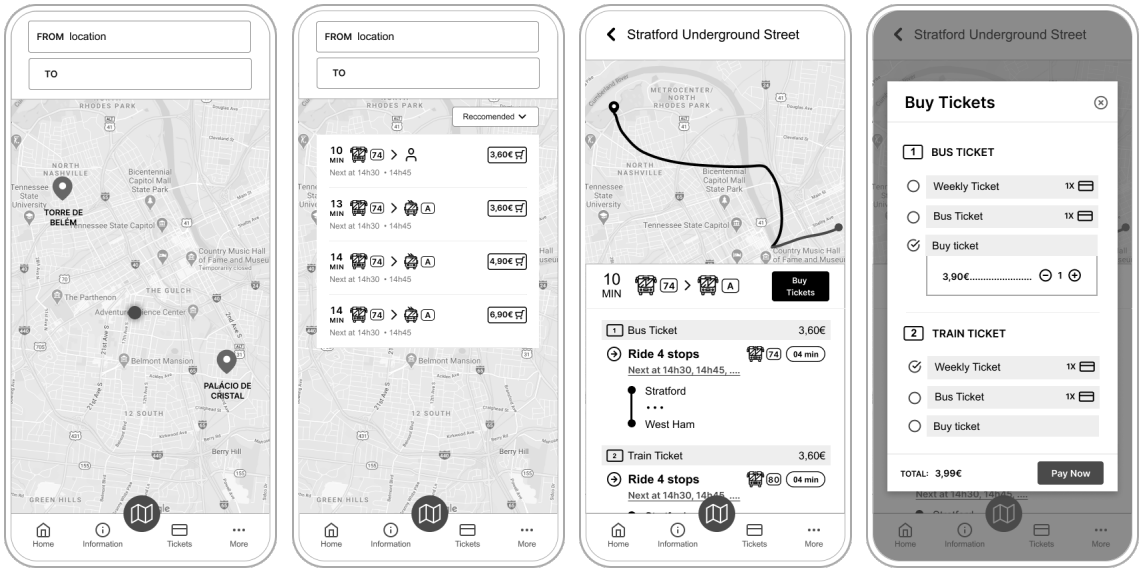
Figure 5.9: Tourist-related suggestions

5.4.8 Navigation

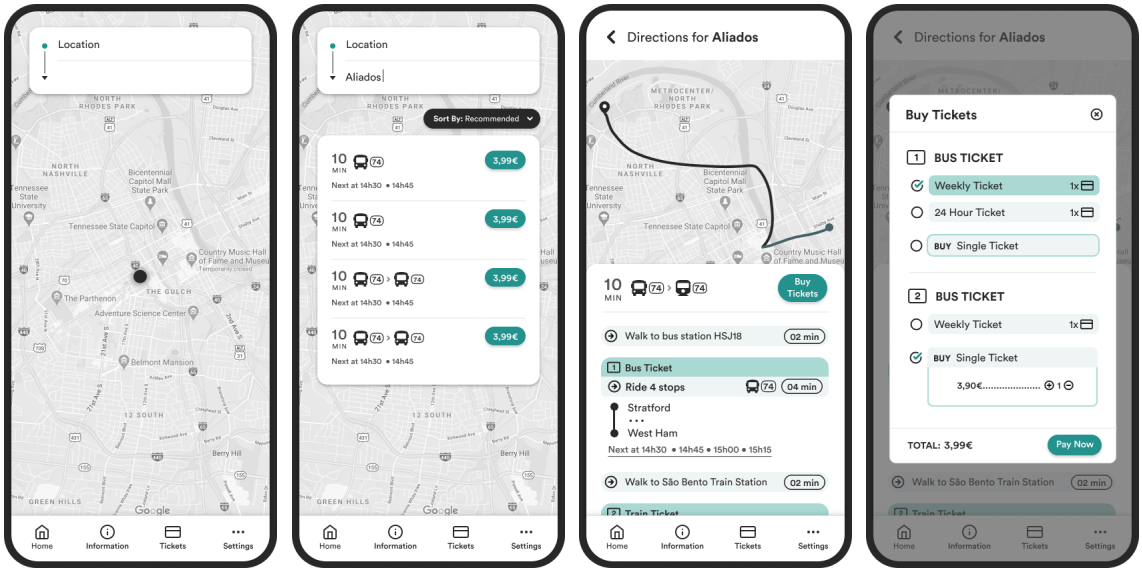
The navigation screens are the ones directly related to route planning, *cf.* *Figure* 5.10.

The user chooses the location they wish to travel to and are able to choose from various options that vary in duration, price, and vehicle changes.

Each route suggested can be viewed in full detail on a separate screen, which also allows the user to buy the necessary tickets for the trip. The tickets are suggested according to the route, taking into account the ones previously purchased by the user.



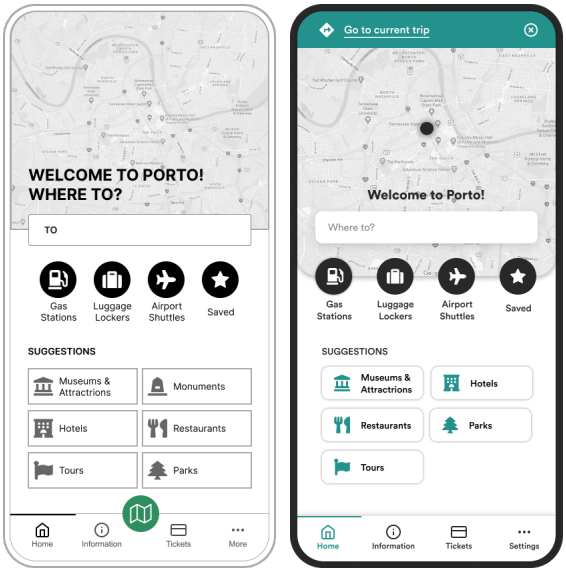
(a) Medium-fidelity



(b) High-fidelity

Figure 5.10: Navigation screens

After choosing the route that best suits them, the navigation starts, giving real-time, step-by-step directions.



(a) Medium-fidelity (b) High-fidelity

Figure 5.11: Status representation of ongoing trip

When the user opens the application with an ongoing trip, this status is constantly presented to the user, *cf. Figure* 5.11. There was a clear change in the representation of this state changed between iterations, due to user feedback further explained in the next chapter.

5.5 Summary

This chapter formally introduces ”*PocketCity* - the go-to travel buddy for tourists“. It acts as a tourist guide, route planner, and ticketing system for tourist activities and public transport.

The interface of the application is organized into four main screens, namely, Home, Information, Tickets, and Settings, that can be accessed through the bottom navigation bar. Through the Home screen, the user can access the suggestions and navigation features. The interfaces follow a minimalist and coherent design.

Certain changes made from the first to the second iterations were displayed, such as the addition of onboarding screens, a map view of the suggestions, and the removal of a central button on the bottom navigation bar. These changes were the product of feedback received from potential users in the usability tests that will be thoroughly explained in the following chapter.

Chapter 6

Usability Testing

This chapter describes the validation of this work. Section 6.1 introduces the validation approach adopted and discussed throughout the chapter. Section 6.2 indicates the tools used in this stage. The three steps of usability testing are presented in sections 6.3, 6.4, and 6.5. Finally, Section 6.7 summarizes what was discussed in this chapter.

6.1 Introduction

In UCD, frequent user evaluation is a very important step, being the final step of each iteration, and providing the feedback necessary for beginning the next. For this work, the approach adopted to measure the satisfaction of potential users was usability testing.

There were two moments of testing, each corresponding to the end of an iteration. The first round of testing was done with the medium-fidelity prototype, and it included 9 people. The second was done with the high-fidelity prototype, and it included 13 people.

The usability evaluation was divided into four steps. Firstly, socio-demographic data was collected from the participants, with form C.1. The second stage was the task assessment, where the participants were first presented with the prototype in evaluation. They were asked to perform a set of tasks upon the prototype. In the third stage, the participants responded to some statements

based on the System Usability Scale, considering the interaction that took place. Finally, the participants had the opportunity to give some open feedback.

Similarly to the requirements elicitation process, there was an attention to the background diversity of the participants, as seen in Table 6.1. This step is important to guarantee that the work developed satisfies as many people as possible and does not disregard certain age groups, for example.

		Iteration 1		Iteration 2	
	Options	Participants	Percentage	Participants	Percentage
Gender	Female	n=3	33.3%	n=7	53.8%
	Male	n=6	66.7%	n=6	46.2%
Age Group	<18	n=1	11.1%	n=1	15.4%
	19-24	n=5	55.6%	n=8	61.5%
	25-34	n=2	22.2%	n=2	15.4%
	35-50	n=0	0%	n=1	7.7%
	>50	n=1	11.1%	n=1	7.7%
Education Level	Secondary	n=2	22.2%	n=2	15.4%
	Bachelor's Degree	n=1	11.1%	n=3	23.1%
	Master's Degree	n=3	33.3%	n=4	30.8%
	PhD	n=3	33.3%	n=3	15.4%

Table 6.1: Usability Testing — socio-demographic sample characterization

6.2 Tools

The usability testing was done remotely and asynchronously with the help of two online tools.

The overall process was hosted in *Google Forms*. The form created guided the participants, explaining each step along the way.

The task assessment was done in *Maze*, an online tool that allows remote usability testing. It works by importing the developed *Figma* prototypes, creating missions for each task, and indicating the valid paths to fulfill it. It records each session and registers the following metrics for each mission:

Average Duration Average time per user to complete the mission.

Misclick Rate Average (%) of clicks outside the intended hotspots.

Success Rate Average (%) of mission completed by the expected path.

Bounce Rate Average (%) of testers who gave up or left the mission.

These metrics attribute a usability score to each screen, Screen Usability Score (SCUS).

$$SCUS = MAX(0, 100 - (DOR * dW) - (MCR * mW) - (MIN(10, MAX(0, (AVGD - 5)/2))))$$

DOR	drop-off and bounce rate
dW	DOR weight; The dW equals 1 point for every drop-off / bounce
MCR	misclick rate
mW	MCR weight; The mW equals 0.5 points for every misclick
$AVGD$	Average Duration in seconds

Furthermore, it uses these metrics to calculate the usability for the mission as a whole, the Mission Usability Score (MIUS).

$$MIUS = DSR + (IDSR/2) - avg(MC_P) - avg(DU_P)$$

DSR	Direct Success Rate
$IDSR$	Indirect Success Rate
MC_P	misclick penalty = $MCR * 0.5$
DU_P	duration penalty = $(MIN(10, MAX(0, (AVGD - 5)/2)))$

With the MIUS score, the platform calculates an average score for the overall system in evaluation.

$$MAUS = avg(MIUS)$$

$MIUS$ Mission Usability Score

Since every single action from the user is recorded, it is able to generate heatmaps of where the users clicked on each interface.

These tools and metrics allow for a deeper analysis of the interfaces, pinpointing the mission, screen, and even area of the screen users have trouble navigating.

6.3 Task Assessment

The step of the validation represented the first contact the users had with the application prototype. The task assessment focuses on effectively measuring the user's interaction with the interfaces, determining where they are having difficulty and, consequently, what could be improved.

The participants were asked to perform a set of tasks on the prototype presented, as follows:

1. Go through the onboarding screens.
2. Register and Set-Up: Register on the application for the first time and set up the city you will be/are visiting.
3. Buy the "City Pass" ticket
4. Show a purchased activated ticket: Open a ticket previously. purchased and activated in order to show to a hypothetical QR code reader.
5. Buy a ticket for a suggested museum: Go to the suggestions and buy a ticket to the nearest suggested attraction.
6. Get directions and start a trip to "Aliados": Choose the quickest way to 'Aliados' and opt to use the City Pass ticket already purchased.
7. Show and activate ticket from the ongoing trip: Go to the ongoing trip directions screen and activate the ticket.
8. Change the location: Change the country and the city in which the application is functioning.

There was only one modification between tasks, which was added only in the second iterations due to feedback given by the users. Besides this task, the rest remained the same, so it would be possible to establish direct comparisons between them.

		Task no								Total Score
		1	2	3	4	5	6	7	8	
1st	Avg Duration (s)	-	4.2	5.9	5.9	4.4	4.9	4.6	2.3	81
	Misclick Rate (%)	-	24.4	20.7	4.3	12.8	16.8	8.7	8.8	
	Success Rate (%)	-	100	55.6	75.0	100	62.5	10	75.0	
	Bounce Rate (%)	-	0.0	33.3	0.0	0.0	0,0	0.0	12.5	
	Usability Score	-	88	50	86	94	73	96	77	
2nd	Avg Duration (s)	4.2	1.9	2.9	2.5	10.3	6.9	2.3	2.3	90
	Misclick Rate (%)	4.8	6.6	0.0	2.7	12.2	18.4	0.0	5.3	
	Success Rate (%)	100	92.3	83.3	100	91.7	100	66.7	100	
	Bounce Rate (%)	0.0	0.0	8.3	0.0	8.3	0.0	33.3	0.0	
	Usability Score	98	93	88	99	84	90	67	97	

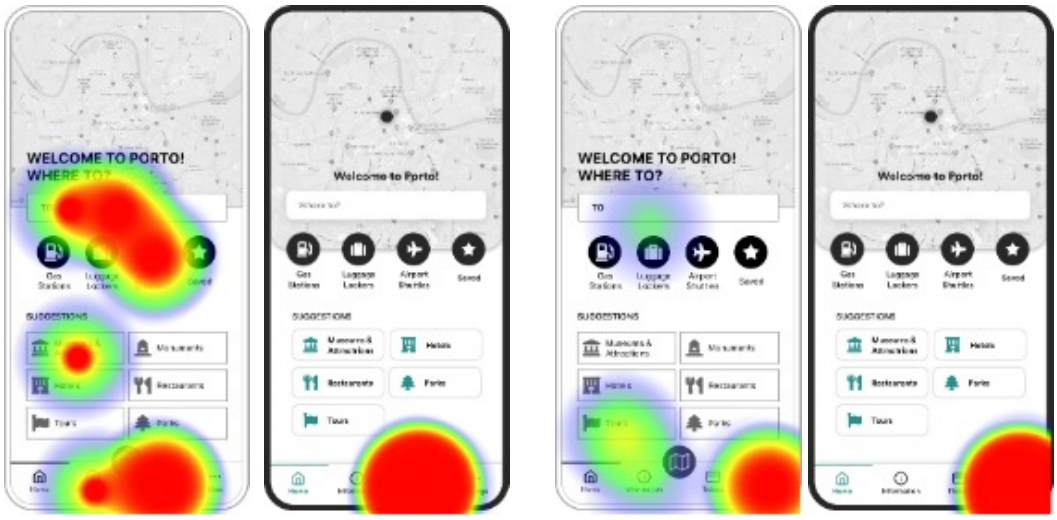
Table 6.2: Metrics registered in the task assessment

The metrics recorded in this step for both iterations are displayed in Table 6.2. The table applies the same color system as *Maze*, in that red represents a bad result, orange represents a result that could be improved, and the green represents a great result.

It is important to note that the first task is only present in the bottom half of the table, corresponding to the second iterations. This was due to user feedback that will be reviewed in Section 6.5.

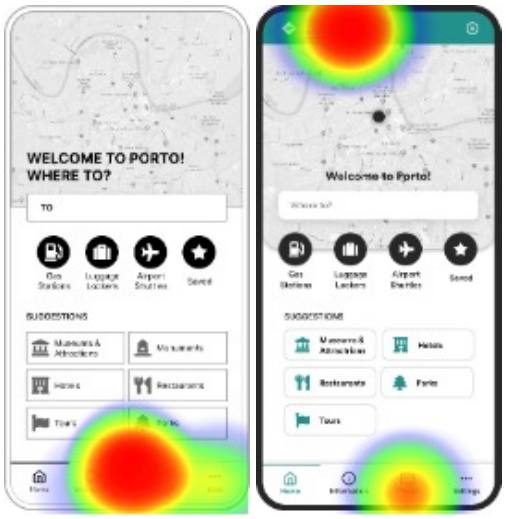
The overall usability score obtained in the first iteration was relatively good. However, four tasks could have scored better, namely the ones highlighted orange (3, 4, 6, and 8).

The second iteration achieved a higher overall usability score, meaning that, in general, the changes made between each iteration made the experience easier for the participants. Most of the mistakes and hesitation were caused on the Home screen, meaning that users struggled most in finding the starting point of the tasks.



(a) Task 4 (b) Task 8

Figure 6.1: Heatmaps of tasks with increasing score



(a) Task 7

Figure 6.2: Heatmaps of tasks with decreasing score

All tasks outlined above have improved significantly, changing to a green highlight. On tasks 4 and 8, specifically, this was justified by choosing a more direct path by users, clearly visible in the heatmaps generated, *cf. Figure* 6.1.

On the other hand, the score of task 5 decreased slightly, and task 7 suffered a big decline, shifting to a red highlight. The changes on task 7 are visible in the heatmaps by observing the dispersion of the user interaction, *cf. Figure* 6.2, meaning there were more mistakes made to reach the goal. This might have been caused by the change made in the visual representation of an ongoing trip, which was triggered by the removal of the central button. Contrarily to task 7, the decline in task 5 can't be attributed to a single aspect. Overall, all but the Home screen achieved a better score SUS. On the other hand, the average duration was significantly longer. Although task 5 was almost equivalent in each iteration, the second time around, there was an addition of a map view, making the user choose the nearest suggestion instead of a random one. An aspect that may have contributed to this result was the omission of this indication from the task headline. This might have lead to confusion and mistakes when reading the task headline only.

6.4 System Usability Scale Adaptation

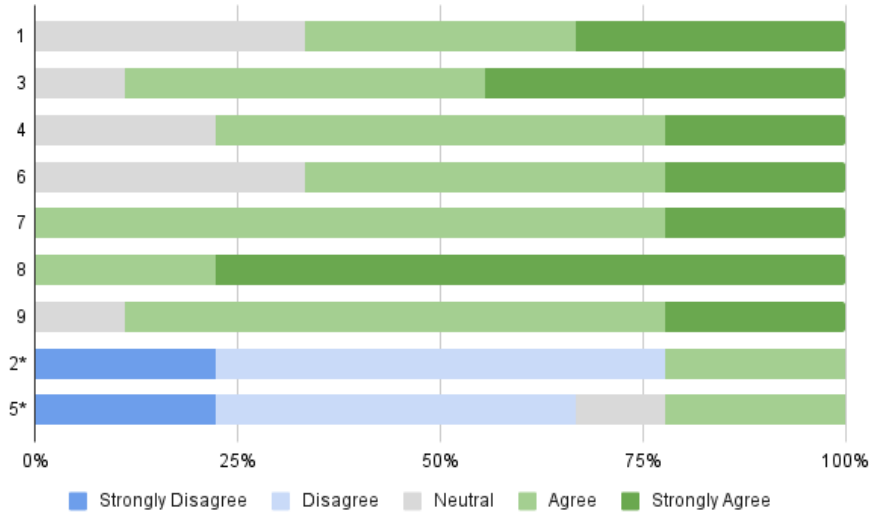
After completing the tasks, the participants went back to the form to respond to the remaining questions. The adaption of the SUS adopted consisted of the following statements:

1. I think the application was easy to use.
2. I think that I would need support to be able to use this application.
3. I think the application is well organized.
4. I could get the information quickly.
5. I found it difficult to keep track of where I was in the application.
6. I think that most people would learn to use this application very quickly.
7. I think that I would like to use this application frequently.
8. I think the application is useful.
9. I found the application pleasant to use.

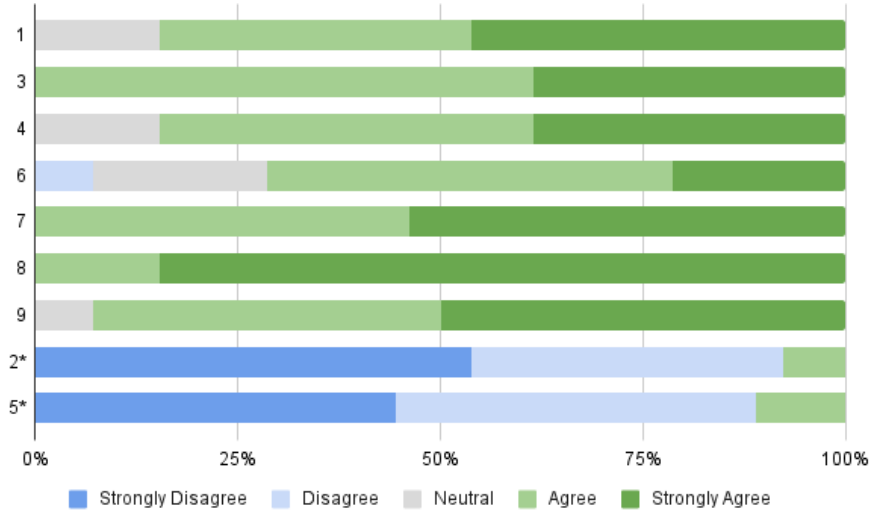
Of the nine statements, the second and fifth are considered negative statements, while the rest are considered positive statements.

The participants were asked to rate these statements regarding their level of accordance, from 'Strongly Disagree' to 'Strongly Agree'. For the positive statements, the ideal opinion is 'Strongly Agree', and the opposite for the negative statements, 'Strongly Disagree'.

Figure 6.3 demonstrates the distribution of the opinions given in iterations one and two, respectively. From the first to the second graph, there is an overall slight growth of green in the positive statements, corresponding to accordance. In the negative statements, the blue, corresponding to disagreement, increased not only in area but also in intensity. This signals an improvement in the opinions of the participants on the interfaces presented in the task assessment.



(a) 1st iteration of usability testing



(b) 2nd iteration of usability testing

Figure 6.3: Opinions collected for the adaptation of the SUS

For more quantitative analysis, the opinions were given numerical scores, based on the original algorithm of the SUS. Each opinion option has a score worth a minimum of 1 ('Strongly Disagree') and a maximum of 5 ('Strongly Agree'). For each positive statement, an average score is given based on the scores attributed by each participant decremented by one (avg(P_score - 1)). For

each negative statement, an average score is given based on the difference between the highest score and the score attributed by each participant (avg(5 - P_score)). In the end, these scores are summed and normalized to 100. The results of this algorithm are displayed in Table 6.3.

	Statement no									Total
	1	2	3	4	5	6	7	8	9	Score
1st	4,00	3,78	4,33	4,00	3,67	3,89	3,59	4,78	4,11	75,31
2nd	4,31	4,38	4,38	4,23	4,15	3,92	4,54	4,85	4,85	85,04

Table 6.3: SUS adaptation

Regarding the total score obtained, a score below 50 represents a bad result, a score in the range]50,75[is a mediocre to good result, and a score in the range [75,100] represents a great result. Having said that, it is possible to conclude that the total score obtained in the first iteration already represented a great, having only four statements rated below 4. In the second iteration, each statement score improved, consequently improving the total score. Once again, this proves that the chances adopted between the iterations effectively improved the user experience and satisfaction.

6.5 Open Feedback

The previous sections were able to quantitatively measure the usability and evolution of the prototype developed. This step focuses on a qualitative evaluation approach.

The users were asked a set of four optional questions that allowed them to openly offer constructive criticism.

1. ”What did you like the most? “

In the first iteration of testing, the most mentioned aspects were the design and organization of the interface (n=4), as well as the ticketing based on the route (n=3). The participants also enjoyed the integration of the various features in one single application, the overall ticketing service, and the integration with tourist activities.

In the second iteration of testing, the most mentioned aspect was not only the organization of the interface but also the modern and aesthetically pleasing design (n=7). The participants complemented the diverse set of features included and their integration, more specifically with ticketing.

2. ”What did you like the least? “

The biggest concern shared between the participants in the first iteration was that, at times, all the information could get confusing, and that the Home screen was a bit crowded (n=3). There were conflicting opinions on the sizing of icons used to represent the transport modes, and one participant worried about the QR code size being too small. Finally, there was a suggestion in stronger highlighting the purchased tickets matching the route in question.

In the second iteration, the only strong opinion shared by three participants was that ticketing could sometimes be confusing. There was one participant that had trouble understanding the purpose Information tab in the bottom navigation.

3. ”What is missing or could be improved? “

In the first iteration, three participants shared the opinion that the application should include an onboarding or small tutorial of the application interfaces. Some other suggestions were the addition of a map view of the suggestions and information on the accessibility of the stops or stations.

In the second iteration, most participants did not have anything else to add. However, interesting features pointed out were a section containing the travel history or the possibility to store actions regarding trips in separated folders. Furthermore, it was mentioned that passengers should receive notifications of line or vehicle changes.

4. ”What would make you use this application in the future? “

The limiting factors mentioned in adopting this application were the reliability, completeness, and correctness of the information, directions, and real-time arrivals; the compatibility with many locations; a reliable ticketing system. Other factors that would motivate users to use this application are the presence of special deals or discounts and the ability to replace a standalone app for ticketing in each city. *”I believe this can be used as a multi-functional tool for foreigners or tourism aficionados“* (M, 20s).

6.6 Discussion

Overall, the user evaluation of the final prototype developed was significantly positive. In the first two stages, good scores were achieved and, in the last stage, users shared their interest in using the designed application.

The open feedback along with metrics and heatmaps resulting from the task assessment, was the basis of the changes made to the prototypes after the first round of testing. These changes were already mentioned in Chapter 3.2.

The biggest change made was the removal of the central button on the bottom navigation. This choice was made in order to simplify the Home screen and the navigation flow, based on the interaction registered in the task assessment and the feedback regarding the complexity of the interface. Although the overall change had a positive impact, it altered the visual representation of an ongoing trip, *cf. Figure* 5.11, which did not perform well (Task 7). Initially, this state consisted of the change of color of the central button. However, in the final prototype, this state is presented with a banner on top of the screen.

There were two other additions made to the prototype, namely, the onboarding screens, *cf. Figure* 5.3, and the map view of the suggestions, *cf. Figure* 5.9.

Although the results obtained from the user evaluation were positive, improvements can be made before starting development. The aspect that most needs revision is the ticketing purchasing for routes, *cf. Figure* 5.10. The efforts made in attempt to simplify this process were not enough, and users continue to find it overwhelming and somewhat complicated.

6.7 Summary

This chapter went over the user evaluation process, which consisted of collecting the socio-demographic information of the participants, a task assessment, the inquiry of an adaptation of the SUS, and open feedback.

The task assessment recorded the users' interaction with the prototype and three metrics: the average duration, success rate, and bounce rate. A usability score was attributed to each screen and overall prototype. These scores were good in both iterations, having shown a significant improvement from the first to the second.

The SUS adaptation collected qualitative opinions on the prototypes and translated them into numerical scores. Once again, both prototypes achieved good scores, having shown a significant improvement between iterations.

In the last stage, the users provided constructive criticism that was considered when making changes for the final prototype presented. They also showed interest in using the application, as well as some possible limitations regarding its adoption.

Chapter 7

Conclusions

This chapter concludes this dissertation. Section 7.1 presents the conclusions of the work developed. Section 7.2 goes over the contributions this dissertation makes. Finally, section 7.3 describes the limitations of this research and future work.

7.1 Conclusion

This dissertation aimed to create a solution that acts as a lifeline for tourists, allowing them to fulfill their daily needs with one single mobile application.

The literature review was able to identify the two biggest challenges tourists face, not solved by existing solutions.

- lack of clear information about the local public transport network;
- dispersion of solutions;
- focus primarily on the needs of locals.

Considering the limitations of the existing solutions, we propose the concept of Tourism as a Service, which consists of developing a holistic solution that covers the tourism experience as a whole. This concept integrates route planning, mobile ticketing, and information on the public transport and tourism sectors.

In order to approach this, a user-centric methodology was followed, namely UCD, which consisted in three main phases: (i) requirements elicitation, (ii) prototyping, and (iii) evaluation.

The requirement elicitation process started off with a few ideas resulting from the literature review. This knowledge was completed with potential users who shared their previous experiences and challenges while doing tourism in focus group sessions, which allowed to better understand how this solution could help them. Following this, a questionnaire was shared with a larger population, which made it possible to prioritize and further confirm the requirements previously identified. It was concluded that the users were especially interested in the integration of ticketing with route planning.

The prototypes were developed based on these requirements. The prototyping process took two iterations, reaching the medium and the high-fidelity prototypes. Each iteration of these prototypes was evaluated through usability tests that fueled the following iteration by identifying areas of improvement and additional features. Between iterations, two extra features were added. The most impactful being the addition of an onboarding process that gives the users initial insight into the context of the application. This proved to be extremely wanted and beneficial. The other addition made was a map view of the suggestions.

The evaluation of the prototypes was made through usability testing that consisted of four steps: (i) task assessment, (ii) SUS adaptation, and (iii) open feedback. The participants performed a set of tasks on the prototype and shared their feedback about it. All of these steps were evaluated quantitatively and qualitatively. Overall, the results of the evaluation made were significantly positive, having improved between iterations. More importantly, this step also proved that there is a need and an interest in the mobile application presented.

7.2 Contributions

With the development of this dissertation, some contributions were made, namely:

***PocketCity* Prototype** This solution includes a prototype of a mobile application that integrates tourist guide features, route planning, and mobile ticketing with the public transport and tourism sectors. This prototype was validated and well accepted by potential users.

***"Tourism as a Service: Enhancing the Tourist Experience"* Paper** During the development of this dissertation, based on the solution developed, we started to conceptualize the idea of Tourism as a Service. This was presented along with the prototype in a separate paper, present in Appendix D, which was submitted and accepted into the 24th Euro Working Group on Transportation (EWGT 2021).

7.3 Limitations and Future Work

Although we believe that the expectations for this dissertation were achieved, we also recognize that it has limitations.

Throughout the user research done in this dissertation, we made an effort to included individuals from diverse backgrounds. However, this was not always achieved. In the focus groups, only

3 out of the 11 participants were outside of the [18,25[age group. In the usability tests, these ratios did not change too much. Considering that these represent a small sample of the population, it did not greatly affect the conclusions taken. On the other hand, in the questionnaires of the requirements elicitation process, this same age group had a perceptual weight of 78.8% in a population of 254 people. This ratio causes a significant bias in the results obtained. For example, it was deduced that in older age groups, there is a bigger tendency to choose private transport over public transport. While this may be true, it is important to study it further with a more balanced population in order to make valid conclusions. Furthermore, a balanced study will better highlight the goals and priorities of each type of user.

Seeing as the solution developed is a proof-of-concept with static interfaces, it was only possible to evaluate functional requirements. However, when potential users were asked about what would motivate them to use the mobile application prototype, they shared limiting aspects that are to do with non-functional requirements, *e.g.*, reliability, availability, and completeness. In order for these aspects to be validated by potentials users, it is required to test them on a functional dynamic prototype. Although this is a natural step in the continuation of this work, the development of the mobile application is a whole other research topic by itself.

Appendix A

Focus Groups

A.1 Sample Characterization Form

1 Focus Group

This study is helpful in for a Master's Dissertation in the Informatics Engineering course at Faculty Of Engineering of the University of Porto. It is composed by an online questionnaire and a discussion group that will take place through Google Meets.

The questionnaire has the goal of characterizing the participants in the focus group regarding their socio-demographics, as well as retrieving some information on their preferences and behaviours in terms of mobility, mobile applications use and tourism. This questionnaire is anonymous and should take around 5 minutes to complete.

The discussion group will have a maximum duration of 60 minutes. Initially, there will be a brief introduction of the moderator and if the study in question. In the second stage, several questions will be asked and discussed by the participants. The session will be recorded for the purpose of transcription, and deleted afterwards. The identity of the participants will be accessible solely to the investigation team.

The answers given are completely anonymous and for technology evaluation means, with the goal of informing the development of applications and scientific articles.
For further information on the study at hand please contact Beatriz Mendes (up201604253@fe.up.pt).

By submitting this form, I declare that I agree with the terms and conditions found in this following document.
Thank you for you contribution.

2	Socio-Demographics		
2.1	Gender	Single Multiple Choice	Feminine
			Masculine
			Non-binary
2.2	Age Group	Single Multiple Choice	<18
			18 - 24
			25 - 34
			35 - 50
			>50
2.3	Marital Status	Single Multiple Choice	Single
			Married
			Widower
			Divorced
			Non-marital partnership
2.4	Children	Single Multiple Choice	0
			1
			>1
2.5	Education Level	Single Multiple Choice	Primary
			Secondary
			Bachelor's Degree
			Master's Degree
			PhD
			Other
3	Behaviours and preferences regarding mobility, technology and tourism		
3.1	How frequently do you do tourism?	Single Multiple Choice	1 a year
			1 - 3 year
			>1 a year
			National & international
			Mostly national

3.2	What kind of tourism do you usually do?	Single Multiple Choice	Mostly international
3.3	Which modes of transport do you use when doing national tourism?	Multi Multiple Choice	Car / Motorcycle
			Underground
			Bus
			Train
			TRAM
			By foot
			Bicycle / Scooter
			Private transport companies (e.g., Uber)
			Taxi
			Other
3.4	Which modes of transport do you use when doing international tourism?	Multi Multiple Choice	Car / Motorcycle
			Underground
			Bus
			Train
			TRAM
			By foot
			Bicycle / Scooter
			Private transport companies (e.g., Uber)
			Taxi
			Other
3.5	Do you usually use applications to plan routes?	Single Multiple Choice	Yes, frequently
			Yes, sometimes
			Yes, but rarely
			No
			Waze
			Google Maps
			City Mapper

3.6	What mobile applications do you use to plan routes?	Multi Multiple Choice	Moovit
			Other
3.7	How comfortable are you with online payments?	Linear Scale	[1,5] 1-I would rather avoid 5-Extremely comfortable
3.8	How often do you use applications that allow you to buy tickets for public transport?	Linear Scale	[1,5] 1-Never 5-Frequently
3.9	Do you possess any special condition that may affect your mobility?	Multi Multiple Choice	Visual problem
			Hearing problem
			Heart problem
			Respiratory problem
			Pregnancy
			Locomotor problem
			Other

Table A.1: Focus groups — sample characterization form

A.2 Session Script

Introduction	∼2 min
- Moderator introduction - Thank for participation - Present the goal of the study - Describe the outline of the session - Confirm permission to record the session	
Rules	∼4 min

- Only one person speaking at a time. It facilitates the session and the transcription
- Avoid parallel conversations.
- Participants can and should initiate discussion with the other participants regarding their points of view .
- There are no right or wrong answers. Don't be afraid to share you opinions or be influenced by other participant's opinions.
- It is not mandatory to answer every question but it would better to get as involved as possible.
- Any questions?

Participants presentation		∼3 min
Questions		∼40 min
1	Do you usually use mobile applications aimed at public transport?	
	(a) What do you feel is missing in them? (b) What are the features you most use? (c). What do you think about the ticketing options in the applications?	
When you do tourism...		
1	In what situations do you use public transport?	
	(a) How does that change from national to international tourism?	
2	Do you usually plan your trip in terms of mobility at the destination?	
	(a) In what way? (b) Do you look up the transport network or search special ticket deals beforehand? (c) How much time would you say you spend doing that?	
3	What are the biggest challenges you face in terms of mobility?	
4	In what way do you rely on your mobile phone to plan/manage the trip?	
5	What features would make you install a mobile application that aims to help tourists get around in the destination?	
	Examples: (a) Ticketing for public transport (b) Cost optimization (c) Information on the closest tourist sites (d) Ticketing for tourist activites	
6	Would you use an application as the one discussed previously?	
7	Anything else to add?	

Conclusion	∼2 min
Thank participants for the participation	

Table A.2: Focus groups — script

Appendix B

Requirements Questionnaire

1	Tourist-Oriented Mobile Application

The goal of this questionnaire is to help in a study for a Master's Dissertation that focuses of designing a tourist-oriented mobile ticketing application - an application that allows for buying and validating travel tickets as well as having other complementary features such as providing information on schedules, maps, etc.

The questionnaire is divided in two parts: the first will inquire about the socio-demographic information of the participant; the second will inquire about the participant's tourist behaviours; the third will ask the participant to rate the importance and value each feature would bring to their lives as tourists.

The answers given are completely anonymous and only used in a statistical context. They will help us in establishing the public's priorities regarding an application that aims to facilitate a tourist's experience in a foreign location.

For further information on the study at hand please contact Beatriz Mendes (up201604253@fe.up.pt).
Thank you for you contribution.

2	Socio-Demographic Information		
2.1	Gender	Single Multiple Choice	Female
			Male
			Non-Binary
			<18
			18 - 24

2.2	Age Group	Single Multiple Choice	25 - 34
			35 - 50
			>50
2.3	Nationality	Short Open Answer	-
2.4	Marital Status	Single Multiple Choice	Single
			Divorced
			Widower
			Married
			Non-marital partnership
			Other
2.5	Children	Single Multiple Choice	0
			1
			>1
2.6	Education Level	Single Multiple Choice	Primary
			Secondary
			Bachelor's Degree
			Master's Degree
			PhD
			Other
3	Tourist Behaviour		
3.1	How often do you usually do tourism?	Single Multiple Choice	0-1 year
			2-3 year
			>3 times a year
3.2	What type of tourism do you usually do?	Single Multiple Choice	Mostly national
			Mostly international
			National and international

3.3	What kind of transport method do you typically use when doing tourism?	Single Multiple Choice	Mostly public transport Mostly private trasport Public and private transport
3.4	Who do you normally do tourism with?	Multi Multiple Choice	Family Partner Friends Alone Other

4	Application Features

The goal of this section is to understand the possible features that you would value in a mobile ticketing application geared towards tourists.

Rate from 1 to 5, where 1 is not important at all and 5 is very important, the following features to be contained in a mobile ticketing application geared towards tourists, according to the importance they have for you.

4.1	Public transport real time arrival information	Linear Scale	[1, 5] 1-Not important at all 5-Very important
4.2	Information on public transport fares (e.g., types of tickets, prices, deals)	Linear Scale	[1, 5] 1-Not important at all 5-Very important
4.3	General information on how each transport mode works (e.g., how/where to board)	Linear Scale	[1, 5] 1-Not important at all 5-Very important
4.4	Integrate the many transport modes and companies	Linear Scale	[1, 5] 1-Not important at all 5-Very important
4.5	Information on where to buy and validate travel tickets	Linear Scale	[1, 5] 1-Not important at all 5-Very important
4.6	Mobile tickets and route planner integration - buy and validate the best travel tickets corresponding to the route planned	Linear Scale	[1, 5] 1-Not important at all 5-Very important

4.7	Information on airport transfer options and tickets	Linear Scale	[1, 5] 1-Not important at all 5-Very important
4.8	Buy and validate airport transfer tickets through the mobile application	Linear Scale	[1, 5] 1-Not important at all 5-Very important
4.9	Follow the journey step by step - see the current station/stop and the ones remaining until you arrive at your destination including information vehicle changes	Linear Scale	[1, 5] 1-Not important at all 5-Very important
4.10	Information on touristic sites (e.g., opening hours, how and where to buy tickets)	Linear Scale	[1, 5] 1-Not important at all 5-Very important
4.11	Suggestion of touristic sites to visit and alerts on points of interest throughout a journey (e.g., notifications of what you are passing by while in the bus)	Linear Scale	[1, 5] 1-Not important at all 5-Very important
4.12	Possibility of consulting the general information on the public network offline	Linear Scale	[1, 5] 1-Not important at all 5-Very important
4.13	Creating a custom route given a series of interest points given by the user, including necessary tickets and information on the public transport needed	Linear Scale	[1, 5] 1-Not important at all 5-Very important
4.14	Information on locations/services useful to a tourist (e.g., lockers to store bags temporarily, gas stations, parking lots, supermarkets)	Linear Scale	[1, 5] 1-Not important at all 5-Very important

Table B.1: Questionnaire

Appendix C

Usability Testing

C.1 Sample Characterization Form

1	Usability Testing for Tourist-Oriented Mobile Application

The goal of this questionnaire is to aid in the usability testing of a mobile application focusing on tourism as a service, designed in the context of a Master's Dissertation.

The application integrates services essencial for tourists - eg.: route planning, mobile ticketing for public transport, museums and attractions, information on public transport schedules, among others.

The questionnaire is divided in three parts: the first will inquire about the socio-demographic information of the participant; the second will ask the user to carry out certain tasks in the application prototypes; the third will ask the participant a few questions about their experience.

The answers given are completely anonymous and only used in a statistical context. They will help us tweak the concept and design to cater specifically to the user's needs and goals.

For further information on the study at hand please contact Beatriz Mendes (up201604253@fe.up.pt).
Thank you for you contribution.

2	Socio-Demographics		
2.1	Gender	Single Multiple Choice	Feminine Masculine Non-binary

2.2	Age Group	Single Multiple Choice	<18
			18 - 24
			25 - 34
			35 - 50
			>50
2.3	Education Level	Single Multiple Choice	Primary
			Secondary
			Bachelor's Degree
			Master's Degree
			PhD
			Other
2.4	Rate how comfortable you are using smartphones?	Linear Scale	[1,5] 1-Not comfortable at all 5-Extremely comfortable
2.5	Did you take part in the first round of usability testing?	Single Multiple Choice	Yes
			No

3	Tasks

By clicking the link at the bottom, you will be redirected to a page where you will be asked to perform certain tasks on the medium-fidelity prototypes presented (e.g., "Login to the application").

Don't hesitate or think too much and don't worry about getting it wrong, we want to see what your first instincts are so we can evaluate the usability of the prototypes.

After you have finished, please come back to complete the form.

4	Post-tasks debrief

In this section, you will be asked to share your opinion on the experience from the previous section.

Although not all questions are required, full honesty and disclosure will help us understand how the application can be improved in order to provide a better experience.

4.1	Please share how you feel regarding the following statements: (1) I think the application was easy to use. (2) I think that I would need support to be able to use this application. (3) I think the application is well organized. (4) I could get the information quickly. (5) I found it difficult to keep track of where I was in the application. (6) I think that most people would learn to use this application very quickly. (7) I think that I would like to use this application frequently. (8) I think the application is useful. (9) I found the application pleasant to use.	Multiple Choice Grid	[1,5] 1-Strongly Disagree 5-Strongly Agree
4.2	What did you like the most?	Open Question	-
4.3	What did you like the least?	Open Question	-
4.4	What is missing / could be improved?	Open Question	-
4.5	What would make you use this app in the future?	Open Question	-

Table C.1: Usability testing — sample characterization form

Appendix D

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Tourism as a Service: Enhancing the Tourist Experience

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Abstract

The tourism sector has been facing continuous growth. It plays a vital role in countries' economic development, highlighting the need to keep nurturing it by making it easier and more attractive. This paper presents Tourism as a Service - an innovative concept that aims to ease a day in the life of a tourist by integrating services that might be found spread out through separate tools and services, including ticketing in public transport and touristic attractions, route planning, information, among others. First, focus groups were done in order to understand the users' needs regarding the use of a mobile ticketing solution in tourism. The findings from the literature reviewed and the previous step were then prioritized by relevance in a questionnaire sent to potential users, allowing the creation of a medium-fidelity prototype. The validation through usability testing confirmed an interest the proposed solution. The critical design choices surrounding the proposed solution were discussed along with improvements and further work to be done.

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Keywords: tourism; smartphone; e-tourism; mobile ticketing; public transport

1. Introduction

The rapid growth that the tourism sector is experiencing is placing tough challenges on many cities worldwide, as many of them were not initially planned to receive large amounts of tourists. Those challenges cause mobility issues such as the overuse of road networks or public transport (Albalate & Bel, 2010). On the other hand, the tourism sector has a powerful impact on countries' economic development, as tourism spending affects a wide range of areas, such as lodging, restaurants, culture and shopping.

Considering public transport as the primary means of transport for tourists (2, Edelmann & Reichenbach, 2014) and given the pressure that tourism exerts on transport infrastructure worldwide and to contain the CO^2 emissions (Gunter, 2017), it is more than ever essential to foster the use of public transport by tourists at their destination.

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Mobile ticketing service solutions are able to free customers from difficult purchase decisions, allowing easier access to services (Ferreira, Dias, & Cunha, 2020). When compared with traditional ticketing systems, mobile ticketing has several advantages. They allow ubiquitous and remote access to payments, to avoid queues and to replace banknotes and coins. Service providers can also achieve operational and productivity gains by increasing performance on closed gate systems and improving bus boarding times (Ferreira, Dias & Cunha, 2020). Additionally, moving most infrastructure functions to the passenger's mobile phone partially frees public transport operators from maintenance costs.

Despite its clear advantages, mobile ticketing services worldwide tend to focus on the needs of local users, disregarding the needs of tourists and lack integration with a tourist's daily activities. While a local public transport user may have certain needs, those needs may be completely different from a tourist user visiting a new city. Thus, a new and innovative solution must arise integrating mobile ticketing in the transport industry with the tourism sector.

The concept of Tourism as a Service (TaaS) takes inspiration from Mobility as a Service (MaaS), that is, the integration of various transport services into a standalone service the users can plan, book and pay for. MaaS provides a convenient way for more sustainable travel, helping to battle the congestion of road networks (Giesecke, Surakka & Hakonen, 2016). By applying the same thinking to tourism, it is possible to integrate the basic daily needs and goals of a tourist into a single service accessible on demand.

This paper presents a mobile application based on the concept of Tourism as a Service that aims to facilitate a tourist's experience while also promoting sustainable mobility. Its conceptualization and design followed a user-centered design approach. First, three focus groups were held with potential users in order to understand their needs. Then a questionnaire was applied to a larger sample (n = 246) in order to understand which features of a mobile ticketing system are most helpful and valued in the context of tourism. A mobile ticketing prototype was designed based on the needs identified and not met by the existing solutions. The prototype was validated with potential users through usability testing.

This paper will cover related work, adopted methodology, the proposed solution and conclusions.

2. Related Work.

2.1. Tourist-Oriented Applications

Mobile tourism is a relatively recent trend that leverages the user's mobile devices as electronic tourist guides (Kenteris, Gavalas & Economou, 2009). There have been several proposals of context-aware mobile tourist guides. A good example is the ones proposed by Panahi et al. 2013, a location-based mobile application that allows the users to explore nearby cultural tourism sites, offering information, directions and allowing them to share them with other people. It makes use of cache storage to allow some offline operations.

Even though not specifically directed at tourism, one of the most popular mobile applications with tourists is Google Maps since it acts as a route planner and provides information on timetables, real-time departures, transport ticket prices and touristic sites. While being a good option for directions and mobility necessities, it isn't the ideal solution for touristic recommendations.

If we consider a tourist guide application with route planning features, the missing element to transform it into a service essential to tourists is the possibility to manage and purchase the tickets necessary for their mobility and touristic desires.

2.2. Mobile Ticketing

Mobile ticketing plays a significant part of the concept presented since it allows tourists to rely mostly on their phones to pursue their daily activities. Nowadays, mobile ticketing solutions in public transport are becoming more and more common.

Many technologies exist to implement mobile ticketing, the most common used today being QR-codes, Near Field Communications (NFC) and Bluetooth Low Energy (BLE) (Gudymenko, 2015). Among the various technologies, there is no correct or incorrect technology to use in a mobile ticketing system, as each has its own advantages and disadvantages. Factors that influence the technology adopted are the compatibility with the pre-existing infrastructure, the investment and maintenance costs, among others. This means that the best technology may vary according to each location, being the solution proposed in this article agnostic to the technology used.

An analysis of mobile ticketing solutions worldwide was done, looking into what services and integrations they offer. A lot of the mobile ticketing services in use today are digital wallets or smart cards with very limited features. More elaborate proposals cover the before, during and after of the trip, as well as additional information such as timetables and real-time departures, like the ones proposed by Finzgar *et al.* 2011 and Ferreira *et al.* 2019. These solutions were designed with the local traveler in mind that has pre-existing knowledge on the transport network and whose needs may be different than the ones of a foreigner.

A few proposals were presented integrating mobile ticketing with both the public transport and tourism sectors. For example, Baldo *et al.* 2010 proposed a mobile ticketing solution based on membership cards that profile the user's ticket purchase behavior and offer special discounts. It also allowed for scanning informative NFC tags located at points of interest all around the city. While it is a step further in the direction we are heading, it is still a weak exploration of the connection to the tourism sector.

What can be concluded in this section is that tourist guide services lack in the integration with mobile ticketing and public transport and public transport-oriented solutions lack integration with the tourism sector. Thus, generating the need for a 'all-in-one' solution.

2.3. Tourists Behavior and Mobility

Mobility is perhaps the biggest challenge tourists may face. It is crucial to understand their mobility habits in order to create something that satisfies current users of public transport but can also divert attention from private transport, supporting sustainable mobility.

The majority of tourists opt for public over private transport to move throughout their destination during their stay, according to Puhe *et al.*, 2014. In 2011, Kinsella *et al.* performed a study on the opinions of newcomers and visitors regarding the public transportation system in Dublin. They concluded that the availability of helpful information on the public transport network has a powerful impact in bettering their experience. Furthermore, the authors concluded that poor service delivery is often a strong motif for not using public transport and in order to promote its adoption among tourists, it is crucial to make it easier to use. That may be accomplished, among other factors, by sharing critical information such as network maps and next stops in multiple languages.

Another study was performed in 2014 by Le-Klähn *et al.* regarding the factors encouraging and discouraging the use of public transport by tourists. The research found that the strongest points in favor are the drive-free benefits, avoidance of traffic and the possibility of car unavailability. On the other hand, the factors discouraging public transport use are the inconveniences and limitations, lack of information and personal preference. Other variables that influence the choice of transport are the length of stay, purpose, age group, usual frequency of public transport use at the place and valid driving license ownership.

Oliveira *et al.* 2020 researched the adoption factors and features of a potential tourist-oriented mobile ticketing solution. The results show that the most desired features are clear information on the public transport network and buying and validating options for public transport tickets.

3. Methodology

To reach the desired mobile ticketing solution, user research was performed in order to understand the context of use, specify the user's requirements and design a potential solution, following a user-centric design (UCD) approach. UCD is an iterative design process that puts the users in the center and focuses primarily on their needs, goals and satisfaction. Therefore, the inclusion of the target audience was done in three stages: the first consisted of conducting focus groups; the second, in sending a questionnaire to gather opinions on the findings of the previous stage; the third, in validating the solution with potential users. These steps allowed us to design a solution centered on the user according to their needs and goals.

3.1. Focus Groups

The focus groups consisted of three different group sessions lasting around 50 minutes each and with a combined total of eleven participants from different age groups and professional backgrounds. The sessions followed a four-part structure, composed of 1) a brief introduction of the participants, 2) a presentation of the guidelines to follow, 3) the discussion and 4) a conclusion. The part of the discussion followed a script with open-ended

questions. Participants were encouraged to open up and exchange ideas about past experiences and challenges they faced as tourists and when using public transport-oriented applications. The sessions were transcribed and carefully analyzed. The goal was to understand the requirements for the designed solution by understanding the tourists' needs, challenges and how to dismiss them.

The focus groups were a vital part of reinforcing and adding to the information gathered from the previous literature. The goal was to define a set of initial functional requirements by understanding the tourists' needs, challenges and how the solution can be designed to ease them.

3.2. Questionnaire

A questionnaire was shared with a significantly larger pool of potential users with the goal of validating and prioritizing the requirements obtained. Furthermore, to ensure the designed solution satisfies the most types of users possible, once again, we strove to reach diversity in the age groups, backgrounds, nationalities, education levels, mobility and tourism habits of the participants.

3.3. Prototyping & Validation

The user insight obtained in the previous steps allowed us to define the requirements for the proposed solution. Finally, medium-fidelity prototypes were created using *Figma*, a collaborative interface design tool.

In order to evaluate the solution obtained qualitatively and quantitatively, we resorted to usability testing. This method requires participants to perform certain tasks on the interfaces while a mediator guides and monitors their progress. Usability testing can uncover problems in the design, opportunities for improvement and help gain more insight to the users' preferences. In this case, we implemented a remote form of usability testing using the tool *Maze* that acted as the mediator. An overall usability score (US) is attributed based on average of the usability scores calculated for the performed tasks (TUS), which by itself is calculated using the direct and indirect success rates, the misclick rate and task duration. Post-testing, an adaptation of the System Usability Scale was used to collect subjective opinions on the prototype tested.

4. Proposed Solution

4.1. Focus Groups and Questionnaire Analysis

Most participants shared experiences in which understanding the local public transport network and their ticketing system was challenging due to its complexity or language in which the resources are presented.

All eleven participants admitted to relying mainly on route planning applications for planning their routes and consulting real-time arrivals and checking the most convenient set of transports to take to reach a certain location. Some additionally mentioned they consult the ticket price feature present in some of these services, such as Google Maps, even though these usually only show the price of standalone tickets.

Participants shared they faced difficulty in searching for a trustworthy, up-to-date and reliable information source when in foreign locations since many of the services available are in the countries' main language and are designed for locals. The bad usability of these applications was another negative factor that was brought up.

Ten out of the eleven participants showed an interest in the possibility of purchasing the transport tickets through a mobile application, according to a certain route. Even so, participants mentioned that simply having information about the transport network, the different types of tickets and where to acquire them would have a tremendous positive impact on their experience, especially if it could be accessed offline.

Potential features that got a positive response were to do with the airport shuttle services and integration with touristic sites and activities. Additionally, participants mentioned that as tourists, they value seeing the journey progress, for example, seeing and receiving updates on how many stops are left until the destination is reached.

Overall, the participants showed great interest in a tourist-oriented mobile application that integrates public transport ticketing with the tourists' mobility needs.

The questionnaire reached 246 people and allowed us to reach a similar conclusion as pointed out in section 2.2, that is that most individuals opt to use mostly public transport or a combination of public and private transport, being that the latter is opted more frequently by older age groups. This tells us who will be the main users of our

proposed solution but, on the other hand, it creates an incentive to design a service that can attract older generations by making it easy to use and accessible.

The participants were asked to rate some potential features from 1 to 5 according to how they value each of them, being that 1 represents no interest and 5 represents a strong interest in the feature. The average priority scores of each potential feature were then calculated and sorted. With this ordered list of desired features, we were able to prototype a solution, as presented in the following section.

4.2. System Architecture

This paper proposes a tourist-oriented mobile application that aims to facilitate the daily life of a tourist by integrating mobile ticketing, route planning and informational services with public transport and touristic activities.

The technology used for the ticketing portion of the application affects how it flows and therefore is built. The mobile ticketing technology mustn't impose significant investment or extra maintenance costs, quite the contrary. The ideal solution relies solely on the mobile device or takes advantage of the public transport infrastructure already in use. However, the infrastructure used can vary from city to city and even transport mode, meaning that the solution would need to be able to adapt to its environment. As this issue is outside the scope of this paper, we decided to focus on creating an agnostic solution that could be easily tweaked to fit different types of ticketing according to the location.

As an example, we considered a QR-code-based ticketing solution as an example due to its widespread usage, easy implementation and testing. The user can activate the ticket in the application and can be checked by QR code readers. For this case, it made sense to prioritize a prepaid ticketing scheme versus a post-paid since tourists usually wish to plan their trip costs ahead and look into ticket deals.

At its core, the application acts as a route planner integrating ticketing for public transport and information on the public transport network and schedules available offline. Additionally, it provides information, suggestions and ticketing for touristic sites.

4.3. Prototype

This section presents the medium-fidelity prototype developed based on the requirements gathered from the literature review and user research.

After the user is successfully registered and authenticated, it is mandatory to choose a destiny location. hence why this decision was made. The adaptation of the application for the specific location implies having a trustworthy source of real-time arrivals and partnership with the public transport companies for the ticketing service, hence why this decision was made.

The basic information about the functionating of the public transport network, such as timetables and network maps, is available on the second screen, see Fig. 1(c).

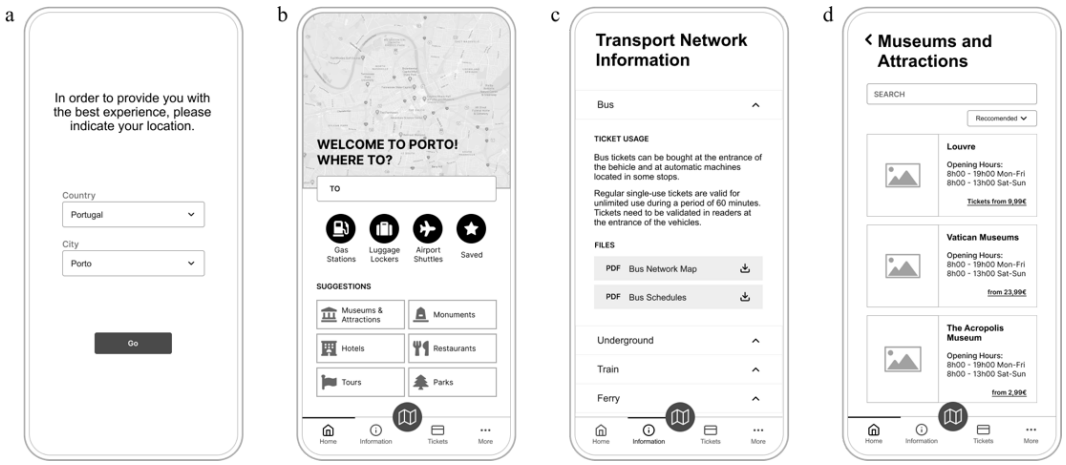

Fig. 1. (a) Choose Location; (b) Homepage; (c) Public Transport Network Information; (d) Suggested Museums and Attractions

The home screen is the Explore screen seen in Fig. 1(b). It contains a preview map centered in the user's current location; an input to start a new journey; shortcuts to relevant actions; and suggestions of tourist related services and activities.

Fig. 2 presents screens related to the navigation and ticketing. The tickets screen contains a list of previously purchased tickets along with their activation and validity status, as well as information on the types of tickets available, including special deals, see Fig. 2(a).

When searching for a destination, the user is presented with a list of possible routes to take, each with the time the journey takes, the vehicles and their first arrival times, a price of all tickets required and information on the tickets already in possession, see Fig. 2(b). When choosing a route, the user is directed to a screen with extended trip details and the possibility to buy the necessary tickets, see Fig. 2(c,d).

The central button on the bottom navigation serves as a quick shortcut to the current trip. In the case that there is no active journey, it acts an alternative path for the user to start one, however, if there is an ongoing trip it redirects to its screen, allowing easy access to the progress and tickets in use.

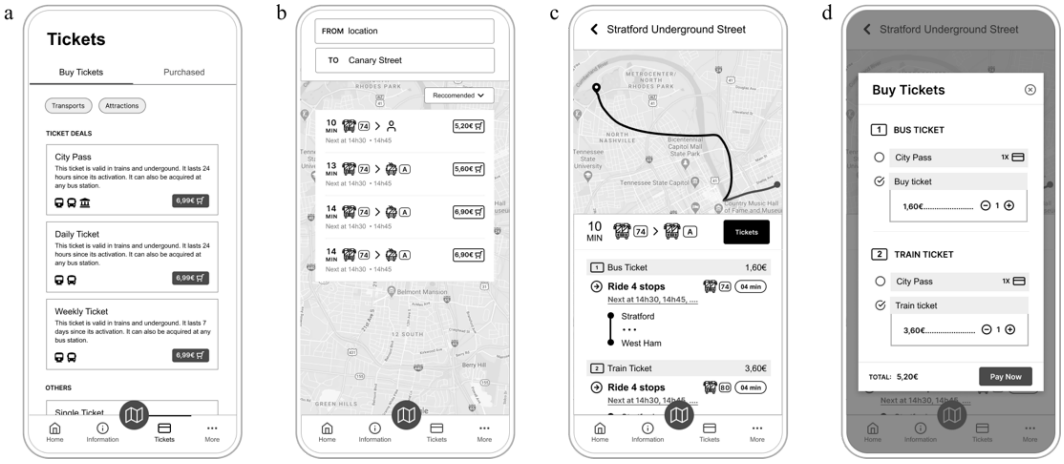

Fig. 2. (a) Tickets; (b) Route Search Results; (c) Route Details; (d) Buy Tickets

4.4. Usability Testing

The validation of the application was done through usability testing. The sample was made up of 7 users with ages from 19 to 50 years old and older, and different education levels. The participants were asked to perform a set of 7 tasks in the application prototype. The tasks revolved around starting and following a trip, buying and validating tickets and accessing certain information.

Overall, the users didn't have much difficulty navigating the application, achieving an average usability score of 83 out of 100, calculated based on the metrics previously mentioned. The testing allowed us to understand where the users are struggling, painting the path on how to correct it.

When asked what they most enjoyed about the application, users mentioned the ticketing features – "the way tickets can be purchased and activated for a particular itinerary"; the good usability – "the user interface was appealing and simple to understand"; and the completeness of the application - "the integration of features and information that usually is encountered in separate applications/websites".

Participants expressed interest in using the application mostly due to its extensive feature integration, removing the need to consult multiple sources and tools. Other conditions important to the usage of the application were mentioned, namely the reliability, availability in different locations, ticket cost optimization and good integration with the public transport system.

The participants made valid constructive criticism regarding certain aspects of the design and suggestion on possible improvements and additions.

To the statements "I think the application is useful" and "I think that I would like to use this application frequently", although in different strength levels, all participants shared their agreement.

5. Conclusions and Future Work

This paper presents a tourist-oriented mobile application that aims to facilitate and make the daily activities of a tourist, achieved with the analysis of literature review and user research.

The potential users played a crucial part in defining the requirements for the application. During the focus group discussions, the challenges users still face as tourists. The participants expressed difficulty in understanding the public transport networks and their ticketing schemes and that the information they need is spread throughout too many channels, making it a less than desirable experience.

The questionnaires merged the ideas collected from the literature review and discussions and asked potential users about their interest in the features mentioned. This step allowed us to prioritize and confirm the desired uses of the ticketing solution.

The presented solution is a mobile application integrating the most essential features used by tourists regularly. Those of which include route planning, information, suggestions and ticketing for the public transport and tourism sectors.

The prototype developed was submitted to usability testing and achieved a relatively good usability score, positive feedback and interest in the proposed solution. It also provided constructive criticism on certain design aspects to be analyzed in the next design iteration.

It's important to note that the reliability of this solution in the market relies on a trustworthy source of data for the arrival times and partnerships with entities at the destination cities to assure the mobile ticketing service.

The next steps for this work include a continuation of the user-centered design process. The prototypes will be revised and incremented with the feedback from the usability tests until a satisfactory high-fidelity prototype has been achieved.

The proposed solution is innovative resulting in the integration between the urban transport field and the tourism sector.

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