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A Methodology for Designing Mobile Ticketing Services: from Ideas to Deployment

Dissertation submitted to the Faculty of Engineering, University of Porto for the Doctoral Program in Transport Systems

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November 2018

Abstract

The pervasive use of mobile phones and its growing functionality allows them to be used to make payments in many services, including public transport. There are several advantages when comparing to traditional ticketing systems, such as remote and ubiquitous access to payment, queue avoidance, and lack of need to carry cash and coins. Markets in developed economies have witnessed the launch of a number of mobile ticketing initiatives over the last years. Even though the emergence of mobile ticketing services may still hold high promises, some of these initiatives have seen stagnation or failure.

The widespread deployment and adoption of mobile ticketing solutions requires action from complex ecosystem of organizations, whose success is dependent on joint action by all the actors together at the same time. However, the struggle for these inter-dependent actors to form coalitions just hindered the emergence of successful mobile ticketing platforms. From a service-dominant logic, value is co-created collaboratively, and when addressing more complex service systems, such as public services, service design engages not only customers but also other network actors.

This environment sets the motivation of this thesis to develop a methodology to design successful mobile ticketing services built on a mind-set based on collaboration and team approach and on contributions from different design fields. The DMTS (Designing Mobile Ticketing Services) methodology seeks to create better mobile ticketing solutions and to promote more inclusive processes that enhance multiple actor engagement. These mobile ticketing services are expected to enhance passenger travel experience, by allowing to travel in a convenient and smooth way, and ultimately promote the attractiveness of public transport. This fundamental goal is achieved through three objectives. The first is concerned with understanding the mobile ticketing ecosystem. The second involves the development of the DMTS methodology. The third consists on applying, and refining, the DMTS methodology.

This thesis provides three main contributions. The first is related to the state-of-the-art of mobile ticketing, by providing an updated and comprehensive literature review about mobile ticketing, enriched by experimental results. The second consists of the DMTS methodology. It combines knowledge, concepts and tools from different fields to design mobile ticketing services in complex ecosystem context. The DMTS methodology was validated, and refined, during the design of four mobile ticketing services. It can be replicated across urban passenger transport systems around the world. It also has been demonstrated that the DMTS methodology can be applied to design other mobile value-added services and to other domains not related to urban passenger transport. The third main contribution is the set of the four mobile ticketing services that were designed. Of these, Anda has been launched commercially in the Metropolitan Area do Porto in June 2018 and is being used by thousands of passengers every day. It represents the tangible outcome of the research and the empirical testing and validation of the DMTS methodology.

Resumo

O uso generalizado de telemóveis assim como as suas crescentes funcionalidades permitem que estes sejam utilizados para efetuar pagamentos de diversos serviços, incluindo transporte público. Existem inúmeras vantagens da bilhética móvel quando comparada com os sistemas tradicionais de bilhética, tais como o acesso remoto e ubíquo ao pagamento, evitar filas de espera e a ausência de necessidade de transportar dinheiro e moedas. Nos últimos anos foi possível observar o lançamento de diversas iniciativas de bilhética móvel nos mercados economicamente mais desenvolvidos. Embora o surgimento de serviços de bilhética móvel ainda se apresente como bastante promissor, algumas dessas iniciativas estagnaram ou fracassaram.

A difusão da implementação e adoção de soluções de bilhética móvel exige intervenção de um ecossistema de organizações complexo, cujo sucesso depende da ação conjunta e simultânea de todos os intervenientes. Contudo, a dificuldade em formar alianças entre este sistema interdependente de atores tem impedido o surgimento de plataformas de bilhética móvel bem-sucedidas. Segundo a lógica serviço-dominante, o valor é cocriado de forma colaborativa, e quando se abordam sistemas de serviços mais complexos, como o caso de serviços públicos, o desenho de serviços envolve não apenas os clientes, mas também os outros intervenientes na rede.

Este ambiente define a motivação desta tese para desenvolver uma metodologia de desenho de serviços de bilhética móvel bem-sucedidos, e construídos de acordo com uma mentalidade baseada na colaboração e trabalho em equipa, assim como em contribuições de diferentes áreas de desenho. A metodologia DMTS (Designing Mobile Ticketing Services) procura criar melhores soluções de bilhética móvel, assim como promover processos mais inclusivos que promovam o compromisso de múltiplos intervenientes. Espera-se que estes serviços de bilhética móvel melhorem a experiência dos passageiros, permitindo viajar de forma conveniente, sem dificuldades e, em última instância, promover a atratividade do transporte público. Esta finalidade é alcançada através de três objetivos. O primeiro diz respeito à compreensão do ecossistema de bilhética móvel. O segundo envolve o desenvolvimento da metodologia DMTS. O terceiro consiste em aplicar e refinar a metodologia DMTS.

Esta tese apresenta três contribuições principais. A primeira está relacionada com o estado da arte da bilhética móvel, fornecendo uma revisão bibliográfica atualizada e abrangente sobre este tema, enriquecida pela análise de resultados experimentais. A segunda consiste na metodologia DMTS. Esta metodologia combina conhecimentos, conceitos e ferramentas de diferentes áreas para desenhar serviços de bilhética móvel, em contexto de ecossistema complexo. A metodologia DMTS foi validada e aperfeiçoada durante a conceção de quatro serviços de bilhética móvel, podendo ser replicada em sistemas de transporte urbano de passageiros em todo o mundo. Também foi demonstrado que a metodologia DMTS pode ser aplicada para desenhar outros serviços móveis de valor acrescentado assim como em outros domínios não relacionados ao transporte urbano de passageiros. A terceira principal contribuição é o conjunto dos quatro serviços de bilhética móvel que foram projetados. Destes, o Anda foi lançado comercialmente na Área Metropolitana do Porto em junho de 2018 e é atualmente utilizado por milhares de passageiros todos os dias. Representa assim o resultado tangível da investigação, bem como o teste e validação empíricas da metodologia DMTS.

Acknowledgements

What a long journey. So many brilliant and generous people I had the opportunity to meet during this journey. I am so lucky (considering that there is no lucky without hard work)!

First and foremost, I am deeply grateful to my supervisors Professor João Falcão e Cunha and Teresa Galvão Dias. I call them supervisors because of their role in this thesis, but for me they mean much more than that. I thank both for the thoughtful guidance, patience, support and encouragement throughout the way. I thank Professor João Falcão e Cunha for challenging me, for trusting my work and for his enormous generosity that allows me to stand out. I thank Professor Teresa Galvão Dias for the sharing of ideas, availability, closeness and the wise word she always had with me. I am sure that without their supervision, none of this would have been possible and I could not imagine having better mentors.

I thank Professor Jorge Pinho de Sousa, director of the Doctoral Program in Transportation Systems at FEUP, for his sympathy and effort in streamlining all the processes related to my journey in the doctoral program. I thank Professor Marta Gonzalez for welcoming me to her research group during my visit to the MIT (Massachusetts Institute of Technology) and for advising me on my research work.

I thank all professors of the Department of Industrial and Management Engineering of FEUP for being so nice to me and showing interest in my work, with a special mention to Professors Sarsfield cabral, José Luís Borges, Jorge Freire de Sousa, Henriqueta Nóvoa, Dulce Lopes, Lia Patrício, Gabriela Beirão and Jorge Teixeira. I would also like to thank the opportunity given by the Professors with whom I teach (or taught) classes, namely Professors Dulce Lopes, João Claro and Alcibíades Guedes. I have been an invited lecturer for 6 years and teaching university students is something that I really love and challenges me. Thank you for trusting my work and teaching me so much about teaching others. I thank the six master students I co-supervised, André Dias, Vitor Santos, Mike Pinto, Luís Duarte, Miguel Botelho and Daniel Amorim. Their work enriched the present research and I learned a lot advising their studies.

I thank all the people from other universities and companies that I met during the research projects in which I was involved, namely people from Universidade do Minho, Instituto Superior Técnico, OPT, TIP, STCP, Metro do Porto, CP, Card4B, Cardmobili, PT Inovação, Creative Systems, Wintouch and Novabase,. I grew up and learned a lot from them and this thesis is a result of our close collaboration and their wise insights. A special thanks to Eng. João Marrana, delegated administrator of TIP, for having taught me so much about public transport and for making my passion for the area grow even more. I also thank all the hundreds of people who participated in the projects as volunteers and who contributed as "experts of the experience" making this thesis possible.

During my research, I shared the office with a lot of fun and talented people. I thank Miguel Oliveira, António Nunes, Carlos Gomes, Nelson Pinho, João Dias da Silva, Ana Loureiro, José Machado and Eduardo Marques for the friendship, advice and willingness to share knowledge. I thank Joana Hora, Thiago Sobral, Sérgio Duarte and Vera Costa, with whom I share the interest for the transport field and learned in every discussion.

I am deeply grateful to my parents, Fernando e Alice, to my sister, Catarina and to my parents-in-law, Henrique e Goreti. I thank them for their patience, for being my pillars, for helping me with my daughter and allowing me to devote to work. I thank all my friends and family, aunts, uncles, cousins, grandfather, in-laws and nephews for joining me on this journey and always being present. A very special thanks to my husband, Henrique, for being strong by my side. His resilience, hard-work, focus, and love inspires me every day. Finally, I dedicate this thesis to the most important person in the world, my Maria Francisca. She was born in the middle of this journey and made everything more challenging and beautiful.

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List of acronyms

AFC – Automated Fare Collection

BLE – Bluetooth Low Energy

CCB – Central Ticketing Computing

CP – Comboios de Portugal

FEUP – Faculty of Engineering, University of Porto

MAP – Metropolitan Area of Porto

MP – Metro do Porto

NFC – Near Field Communication

OPT – Optimização e Planeamento de Transportes

OTA – Over-the-air

POS – Point-of-sale

QR Codes – Quick Response Codes

RFID – Radio-Frequency Identification

SAM – Security Application Module

SIA – Intermodal Andante System

STCP – Sociedade de Transportes Colectivos do Porto

TIP – Transportes Intermodais do Porto

UI – User Interface

1. Introduction

This thesis is concerned with the design of mobile ticketing services, covering the entire design process, from conceptualization to implementation. A comprehensive literature review on mobile payments is presented providing the theoretical framing for the research. The DMTS (Designing Mobile Ticketing Services) methodology is then presented, being preceded by an introduction of the theoretical concepts and perspectives that underpin the methodology proposed. The DMTS methodology represent a holistic design approach to design successful mobile ticketing services in complex ecosystems context. It is empirically validated, and refined, through the design of four different mobile ticketing services. This chapter describes the motivation for the research, the problem and research objectives, the methodological approach, the main contributions to the literature and to the practice and, finally, the outline of the thesis.

1.1 Motivation

The world is increasingly urban. Today, more than 50% of the world's population lives in cities, and by 2050, 68% of the world's population is projected to be urban (United Nations 2018). The most urbanized regions include Northern America (with 82 % of its population living in urban areas in 2018), Latin America and the Caribbean (81 %) and Europe (74 %) (United Nations 2018). It is increasingly recognised that compact cities are resource-efficient ways for people to live and for businesses to exist, as close proximity provides potential efficiency gains. However, urban sprawling has considerable impacts on environmental issues and sustainability. The exposure of city-dwellers to pollution, grime and other environmental issues is 2.3 times higher than people living in rural areas (Eurostat 2016).

As the world continues to urbanize, sustainable development depends increasingly on the successful management of urban growth. Transport is an important factor in the context of sustainable development due to the pressure it places on the environment, its economic and social impacts, and its linkages with other sectors. In fact, transport represents almost a quarter of Europe's greenhouse gas (GHG) emissions and is the main cause of air pollution in cities (European Commission 2016). Within this sector, road transport is by far the biggest emitter accounting for more than 70% of all GHG emissions from transport in 2014 (European Commission 2016).

The promotion of sustainable urban transport is already happening in several cities around the world. A landmark agreement to combat climate change, known as Paris Agreement, was signed, in December 2015, by parties of the United Nations Framework Convention on Climate Change (UNFCCC) to accelerate and intensify the actions and investments needed for a sustainable low carbon future. The objective is to keep a global temperature rise below 2 degree Celsius above pre-industrial levels (United Nations 2015). A European strategy for low-emission mobility was then outlined and identifies as a priority area for action the use of digital mobility solutions to make transport safer, more efficient and inclusive (European Commission 2016).

Urban sustainability requires rational mobility and sustainable transport, which in turn requires a mind shift towards public modes of transport at the expense of private cars. Improving the mobility of passengers using means that are sustainable, safe and high-quality is essential in order to reduce congestion in urban and metropolitan areas. Reducing the problems of urban congestion and stress will benefit businesses and citizens in the form of lower costs, time savings and improved accessibility. Reducing dependence on fossil fuels and cutting levels of pollution and GHG emissions will benefit human and ecosystem health and the climate system (Litman 2018). Car use may also become more sustainable with the adoption of lower emission vehicles using electrical energy (Canals et al. 2016, Vasconcelos et al. 2017), and with the introduction of new technologies allowing the emergence of automated vehicles (Nieuwenhuijsen et al. 2018). However, cars will hardly mitigate social inclusion issues, and their scope for reducing congestion and releasing public space is constrained.

However to promote a mind shift is not an easy task. Complex transport networks and lack of seamless options have proven to be barriers to the adoption public transport services (Assessment and Parliamentary 2014). The attractiveness of public transport therefore increases as it becomes easier to use. This thesis aims to contribute towards the attractiveness of urban passenger transport by introducing personal mobile phones in the service delivery process.

The general adoption of mobile devices and its increasing functionality is changing the way people use mobile phones. Currently, it is already possible to make payments with mobile phones in several countries. This wide-spreading reality is being applied to several sectors, including urban passenger transport. Modern mobile ticketing service solutions are able to free customers from difficult purchase decisions, allowing easier access to services. While it is already possible to find multiple mobile ticketing solutions, mobile ticketing still remain essentially an emerging technology, seeking to fill the gap between its envisioned potential and widespread usage.

The pervasive deployment and adoption of mobile ticketing solutions requires action from complex ecosystem of organizations (e.g. passengers, transport operators, transport authorities, banks, mobile network operators, third parties and others) to create a mobile ticketing service solution. Each entity desires to have the leading place in the mobile ticketing ecosystem and dominant role in the value chain. Mobile ticketing entail a complex, system-interdependent ecosystem players whose success is dependent on joint action by all the players together at the same time (Ezell 2009). However, the struggle for these inter-dependent firms to form coalitions just hindered the emergence of successful mobile ticketing platforms.

From a service-dominant logic, value is co-created collaboratively, being an "interactive process that takes place in the context of a unique set of multiple exchange relationships" (Vargo and Lusch 2010). When addressing more complex service systems, such as public services, service design engages not only customers but also other networks actors (Patrício, Gustafsson, and Fisk 2018). Different perspectives are needed in order to understand both a service's demand side, i.e. users' and customers' needs, and its supply side, i.e. technologies and processes, in order to develop successful services (Steen, Manschot, and Koning 2011). Sanders and Stappers (Sanders and Stappers 2008) anticipated that "Future codesigning will be a close collaboration between all the stakeholders in the design development process together with a variety of professionals having hybrid design/research skills."

The aforesaid environment affords an opportunity to develop a methodology for designing successful mobile ticketing services built on a mind-set based on collaboration and team approach. These mobile ticketing services are expected to enhance passenger travel experience, by allowing to travel in a convenient and smooth way, and ultimately promote the attractiveness of public transport.

1.2 Problem and Research Objectives

The main aim of this research is to stimulate behavioural shifts towards more sustainable transport by increasing urban passenger transport attractiveness. The idea is to take advantage of the widespread use of mobile phones and its increasing functionality to deliver mobile ticketing services to passengers and allow easy access to mobility services. Hence the fundamental goal translates into the following research problem:

How to design mobile ticketing services for urban passenger transport in complex ecosystem context?

To address the aforementioned question, three main research objectives were identified:

R.O.1 Understanding mobile ticketing ecosystem

R.O.2 Development of a methodology to design mobile ticketing services in complex ecosystem context – DMTS methodology

R.O.3 Design mobile ticketing services based on the DMTS methodology

The first research objective (R.O.1) provides the theoretical framing of this thesis. Its purpose is to understand the mobile ticketing ecosystem dynamics and context. Achieving this objective requires exploring and clarifying concepts related to the urban passenger transport context and understand the concept of mobile ticketing. The latter also involves an in-depth theoretical understanding of the main technologies used to intermediate the interaction between customers' mobile devices and transport operators management channels and platforms, and of the key benefits and challenges related to mobile ticketing solutions. Lastly, it involves the identification of the main actors involved in the mobile ticketing ecosystem, their drivers, concerns, contributions and expected benefits. The theoretical framing described in R.O.1 sets the scene to the next research objective – R.O.2. It should be noted that R.O.3 also contributed to complement the literature review conducted for the R.O.1. Several statements and conclusions presented, result from qualitative analysis performed in R.O.3. The R.O.1 is addressed in Chapter 2.

The second research objective (R.O.2) consists of the main theoretical contribution of this thesis. It comprises the development of a methodology to design mobile ticketing services in complex ecosystem context – Designing Mobile Ticketing Services (DMTS) methodology. The DMTS methodology joins contributions of several design methodologies and promotes a close collaboration between all stakeholders of the mobile ticketing ecosystem. The definition of the DMTS methodology is closely related to R.O.3, which provides the empirical validation of the methodology. The R.O.2 is addressed in Chapter 3.

The third research objective (R.O.3) is related to the empirical validation of the DMTS methodology in four different research projects. Four different mobile ticketing solutions were designed, developed, and evaluated, culminating in the deployment of the last one, providing the case studies for evaluating the DMTS methodology. Most of the time of this research consisted of interchanging between R.O.2 and R.O.3, which allowed to refine the theoretical aspects from practice and practicing the theory on the four different mobile ticketing solutions. The R.O.3 is addressed in Chapter 4.

The main aim of this thesis was to propose a methodology to design mobile ticketing services applied to the urban passenger transport domain. However, its potential for application to other fields not related with transport and in the design of other value-added mobile services was evident during the projects. The research projects included the development of other services such as performing basic payments at bars and peer-to-peer transactions, purchasing and validating meal tickets, receiving and redeeming loyalty coupons, planning a public transport journey and sharing public transport relevant information among passengers. It is clear that the fundamentals and conceptual foundations of the DMTS methodology can be generalized across domains.

1.3 Methodological Approach

To pursue the objectives mentioned in the previous section a combination of methods was followed. The first two research objectives (R.O.1 and R.O.2) consisted on applied research, being concerned with the theoretical framing and development of a methodology to design mobile ticketing services in complex ecosystems context. The third research objective (R.O.3) consisted of experimental development of four mobile ticketing services that were designed based on the DMTS methodology developed in R.O.2 and on insights drawn from R.O.1. The methodological approach is represented in Figure 1 and is detailed above.

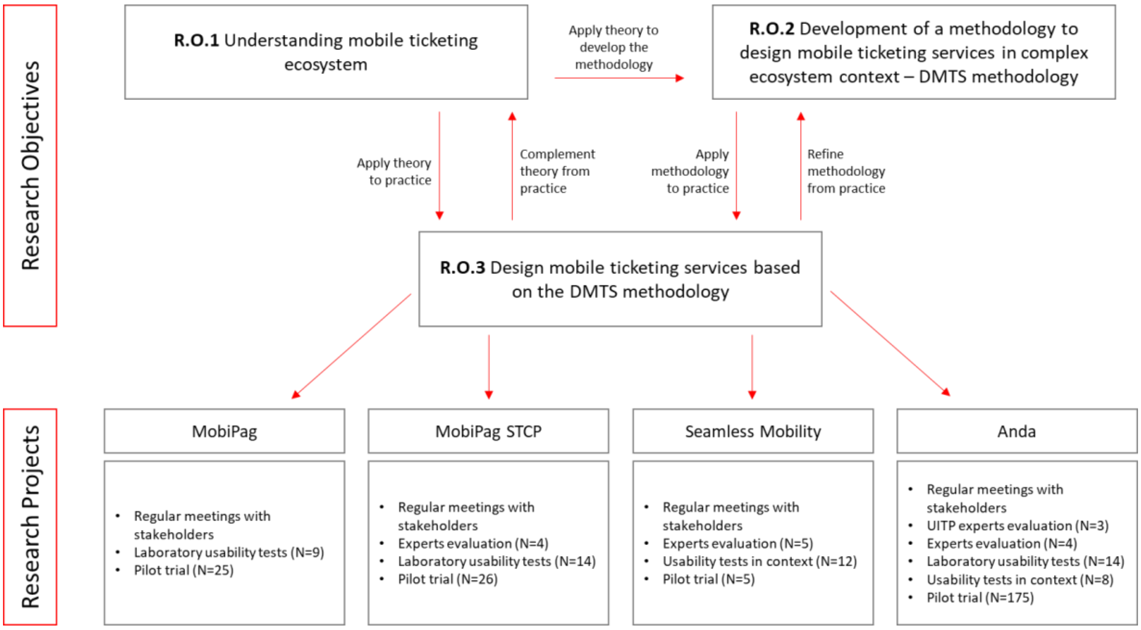

FIGURE 1. METHODOLOGICAL APPROACH OVERVIEW

The literature review provided the theoretical framing of this research. It covers public transport and mobile ticketing related topics, which were key to undergo the subsequent phases. The literature review was also improved with the results of the qualitative analysis of the projects. In addition, it contributed towards the conceptual foundation of the DMTS methodology, alongside with review of different design perspectives, meetings with stakeholders and empirical work from the projects. The DMTS was applied and refined during the design process of four different mobile ticketing service solutions, in the scope of four projects: MobiPag, MobiPag STCP, Seamless Mobility and Anda.

The MobiPag project was a National Initiative for Mobile Payments, whose main goals were to promote the dematerialization of money and leverage new features and uses of personal mobile devices. The project was developed over two and a half years (December 2010 – April 2013) and was co-funded by "Agência de Inovação" and the national QREN program through the COMPETE program (Project 13847). The solution comes from the effort of a consortium of companies (CardMobili, PT Inovação, Multicert, Creative Systems, and Wintouch) and universities (FEUP, Instituto Superior Técnico and Universidade do Minho) with the coordination of CEDT. The advisory board composed of the main national banking institutions (Gaixa Geral de Depósitos, Millenium BCP, BES and BPI), mobile operators (TMN, Vodafone and Optimus) and other financial institutions (SIBS, Visa, Mastercard and CTT), supported the initiative and contributed with their know-how and expertise. The project consisted on designing, developing and testing an integrated mobile service solution (payment, ticketing and couponing) based on NFC.

MobiPag STCP was a 6-month project (December 2012 – June 2013), developed under the MobiPag project and results from the partnership between a university (FEUP), technology company (OPT) and bus operator (STCP). The goal was to apply the knowledge generated in the MobiPag project to the public transport field. Transport operators were very receptive to the idea, however due to the financial crisis that the country was going through, they did not want to invest in new equipment or infrastructures. So, the challenge was to design a mobile ticketing solution based on passengers' mobile devices, requiring no interaction with transport operators' infrastructure. It was tested in real environment by STCP customers, during their daily use of transport services.

Seamless Mobility was a 18-months project (January 2014 – June 2015), which main objective was to leverage personal mobile devices and ubiquitous communication networks for the dematerialisation of tickets and the offering of timely information to passengers, according to their travel patterns. The idea was to complement the payment for the journeys by additional mobility related services, such as route planner and sharing information between passengers. The project was financed by the ERDF – European Regional Development Fund through the COMPETE Programme (operational programme for competitiveness) and by National Funds through the FCT – Fundação para a Ciência e a Tecnologia (Portuguese Foundation for Science and Technology) within project "SI IDT – 38957/2012 F3". The solution comes from the joint collaboration between a university (FEUP) and technology company (Octal, company of the Novabase group). Other technology company (OPT) and transport operators, such as Metro do Porto, STCP, Transdev and TIP also collaborated in the project. The final solution is based on QR Codes technology and integrates three main components: mobile payments, route planner, and social network.

The Anda project was a 22-months project (September 2016 – June 2018), which main objective was develop a mobile ticketing solution to be launched in the market. The project was funded by the Portuguese Ministry of the Environment under the Protocol of Collaboration with Environmental Fund. The solution comes from the joint collaboration between transport authorities (TIP), university (FEUP) and technological partners (OPT, Card4B, BIT, AMI and Dynasys). The project consisted on designing, developing, testing and deploying a mobile ticketing service solution based on BLE and NFC technologies. The final solution was deployed in the entire Metropolitan Area of Porto (MAP), Portugal, in 2018 June 29th. Currently, a total of

11 transport operators, consisting of metro, train, one public bus operator and 9 private bus operators, accept the Anda as a mean of payment for the trips of their passengers. Three months after its launch, the Anda mobile application has more than 5.000 customers completely registered (with bank account associated) and more than 2.000 validations per day. From July to September the average weekly growth rate was 8%, and this rate rises to 12% if only the month of September is considered.

The design of the mobile ticketing solutions followed the DMTS methodology and as such several research methods from different fields were applied. Service design principles are used to address complex stakeholder relationships, overcoming the inability of interaction design approaches to take on this challenge. However, despite its superiority to interaction design in this subject it still relies on a rather simplistic framing of customer and service provider. Therefore, the DMTS methodology tackles this issue by addressing more effectively the design of ticketing services in complex ecosystem environment. It follows a user-centred design approach, using participatory design techniques to actively involve all stakeholders in the value co-creation process.

Interaction design is used in the DMTS methodology for creative exploration. Compared to service design it is less structured, more emphatic and has a tradition of pushing new technological systems into the world. Mobile ticketing is about disruptive solutions and cannot rely on the adoption of well-know and well-understood technologies, as does service design. Finally, more structured models from software engineering are used in the DMTS methodology to fill the gap in specification and development of the mobile ticketing solution that other perspectives are not capable of.

Evaluation phases consisted of technology tests, experts' evaluation using heuristics evaluation techniques, usability tests with users conducted in laboratory and in context and pilot trials performed in real environment with potential customers. These experiments were accompanied by questionnaires, interviews, focus groups and interactions through social networks. A total of 60 in-depth individual interviews and 6 focus groups were conducted, recorded, literally transcribed and analysed following qualitative research tenets (Charmaz 2006; Strauss and Corbin 1998). Comments on social networks and emails were also carefully analysed according to qualitative methods (Charmaz 2006; Strauss and Corbin 1998). These analysis were incorporated in the design of the solutions, allowing to improve them, and provided important contributions to the theory and to the refinement of the DMTS methodology.

1.4 Contributions

This thesis provides three main contributions. The first contribution is related to the state-of-the-art of mobile ticketing. This thesis provides an updated and comprehensive literature review about mobile ticketing, complemented by empirical work. It details and compares the main technologies used to perform payments with the mobile phone and presents the main benefits and challenges associated to mobile ticketing services. Finally, the mobile ticketing ecosystem is described, by identifying the main stakeholders, their motivations, concerns, contributions and expected benefits from participating in a mobile ticketing initiative.

The second main contribution is also to the existing theory and consists of the DMTS methodology. The DMTS methodology encompasses a holistic vision of designing mobile ticketing services, which can be replicated across urban passenger transport systems around the world. It combines knowledge, methods and tools from different fields to design mobile ticketing services in complex ecosystem context. The DMTS methodology was validated, and refined, during the design of four mobile ticketing services. The last one has been deployed in the Metropolitan Area of Porto, Portugal, and is being used by thousands of passengers every day. It has also been demonstrated during the research projects that the DMTS methodology can be applied to design other mobile value-added services and to other domains not related to urban passenger transport, such as basic mobile payments, peer-to-peer transactions and loyalty schemes.

The third main contribution is the four mobile ticketing services that were designed. They represent the tangible outcome of the research and the empirical testing and validation of the DMTS methodology. They contribute to the theory and to the practise of the mobile payments field, and ticketing in particular. Each of the solutions has innovative characteristics, contributing to the advancement of research. Also the fact that each solution has been implemented in real context through field trials fill the gap in literature identified by Dahlberg, Guo, and Ondrus (2015), who "strongly encourage researchers to collect data from the real world. For example, field tests, experiments and experiences about real services, or data about the actual usage of mobile payment services will improve the relevance and impact of academic research." The deployment of the Anda mobile ticketing solution had also great impact on the society and citizens lives.

1.5 Thesis outline

This thesis is organized as follows. Chapter 2 provides a literature review about mobile ticketing. First, it clarifies some general concepts regarding transport ticketing. Then it proposes a mobile ticketing definition according to the scope of the thesis. It details and compares the main technologies used to perform payments with the mobile phone. It presents the benefits of mobile ticketing services and the factors that are hindering its expansion worldwide. Finally, it describes the mobile ticketing ecosystem by identifying the main stakeholders, their motivations, concerns, contributions and expected benefits from participating in a mobile ticketing initiative.

Chapter 3 presents the DMTS methodology. It begins by describing theoretical concepts and designing approaches on which the DMTS methodology is based. Then it details every design stage of the DMTS methodology that are illustrated using examples of the projects.

Chapter 4 describes the four mobile ticketing solutions that were designed using the DMTS methodology in the scope of four research projects. For each mobile ticketing solution it presents the architecture, use cases, prototype, evaluation procedure, results and conclusions and a critical analysis of the application of the DMTS methodology to the design process.

Chapter 5 concludes this thesis. It discusses the main findings and contributions of the research, lists the main publications and provides future research directions.

2. Mobile Ticketing

2.1 Public Transport Context

Nowadays, new technology innovations and widespread adoption of mobile devices are contributing to a transition phase in mobile ticketing market, between numerous tried and failed solutions and a future of promising but yet uncertain possibilities. Before describing mobile ticketing and presenting the most used technological solutions, an introduction to the public transport context is presented. Pricing, ticketing, open gate and close gate solutions, automated fare collection systems and electronic ticketing schemes are concepts that are worth clarifying before exploring the mobile ticketing environment.

2.1.1 Pricing and Ticketing

To use public transport services, customers have to pay a fare, which represents an exchange value of a journey (Mezghani 2008). From an economic and financial point-of-view the fare paid by customers should be such that the total revenue earned by a public transport operator is sufficient to cover the total cost of providing the service plus a reasonable profit. However, in the majority of the cities, public transport has some characteristics of a public good and pursues social objectives. Therefore, the price policy of public transport services should be the right balance between several and sometimes contradictory objectives from authorities, transport operators and passengers. While authorities seek to establish low prices and simple tariffs in order to promote social inclusion and increase the number of citizens using public transport, transport operators seek to maximize profits and decrease costs. Finally, passengers want to travel in good conditions at the minimal possible cost. The main challenge in defining the pricing policy is to reconcile these competing objectives.

There are several types of fare structures that are being implemented in cities around the world. The most common are the following ones:

- **Flat fare**: all passengers are charged the same fare regardless of the route and distance travelled. These are simple to implement, do not require as much infrastructure as a tap-in/tap-out system, and are easy to use. Flat fares might be the most equitable for sprawling cities with low-income groups on the urban peripheries, by providing these groups access to the city centre regardless of how far away they live. However, this type of system presents a low farebox recovery ratio, which means that the cities have to rely more heavily on their budgets to cover operating costs (Diaz and Bongardt 2013). Also, this scheme does not in any way reflect the quantity of service that the passenger receives, since a passenger traveling three blocks pays the same amount as a passenger traveling 8 or 10 km (Vuchic 2017). Examples of cities with flat fare structure implemented include Vienna (Austria), Atlanta, Austin and Boston (USA) and Toronto (Canada).
- **Distance-based fare**: the price varies according to the distance travelled. Usually each route is divided into fare stages and the spacing may reflect differences in operating costs or demand characteristics. It requires higher investment on infrastructure to be implemented, but are economically more efficient from an operational perspective, since the price of the fares reflect the cost of providing the service. However, this solution may be disadvantageous for low-income groups who live far from employment centres and have to pay more to travel to the city (Farber et al. 2014). Examples of cities

with distance-based fare structure implemented include Hong Kong (Hong Kong), Singapore (Singapore), Tokyo (Japan), Amsterdam (Netherlands) and Sydney (Australia).

- **Zonal fare**: the city is divided into zones with a flat fare within each zone. The price to be paid by the passenger will depend on the number of zones crossed. This combines the distance-based and flat fare structures, which increases the complexity of the implementation and the difficulty in use. The objective is to achieve an equitable model, however some authors argue that it is not equitable for passengers travelling short distances across two zones as they have to pay for two zones (Mezghani 2008). Examples of cities with zonal fare structure implemented include Porto (Portugal), Berlin (Germany), London (UK), Zurich (Switzerland) and Auckland (New Zealand).
- **Time-based fare**: passengers can travel within the public transport network and make free transfers during a period of time. This time period can range from a time period of one or two hours to a week or month. Usually, this scheme is combined with distance-based or zonal fare schemes. Examples of cities with zonal and time-based fare structures implemented include Porto (Portugal), Washington DC (USA) and Melbourne (Australia).

The price may also vary according to the journey purpose (lower prices for leisure via 3-days tickets or weekend tickets), time of day (generally higher for peak hours), regularity of use (individual daily tickets are more expensive that monthly passes), and characteristics of the passenger (such as children, student, unemployed, elderly and pensioners).

Ticketing is a tool for the implementation of a public transport fare policy at the level of the whole public transport network (Urban ITS Expert Group 2013). The ticketing system is the translation of fares into concrete means of payment for the passenger and fare collection for the operator (Assessment and Parliamentary 2014). In the public transport network, several types of tickets can be identified, such as single journey tickets, single-operator tickets, multi-operator tickets, weekly or monthly passes, group tickets and special event tickets.

The ticketing media has been evolving over the years, and today several types may coexist even in the same city. Paper tickets were the first to appear and are still widely used worldwide. Despite of being less expensive and easy to combine with other payment technologies, they are highly susceptible to fraud and have limited data collection capabilities.

Magnetic stripe cards are also a ticketing media and although they support a high number of uses, they are susceptible to accident erasure and have a large variance in reliability. They are easy to copy and only able to save very little information. Contactless cards, which appeared in the 90s, are rapidly replacing these two types of tickets. They use Radio Frequency Identification (RFID) or Near Field Communication (NFC) to establish a communication between the card and the validation device. This system has many advantages over traditional payment methods such as secure data transfer, large memory capacity, high reliability and resistance to fraud.

Mobile ticketing systems are more recent and are based on the use of the travellers' mobile phone to pay for the trip. The use of mobile phones in public transport allows not only to make payments but also to process and exchange a large amount of information between the customer and the service provider.

2.1.2 Open Gate vs. Close Gate Solutions

Ticketing systems may be classified in two types: gated (closed) and non-gated (open).

Gated systems are usually closed through physical gates (turnstiles). Typically these gates are equipped with ticket readers. The passenger has access to the mean of transport after validating his/her fare media on the reader. If the ticket is recognized by the reader as valid, the turnstile opens and the passenger passes. In terms of revenue loss, the main system fraud are individuals that enter and exit the system without paying (Mayes, Markantonakis, and Hancke 2009). The introduction of reliable gates and machine-readable ticket reduced the fraud in public transport by decreasing the number of passengers traveling without a ticket (Mayes, Markantonakis, and Hancke 2009).

Non-gated systems usually have no physical barriers preventing passengers to pass. It is assumed that the passenger would buy an appropriate ticket for his travel under the threat of randomly applied ticket inspection. It may also be necessary to validate the ticket before entering the vehicle at readers placed along metro and train platforms or inside buses. In currently deployed non-gated ticketing systems, it is often hard to accurately determine journey length or duration, since it is impractical to collect data about the journey endpoint (Ekberg and Tamrakar 2012). When the alight station/stop cannot be collected, a typical solution is to define transport zones and to assume that the user buys an appropriate ticket for his/her travel. These mechanisms are coarse-grained, and often difficult to solve for users traveling along unfamiliar routes.

Although for mobile ticket implementation the choice between these two models (gated and non-gated) is usually a political decision, the technology and approaches involved may be more adequate to one of the options, concerning the user experience and fraud control. As an example, despite non-proximity mobile payments being more geared towards non-gated mobile tickets, many companies opt to use them in gated mobile tickets as a way to ensure there is no fare evasion.

Similarly, in gated mass transport, rapid people throughput is a paramount consideration. Smart Card Alliance sets the unofficial maximum transaction time to 300 ms per gate entry (Smart Card Allianc 2006). This time constraint, in practice, eliminates the possibility of online verification supported by a backend, since a tap-and-hold transaction is about 700ms (Ekberg and Tamrakar 2012).

2.1.3 Automated Fare Collection Systems

Automated fare collection (AFC) is the central element of intelligent transportation systems (ITS) and its function is the automation of the collection of fares for a public transport network. AFC systems were first introduced to help cut costs, control increasing fraud rates experienced by the public transport industry and simplify the passenger experience (New Science 2014). AFC systems usually consists of fare media (such as public transport smart cards or mobile ticketing), readers/ writers for ticket status and passenger control, back office computers and a central clearing house to gather revenue data and performance reports (Puhe, Edelmann, and Reichenbach 2014).

AFC can bring added value to passengers and the transport authorities. It is perceived as a secure method of user validation and fare payment (Pelletier, Trépanier, and Morency 2011) as well as a transparent method of fare collection, improving the customers' satisfaction (Vidyattama and Nakanishi 2016). It also makes the drivers' job easier, as they no longer have to collect the fare. Modern AFC systems are able to calculate the best price for the user, eliminating the necessity of fare learning by the users, improving interaction and building trust. Additionally, AFC systems generate continuous data regarding the passenger flows that can be used for many purposes other than revenue collection.

These continuously generated data have received much attention from researchers. Analysis of AFC systems data include: estimation of the destination of individual passenger journeys (Nunes, Dias, and Cunha 2016); validation of travel behaviour (Munizaga et al. 2014); influence of meteorological conditions on the number of public bus trips (Arana, Cabezudo, and Peñalba 2014); detection and estimation of activities of public transport users (Devillaine, Munizaga, and Trépanier 2012); improving public transport decision making, planning and operations (Oort and Cats 2015); and modelling transit travel patterns from location-stamped smart card data (Chapleau and Chu 2007).

2.1.4 Electronic Ticketing Schemes

Depending on the type of interaction that occurs between the passenger and the AFC system, different schemes can be distinguished. These are presented below and summarized in Table 1.

- Check-in (CI): requires an intentional user action when entering a vehicle. The customer needs to indicate the boarding station, by holding his mobile phone or smartcard in front of a reader or by selecting the boarding station directly on the smartphone. This type of technology is well suited for open gated systems, since it is not necessary an action from the passenger at the end of the journey to open the gate. Examples of such implemented systems is the Andante smartcard in Porto (Portugal) and a proposal for a public transport ticketing solution based on customers' mobile devices that only need to have internet connection to check-in when entering a vehicle (Ferreira, Nóvoa, and Dias 2013)
- Check-in/Check-out (CICO) (also called Tap-In/ Tap-Out or Touch-In/ Touch-Out): The check-in/check-out process requires customers to hold their mobile phone or smartcard in front of a reader to check-in when entering a vehicle and when leaving the vehicle at the end of the journey to check-out. This scheme is very typical of closed systems, such as the oyster smartcard in London (UK), Octupus card in Hong Kong (China) and EZ Link in Singapore (Singapore). The Ring&Ride project, in Germany, is also based on a CICO concept, where the passenger dials a number at the beginning and at the end of the journey (Lüke et al. 2009). (Costa et al. 2015) also propose a CICO solution through which the passenger reads, with his mobile phone, the QR Code of the boarding station at the beginning of the journey and the QR Code of the alight station at the end of the journey. The fare to pay for the journey is then calculated.
- Be-in/Be-out (BIBO): This principle no longer requires the passenger to actively register at specific access control points as the system automatically detects and registers the presence of a smartcard or smartphone in a vehicle. The system automatically captures the fare media when entering or exiting a transport mode and also periodically during

TABLE 1. ELECTRONIC TICKETING SCHEMES

	Check-in (CI)	Check-in/Check-out (CICO)	Be-in/Be-out (BIBO) Walk-in/Walk-out (WIWO)	Check-in/Be-out (CIBO)
User interaction	At the beginning of the journey.	At the beginning and at the end of the journey	No user interaction is required	At the beginning of the journey
System	Records the boarding station. Do not identify the alight station.	Records the boarding and alight station.	Identifies and records the boarding and alight station.	Records the boarding station and Identifies and records the alight station.
Open (non-gated) vs. gated systems	Well suited for open systems	Well suited for gated systems	Well suited for open systems	Well suited for open systems
Fares	Flat fare or pre-purchased tickets	Automatic fare calculation	Automatic fare calculation	Automatic fare calculation
Advantages	- Exact data on origin. - Public awareness of voluntary check-in action.	- Exact data on origin and destination - Public awareness of voluntary check-in/check-out actions (reduced fraud)	- Convenience: no user actions required. - Reduce barriers to access the public transport service, such as fare literacy and correct validation of the ticket - Automatic fare calculation, allowing the integration of complex and flexible fare policies - Exact measuring of journey stages as a basis for revenue sharing in an integrated public transport network - No visible terminals, therefore less opportunity for vandalism	- Exact data on origin. - Exact degree of transport capacity utilisation by time, line and vehicle. - Automatic fare calculation, allowing the integration of complex and flexible fare policies. - Exact measuring of journey stages as a basis for revenue sharing in an integrated public transport network.
Disadvantages	- Late or no validation. - No data on destination and public transport usage. - Do not allow implementation of complex and flexible fare policies.	- Less convenient to passengers: requires implicit actions. - Users may forget to check-out, being charged a higher fare. - Early check-in. - Late or no validation.	- Risks of malfunction: be-in/be-out not detected, compromising the calculation of the fares and passengers' trust on the system - No user actions under public awareness - Manipulation of the detection process by users (shield or switch off the fare media while boarding or during the trip)	- Risks of malfunction: be-out not detected, compromising the calculation of the fares and passengers' trust on the system - Manipulation of the detection process by users (early be-out)

the trip. For instance, (Narzt et al. 2015) propose a BIBO ticketing solution based on BLE technologies. This type of schemes are really convenient for passengers, since no implicit action is required from them. However it has several implementation challenges such as be-in and/or be-out not detected, compromising the calculation of fares and users' trust in the ticketing system (Lorenz 2009)

- Check-in/Be-out (CIBO): requires an intentional user action when entering the vehicle while the alight station is automatically detected by the system, as well as intermediary stations along the trip. For non-flat fare structures this information is crucial to reconstruct the route and calculate the fare to be paid by the passenger. This scheme has the advantage of requiring a user action under public awareness at the beginning of the journey (check-in), helping to reduce the risk of fraud (Lorenz 2009). The cases of failure are limited to the second step of the CIBO, i.e. to find out whether a user device is still inside the vehicle or not. An example of a check-in/be-out system is the Anda mobile ticketing solution implemented in Porto (Portugal). The check-in is done through an NFC connection between the reader and the passenger's smartphone and the rest of the journey stages are captured through the interaction between the beacons placed in stations/buses and the BLE's smartphones, as described later in section 4.5.
- Walk-in/ Walk-out (WIWO): The walk-in/walk-out principle works similar to be-in/be-out as no action is required from the passenger. The difference is only a technical, as the systems are based on the recognition of the direction of passenger movement while passing the vehicle's doors: walking in or walking out. Usually, antennas are placed at vehicle doors, which activate the passengers' devices from the sleep mode and send specific data to it (Lorenz 2009).

2.2 Mobile Ticketing Definition

Mobile payments can be defined as "the use of a mobile device to conduct a payment transaction in which money or funds are transferred from a payer to a receiver via an intermediary, or directly without an intermediary" (Mallat 2007) . While some definitions include the whole payment actions "any payment where a mobile device is used to initiate, authorize and confirm an exchange of financial value in return for goods and services" (Au and Kauffman 2008)) other definitions relax this requirement: "Mobile payments are payments for goods or services initiated from a mobile phone or similar device (such as a personal digital assistant or smart phone)" (Smart Card Alliance 2007) broadening the scope of application of the term mobile payments.

Concerning the diversity and heterogeneity of the different approaches to mobile payments, a broader scope definition seems more adequate such as "Money rendered for a product or service through a portable electronic device such as a cell phone, smartphone or PDA." (Investopedia, n.d.). Mobile payment, m-payment and mobile money or m-money seem to also to be used interchangeably, with the latter being defined as "financial transactions and services that can be carried out using a mobile device such as a mobile phone or tablet" (International Telecommunication Union 2013). Mobile devices include mobile phones, watches, PDAs, tablets and any other devices that can connect to communication networks at least at any of the stages of the payment process and make it possible for payments to be made (Herzberg 2003).

Mobile payments are broadly classified into remote and proximity (also known as contactless) payments, according to the location of the mobile phone user in relation to the service provider (European Payments Council 2012). For remote payments the transaction is conducted over telecommunication networks such as Global System for Mobile Communications (GSM) or Internet, and can be made independently of the payer's location. This could be done using SMS, Unstructured Supplementary Service Data (USSD), Wireless Application Protocol (WAP) Wireless communication technologies (Wi-Fi or 3G/4G). For proximity payments the customer and the service provider are in the same location, communicating with each other using contactless technologies, such as Bluetooth, RFID and NFC for data transfer.

Mobile ticketing is used in transport networks to buy and display tickets on mobile phones. Juniper Research defines mobile ticketing as "someone who stores a ticket on their mobile phone for later redemption"(Juniper 2010). This definition excludes the need to initiate the purchase through the mobile device, which coincides with the (Puhe, Edelmann, and Reichenbach 2014) definition of mobile ticketing: "Mobile ticketing is basically a virtual ticket that is held on mobile phones, tablets or personal digital assistants (PDAs) and can be ordered and obtained from any location." (Mut-Puigserver et al. 2012) introduce the need of validating a ticket in the definition: "Commonly, the ticket validation is required in order to use the service. Depending on the conditions of the ticket, it can be validated once, a predefined several times or indefinitely until a deadline."

In this dissertation mobile ticketing is considered as the use of a mobile device to purchase and/or validate a travel ticket or to initiate a journey. This definition includes the use of a mobile device to previously purchase and/or validate a travel ticket or to start a trip through a declared check-in or through a be-in/be-out scheme, whose information will then allow to calculate the price to be paid for the journey. Next section presents the technologies most used in mobile ticketing solutions.

2.3 Technologies

Mobile ticketing often involve more than one type of technology. As mobile ticketing take place through mobile unwired devices, data communication assumes a fundamental role, mainly between the user's mobile device and the service provider. This is especially important for proximity mobile payments, where each technology may pose important constraints on the payment execution.

Technologies for mobile ticketing have paved a long road, some of them are now basically defunct in terms of practical use, such as the case of the Infrared (IrDA), while others have appeared recently and their presence is not yet universal such as the case of the Near Field Communication (NFC). The existing mobile technologies that can be used to power mobile ticketing solutions are what we call "Mobile Phone Data Technologies" (GSM and its successors), IrDA, RFID, Bluetooth, ZigBee (and its RF4CE derivative), Wi-Fi and NFC. With the onset of the wearable devices, some proprietary technologies such as the ANT (by Garmin) and Nike+ (from Apple and Nike) may also be used for mobile payments. We excluded Nike+ from our research as it is a closed technology.

The following subsections describe the technologies: SMS and phone calls, Wi-Fi and 3G/4G, RFID, near field communication, Bluetooth low energy, and quick response codes. A brief summary and comparison is presented in subsection 2.3.7.

2.3.1 Short Message Service and Phone Calls

Global System for Mobile Communications (GSM) was the first supranational digital technology used to connect mobile phones and laid the ground for the possibility of using mobile phones for applications other than voice calls. This standard was developed by the European Telecommunications Standards Institute (ETSI) in the decade of 1980 and was first deployed in Finland in December 1991 (Huurdeman 2003). Since then it has expanded globally with more than three billion users. One of the biggest problem of GSM was its low data rate: 9.6 Kbit/s (Rohde & Schwarz 2016). GSM is, by nowadays standards, obsolete, with mobile phone operators in some countries shutting the network down in favour of more recent developments, such as the 3G and 4G, which offer data rates up to 1 Gbps (theoretical).

The introduction of these digital cellular radio systems caused an enormous boost in telecommunications, allowing to make phone calls and send Short Message Services (SMS) through mobile phones. SMS was introduced on GSM networks in Europe in the mid-1990s, followed by Asia and USA in the end of 2000 on non-GSM networks (Huurdeman 2003). It uses standardized communication protocols to enable mobile devices to send and receive short text messages of up to 160 alpha-numeric characters (or multiple of this).

Early mobile data technologies, despite their low data throughput, were the first to support simple mobile tickets purchases, by sending SMS or making phone calls. The Ring&Ride mobile ticketing project, supported by the German Federal Ministry of education and Research, is based on the check-in/check-out concept, i.e. the customer has to take an action not only at the beginning, but also at the end of the trip (Lüke et al. 2009). When starting, he dials a toll-free phone number and receives a ticket (SMS) that is valid for both long and short distance travel. At the end of the trip, the passenger dials the number again to signal that the trip has been finished. The customer's location is determined at the starting point and at the destination, but also during the trip at defined time intervals. The ticketing system uses different localization information, such as GSM cell IDs, WLAN SSIDs and GPS coordinates for reconstructing the route which is taken and calculates the corresponding fare.

Paybox[1] in Austria allows the Austrian railway OBB customers to purchase travel tickets via SMS or through the Vodafone live! Portal, allowing the customers to pay for the tickets through their monthly phone bills. Proximus SMS-Pay[2] in Belgium, Mobipay[3] in Spain and AvantixMetro[4] in UK are also examples of mobile ticketing systems based on SMS that have been implemented. Sarma (2014) proposes a system that allows passengers to book travel tickets using USSD messages, then the passenger receives his ticket details through SMS. Another example of a

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[1] https://www.paybox.at/

[2] https://www.proximus.be/en/id_b_cl_bemobile/companies-and-public-sector/discover/news-blog/news/de-lijn.html

[3] http://www.fujitsu.com/es/about/resources/case-studies/mobipay_en.html

[4] http://www.casiomedia.co.uk/files/MobileDevices/downloads/case%20studies/newcasestudies/HEATHROW_CaseStudy.pdf

mobile ticketing system is given by the Czech bus reservation system AMSBUS, which, in February 2007, introduced the product “e-jízdenka” on several bus routes. Since November 2007 it has been possible to buy an SMS-ticket (SMS jízdenka) for use on Prague's urban transportation (Ghiron et al. 2009).

While SMS can be considered a simple and easy way to use technology, it has limitations when used to make payments. SMS uses store and forward technology, does not use any encryption method and there is no proof of delivery within the SMS protocol (Boer and Boer 2009). Most SMS-based mobile payment models do provide a proof of delivery, requiring a second separate message to be sent, which increases the costs of a transaction. This problem is particularly pertinent when small payments are at stake. Additionally, in the study conducted by Nina Mallat (Mallat 2007), interviewees reported a number of problems, such as: the message formats are often complicated and slow to key in, the existence of various payment codes and premium service numbers make them difficult to remember and the difficulty in finding instructions to make payments.

Because remote payments do not require a new infrastructure (unlike contactless payments) and enable payment transactions regardless of distance, this service is growing in developing countries as the best or the only way of performing domestic or even international money transfer, in areas where there is little, if any, bank infrastructure. In developed countries recent developments such as 3G and 4G are the main data connection for mobile phones (other than WIFI), powering all kinds of digital services, including mobile payments.

2.3.2 Wi-Fi and 3G/4G

Wi-Fi is a wireless technology that allows devices to connect to a wireless local area network. Wi-Fi has two connection modes:

- **Infrastructure mode** – Several devices can connect to an access point, which manages the data flow in the network and can also be used in conjunction with a router to provide internet access to electronic devices in the network.
- ***Ad-hoc* mode**, where two devices can establish a peer-to-peer data connection.

Wi-Fi works in the 2.4 or 5 GHz spectrum providing up to 150m of communication range and can be used as cheap way to provide internet access to mobile devices (*hotspot*) as an alternative to more expensive data connections provided by mobile network operators. Wi-Fi can act in mobile payments as a way of providing a cheap data connection to get cloud data, offers and coupons and also as a data gateway to proximity and remote payments. It has high bandwidth and the cheapest cost per bit and it has low latency (for higher power modes). It has also a low power mode (which reduces bandwidth to 6 Mbps).

It is worth to mention that in January 2016 a new protocol called WiFi HaLow was presented[5]. Wi-Fi HaLow operates on the 900 MHz, offering longer range, lower power consumption. It can penetrate walls and it is well suited for Smart Homes and Smart Cities, powering the “internet of things” (IoT), and can possibly be used for mobile payments, although the precise extent is not yet known.

[5] https://www.wi-fi.org/discover-wi-fi/wi-fi-halow

Ferreira, Nóvoa, and Dias (2013) propose a mobile ticketing solution for public transport using passengers' smartphones with Internet connection. The purchase and validation of tickets is made Over-The-Air (OTA), and location providers are used to locate the traveller and reduce the number of options when it comes to purchase or validate a ticket. This solution was tested in the city of Porto, by real passengers of Sociedade de Transportes Colectivos do Porto (STCP), the main bus transport company, during their normal use of public transport services. The Indian Railway Catering and Tourism Corporation Limited (IRCTC) developed a mobile application through which registered passengers can book railway tickets and confirm the payment using the 3G/4G mobile data from their phone network providers to access the internet on the move and ubiquitously (Kapoor, Dwivedi, and Williams 2015).

2.3.3 Radio-Frequency Identification

RFID (Radio Frequency Identification) is "*a non-contact, automatic identification technology that uses radio signals to identify, track, sort and detect a variety of objects including people, goods and asset without the need for direct contact or line-of-sight contact*" (Knospe and Pohl 2004). It has been around since the Second World War (Landt 2005), increasing its presence on our daily life, from shopping product identification to transport systems (such as the Oyster card from Transport for London or the Andante card from Transportes Intermodais do Porto).

RFID systems are comprised of three elements:

- An RFID tag or transponder that carries object-identifying data
- An RFID tag reader, or transceiver, that reads and writes tag data
- A back-end database, that stores records associated with tag contents.

An RFID reader emits a low-level radio frequency magnetic field that energizes the tag. The tag responds by announcing its presence via radio waves, transmitting its identification data. The operating range may be up to 10 meters depending on the operating frequency.

As it is a contactless technology and requires no Line-Of-Sight (LOS), it can be fitted in mobile payment systems. The technology is well known, relatively cheap, widely available and ready to use. That is why it has been chosen several times, mostly by credit card companies in association with mobile phone manufacturers, to power mobile payment experimental projects. However, it has some disadvantages in what concerns to security, being fairly easy to clone a RFID-card (Heydt-Benjamin, Bailey, and Fu 2007).

Since RFID technology is mostly applied to cards rather than to mobile devices, the studies regarding mobile payments based on RFID are scarce and usually focused on security. He (2012) proposes a RFID-SIM card mobile payment scheme based on a low-frequency magnetic coupling activation strategy. Simulation results show that the proposed mobile payment scheme is reasonable, secured, robust, low-cost, and easy to promote. Ahmad-Reza, Ivan Visconti (2008) presented an efficient RFID-based e-ticket scheme for transit applications. However, they assumed the existence of external trusted devices and their system do not protect privacy against a prying transport authority but only against prying outsiders.

2.3.4 Near Field Communication

Near Field Communication (NFC) is a short-range, high frequency, standards-based wireless communication technology that enables exchange of data between devices in close proximity. This requires at least one device to transmit a signal and another to receive it. NFC devices can be passive or active. A passive device, such as an NFC sticker, contains information that other devices can read, but does not read information itself. Active devices, like smartphones, point-of-sale terminals and other digital devices can both read and send information to other compatible devices (Hayashi and Bradford 2014). The contactless NFC chip can be embedded into the phone, in the SIM card, or in a sticker. NFC technology can operate in three different modes: as card emulators (replacing information stored on plastic cards), in peer-to-peer mode (exchanging data with other devices), and in card/tag reading and writing mode (reading or changing information stored in a RFID tag or contactless card).

NFC can be RFID compatible and can be implemented in mobile payment systems, as it needs very low power consumption, it offers great security mechanisms and it is easy to use and to establish a connection (J. J. Chen and Adams 2004). It supports both file transfer and data transfer. The downside is that it works only at very short distances (approximately 4cm) and only supports peer to peer connections. This contactless technology is enabling "wave and pay" transactions, where mobile devices or phones equipped with NFC may be waved in front of a contactless reader in a store or at a purchase point. The NFC chip in the phone transfers the payment details to the terminal.

Most recent approaches by big technology corporations such as Google's Android Pay, Apple Pay and Samsung Pay use NFC as their short distance payment technology. Phones with embedded NFC are becoming common and NFC-powered mobile payments, and recent industry market research agree on a strong market growth prediction, with some forecasts[6] estimating a fivefold growth of the NFC mobile payments over the next eight years, reaching 47.43 USD Billion in 2024.

Incorporating NFC technology in mobile phones promises to offer numerous valuable services to end users, while generating profits for the actors involved in providing these services. One possible break-through service for NFC in mobile phones is considered to be mobile ticketing in public transport. This service could fuel the growth of the NFC ecosystem and be profitable by itself. NFC was considered a good choice for mobile payments in terms of speed, security and usability when compared with traditional mobile payment service concepts, such as Interactive Voice Response, SMS, Wireless Application Protocol and One Time Password Generator (Massoth and Bingel 2009; K.-Y. Chen and Chang 2013). The introduction of NFC technology in public transport environment helps transport operators to decrease costs by reducing cash handling in vehicles and facilitating the sale of tickets to the passengers (Juntunen, Luukkainen, and Tuunainen 2010). Furthermore, many transport operators already have a travel card reader infrastructure that is compatible with NFC, which reduces the investments needed to provide the service.

However, despite optimistic predictions, NFC is failing in getting critical mass. Several factors account for the slow adoption and diffusion of NFC services. First, technical standardization of important protocols was only recently completed, and there is a lack of handsets supporting the

[6] https://www.grandviewresearch.com/press-release/global-near-field-communication-nfc-market

newest standards on the market. Second, unclear revenue logics for the supply side of players as well as the complicated co-operation between banks and operators have caused uncertainties for the NFC ecosystem. In addition, possible restraints for NFC services in the future include the difficulty of changing telecommunication operators by the users due to the use of the Universal Integrated circuit Card (UICC) as a secure element, as well as the limited number of current NFC services that are attractive to end users (Juntunen, Luukkainen, and Tuunainen 2010).

Several pilots of mobile ticketing with NFC-enabled phones have been launched in the public transport sector. For instance, the Touch&Travel[7] service in Germany allows passengers to make payments with their mobile phones. Passengers have to tap their NFC-enabled mobile phone to the Touchpoint device at the departing station and at the destination. The length of the journey and the ticket price are calculated at the end of the journey, and the customer receives, each month, a statement with all travel data and an attached invoice. A NFC pilot was also launched in London (NFC Forum 2011), where 500 customers were given Nokia handsets with Oyster functionality. Passengers could top up their Oyster by touching their handset on Oyster ticket machines in tube stations or at Oyster tickets shops. Key findings of the research were that customers maintained high levels of interest and satisfaction throughout the trial and that the main customer benefits were convenience, ease of use, and status. Others (Rodrigues et al. 2014) present an integrated mobile service solution based on the Near Field Communication (NFC) protocol. The solution was tested in real-world payment situations and the results showed the lack of reliability of NFC as the major technical challenge.

Ghiron et al. (2009) present a prototype of a NFC-based virtual ticketing application, called NFCTicketing, which allows to buy travel tickets with NFC-enabled mobile phones and discuss the results of the usability tests performed. This NFCTicketing application combines NFC and SMS technologies. Ivan and Balag (2015) describe the design and implementation of a mobile ticketing system for urban transport based on NFC technology. Finally, Ceipidor et al. (2013) have identified several security issues that are common in mobile ticketing and propose some methods to solve them, such as a protocol to provide secure validation and travel tickets check that is independent of the NFC operating mode (card-emulation vs. peer-to-peer).

2.3.5 Bluetooth Low Energy

Bluetooth Low Energy (BLE) was integrated in the Bluetooth 4.0 Specification introduced in 2010 by the Bluetooth Special Interest Group (Carroll and Heiser 2010). It is a digital network technology that operates at the 2.4 GHz frequency band (J. J. Chen and Adams 2004). Since the initial version 1.0, subsequent versions brought several improvements, such as increased data throughput, longer range, improved connection experience, and reduced power consumption. The current versions (4.x) brought a subset of protocols called BLE which is focused on lowering the power consumption, lower connection latency from non-connected state, and improved range. BLE can connect to more devices because of the small data packages and quick connection set-up (van Klaarbergen 2013). The main feature of BLE, and that differentiates it from the standard Bluetooth specification, is the low power consumption it allows, making BLE ideal to be used in Bluetooth beacons. In addition to this, the vast majority of smartphones now

[7] http://www.touchandtravel.de/

being manufactured support BLE (Geddes 2014), which makes them a perfect counterpart for the BLE beacons.

A beacon in wireless technology is the concept of broadcasting small pieces of information. Different beacons may transmit different types of information, either static, such as simple identification data, or dynamic, such as information coming from sensors (temperature, humidity, location, orientation, or others). BLE beacons implement this by using BLE technology. The signal broadcasted by the BLE beacon can be picked by any Bluetooth enabled device within the emission range of the beacon (50m to 70m).

Communication between BLE beacons and other devices can either be one-directional, or connection based (Akinsiku and Jadav 2016). In one-directional communications (connectionless), the two parties involved are defined as the broadcaster (non-connectable device only with advertising capabilities) and the observer (device that scans for broadcasters' advertisements, without connecting to them). For connection-based communication, there are also two categories of devices involved: peripheral device (works in a similar fashion to the broadcaster, but allows connections to be established, in which it acts as a slave) and central device (similar to observer, but takes initiative to start connections with peripheral devices, acting as a master). BLE beacons' role in the communication process fall under the broadcaster and peripheral categories, while other devices, such as smartphones or computers, perform the observer and central device's tasks.

There are several protocols that have been defined by vendors to format how data is broadcasted by beacons. The two most notorious are the iBeacon and Eddystone. Both protocols are one dimensional and require a broadcaster and an observer (Akinsiku and Jadav 2016). The iBeacon is a proprietary protocol introduced by Apple in 2013. iBeacon transmits a 31 Byte packet and can be used in two ways: for monitoring (works even if the app is in a killed state) and ranging (works only for active apps). Eddystone was introduced in 2015 by Google as an alternative to the iBeacon protocol. Its implementation is more complex than Apple's iBeacon, but it provides a more flexible protocol allowing to send more information, has more features, and also has the advantage of being completely open source.

There are many studies focusing on the use of BLE technology for various Location-Based Services (Ito et al. 2016) (Fard, Chen, and Son 2015) (Dani and Cemgil 2017). By deploying several beacons in a limited space, any Bluetooth enabled device can calculate its position based solely on the signals from them, by using adequate algorithms. Although beacons are mainly used for location tracking, it is important to note that the tracking is not done by the beacons themselves, but the user's application/device. Beacons act only as broadcasters of a signal, and usually don't even connect with other devices. (Narzt, Furtmüller, and Rosenthaler 2016) conducted a series of experiments to measure the interference between environment conditions and BLE signal. They concluded that the presence of human bodies and metal near a BLE-enabled smartphone (approximately 20cm) have a significant shielding effect, affecting communication and distance calculations.

The use of BLE technology to support mobile ticketing services is recent and the studies about the topic are scarce. Narzt et al. (2015) propose a be-in/be-out ticketing system for public transport using BLE technology. Passengers carry a BLE beacon or BLE-enabled smartphone, which advertises a unique ID via a broadcast. This signal is received by an on-board system (OBS), in this case a Raspberry Pi, placed inside each vehicle. The information regarding the passenger

ID and route details are processed remotely on a decoupled system, which calculates the price to pay for the journey.

Another mobile ticketing pilot test using BLE technology was carried out in Soest, Germany, in 2016 (Kahvazadeh 2016). This pilot consisted on testing a check-in / be-out solution, through which the passenger checks-in in the vehicle by selecting the bus detected by the mobile application. Then, all bus stops along the journey are detected and recorded. When the passenger leaves the vehicle, the mobile application loses connection to the bus and the app closes the journey. The journey data and fare prices are calculated in the back office and the passenger receives the bill to pay for the journey by email.

Finally, a mobile ticketing solution based on BLE technology, called Anda[8], was deployed in the city of Porto, Portugal, in June 2018. It is based on a check-in/be-out scheme, requiring an intentional user action when entering the vehicle (tap the mobile phone against an NFC ticket reader), and the alight station is automatically detected by the system, as well as intermediary stations along the trip. The mobile phone interact with BLE beacons installed in metro and train stations and inside buses, through Bluetooth connection, to locate the customer along the transport network (Ferreira, Dias, and Cunha 2018). The price to be paid by the customer is calculated through a fare optimization algorithm, which minimizes the cost for the passenger.

2.3.6 Quick Response Codes

Barcode and quick response (QR) code *"are a machine readable means by which information can be pulled"* (Hayashi and Bradford 2014). Linear barcodes comprise a set of vertical lines and white spaces of variable width, representing numbers, which are read by a barcode reader to extract the information they represent. QR codes are bi-dimensional by patterns of black and white dots typically arranged in a square grid, carrying several hundred times more information than regular barcodes. These codes can be read by dedicated readers, or using smartphones as long as they have camera and autofocus feature. The reading distance between the reader/smartphone to the code depends on the size of the QR Code. It can range from 2,5cm to 2m. The bigger the QR Code, the bigger the distance at which the QR Code can be read effectively (Couto et al. 2015). Credentials used for payments may be encrypted within codes or stored in the cloud.

Code base mobile payments require a printed surface to present the code and a reader connected to a database to extract the code and identify the product or service. Although code-based payments are mostly suited to proximity payments, they can also be used for remote payments (for example as mean of redeeming coupons, promotions), as mobile phones can also read codes with their cameras. As a security matter, the one that is most mentioned has to do with the replacement of a QR Code by a malicious or unintended one(Leyden 2018). Even though QR Codes contain information and data, they can also contain commands to open a browser and redirect the user to malicious websites. Furthermore, some scanning applications keep track of all the scans done in an internal database. SQL Injection can also be exploited here, circumventing authentication mechanisms (Krombholz et al. 2014).

Therefore, the payments based on QR Codes can be of two main categories:

[8] http://www.linhAndante.com/noticias-det.asp?noticiaid=141

1. The QR Code is presented on the mobile device of the customer paying and scanned by a POS of the service provider. This solution is being mostly adopted by retailers.
2. The QR Code is presented by the service provider, in a static or one time generated fashion and it is scanned by the customer executing the payment. This solution is cheaper to implement since the previous one would require to huge investments in QR code readers at every stop and/or vehicle.

Finzgar and Trebar (2011) propose a mobile ticketing system based on QR codes and RFID tags that are used for registering passengers at the beginning and at the end of their journeys. Justride (Masabi 2017) is a cloud-based ticketing solution implemented in several transport operators such as New York MTA, Las Vegas RTC and LA Metrolink. Passengers access to the transport services by presenting the QR Code on their smartphone to the reader, which enables the identification of the passenger. Costa et al. (2015) present a mobile ticketing solution based on a check-in / check-out concept requiring the reading of the corresponding QR Code station. This application was tested by users in real environment, in the city of Porto, Portugal. The results show that users considered the system extremely useful, since it is more convenient than traditional systems (Ferreira, Fontes, et al. 2017). The use of the QR Codes to perform the payment has shown to be one of the main challenges to be addressed, since lighting conditions, position and distance to the QR Code influences the reading process.

2.3.7 Technology Comparison

The relative comparison of the main technologies involved on mobile payments approaches found in the literature, is shown in Table 2. Mobile payments can take advantage of more than a single technology. Recent mobile ticketing trends show that current approaches commonly use more than one technology, by using each one to address the shortcomings of the other. As an example, the Anda mobile ticketing solution is using a combination of NFC, WIFI/Mobile Phone Data and BLE to power their mobile ticketing experience.

2.4 Mobile Ticketing Benefits

"Offering products or services alone is no longer enough: organizations must provide their customers with satisfactory experiences" (Berry and Carbone 2002). In fact many organizations, including transport operators, have already realized that the integration of mobile phones in their service delivery process is a mean to strengthen and tighten their relationship with customers. Thus, "Mobile operators recognize that offering additional services can attract new customers and stabilize their subscriber base." (Smart Card Alliance 2007). Mobile phones have several features that make them unique and suitable to be used to make payments and provide additional services. Mobile phones are network-connected, have easy-to-use sound and text interfaces, provide anytime-anywhere access to information, and applications are easy to download over-the-air (OTA) and manage on the phone.

TABLE 2. RELATIVE COMPARISON OF THE COMMON MOBILE TICKETING TECHNOLOGIES

	SMS and Phone Calls	Wi-Fi and 3G/4G	NFC	BLE	QR Code
Type of payment	Remote	Remote	Proximity	Proximity	Proximity
Transmission distance (coverage)	>1000m	150m and >1000m	0,04m–0,10m	50m–70m	0,25m-2m
Transmission security technology	Low	Low	High	Low	Medium
Communication	One to one	One to one	One to one	One to many	One to one
Energy consumption	Low	Low	Very low	Medium (broadcasting aggressive mode)	Very low
Environment conditions interference	Medium	Medium	Low	High	High
Security	Low	Medium	High	Low/ Medium	Medium
Required investment from Service Provider	Minimal	Minimal	Significant: NFC-readers; software installation and integration	Significant: beacons; software installation and integration	Moderate: QR code scanners or printed QR Codes. Software installation and integration
Availability	High	High	Low	Medium	Medium
User interaction	High	No interaction (case of Be-in/ Be-out systems)	Low	No interaction (case of Be-in/ Be-out systems)	Medium
Check-in/check-out compatible	✓	✓	✓	✓	✓
Be-in/be-out compatible		✓		✓	
Advantages	- High availability - Familiar to every user - No or very low infrastructure investment	- High availability - Data transmission with the backend in real time - No or very low infrastructure investment	- Secure (data is encrypted and stored in a secure element) - Low user interaction - Faster read-speed	- Long distance reception - No user interaction (case of Be-in/ Be-out systems) - Provide more fine-grained data about passengers' movements	- Easy to create and print - Can be read by every smartphone with autofocus camera - Can be shown on any device's screen
Disadvantages	- Low security (no encryption) - No proof of delivery - Transaction costs (premium numbers) - Messages formats complicated, difficult to remember, hard to key in - High user interaction	- Network connection problems (underground stations, crowded stations/vehicles) - Insecure public Wi-Fi networks	- Lower availability - Not well-known - Only works well at very short distances - High infrastructure investment and maintenance costs	- Low/medium security (data transfer performed at long distances) - Power source needed - High installation and maintenance costs - High environment conditions interference	- High user interaction - High environment conditions interference - Less flexibility - High exposure to vandalism (case of printed QR codes) - QR Code reading process is not fast enough

In the context of public transport, mobile phones provide remote and ubiquitous access to payment services, as well as the possibility to avoid queuing and complement cash payments. This is especially important in certain use situations such as the presence of queues, unexpected need for a payment, time pressure, and lack of cash or loose change (Mallat 2007). When compared with paper magnetic stripe tickets, mobile tickets are less likely to be lost, and studies repeatedly have shown that people are less likely to leave home without their phones than with their wallets (Juntunen, Luukkainen, and Tuunainen 2010). Additionally, paper season tickets are worn with intensive use and must be replaced frequently, making tickets stored in mobile phones more robust and convenient than paper tickets, besides being a better solution to the environment (Ferreira et al. 2012).

Mobile phones have also advantages in comparison to contactless cards. Phones can hold more than one different ticket from more than one transport operator, while with contactless smart cards, it may be necessary to carry more than one card in the wallet (NFC Forum 2011). If in the wallet there are more than one contactless ticket card, and the entire wallet is presented to the reader, the reader cannot decide which one to read, so the traveller must remove the chosen card from the wallet. In addition, with mobile phones, users can manage their cards and tickets anywhere at any time. For instance, season ticket can be automatically renewed over-the-air, avoiding queues in ticket offices. Mobile phones can also hold multiple payment applications, allowing the traveller to select which method to use (credit, debit, travel passes, or prepaid tickets), thus offering easier ways to reload value or renew passes (NFC Forum 2011).

Additionally, as mentioned above, mobile phones' features allow PTOs to offer several additional services that other technologies do not allow. Users can, for instance, check their ticket balance and last journeys, access to transport timetables and location-relevant maps (Ferreira, Nóvoa, et al. 2014). PTOs can also interact with passengers by advising them to buy other types of tickets or travel cards that suits better with their travel profile, offer special discounts and loyalty points (Ferreira, Costa, et al. 2017).

The use of mobile phones in public transport allows customers to participate to a greater extent in the service delivery process, enhancing the customers' travel experience. In this new context, value is no longer embedded in tangible offerings but is co-created with customers through relational exchanges in interaction experiences (Normann 2001; Vargo and Lusch 2004). The use of mobile phones to purchase travel tickets, validate them, and get information, transforms the person-to-person public transport service into a self-service one. Additionally, passengers can co-create the service by, for instance, exchange with other passengers' operational and emotional information about the transport service that they are experiencing. This information can be then classified as correct or incorrect, and transport operators could reward users contributing with valuable data, as well as enhance the quality of their service (Nunes et al. 2016).

In addition to these benefits for customers, the use of mobile phones in public transport will have serious implications on transport operators' supply chain (Ferreira et al. 2012). Nowadays, the most common public transport suppliers are ticketing companies, ticket vending machines and ticket reader machines suppliers. The use of phones to purchase tickets over-the-air, will decrease the need of ticket machines, paper tickets, ticket sellers, and even ticket collectors, as well as will decrease the need of cash handling. It is estimated that the manufacture and distribution of fare media, ongoing equipment maintenance, and the collection and processing of cash may require agencies to spend 5–15 percent of their total revenue to collect fares (Smart Card Alliance 2011). PTOs can benefit from reducing this operational and maintenance costs. Paper tickets also require production, storage, and distribution, kiosks need maintenance and personnel. These costs can also be reduced with the introduction of mobile phones on the service delivery process (Niegel and Schättgen 2014). The introduction of mobile phones in public transport service delivery process will shorten the supply chain by eliminating some current suppliers. However, it will open doors to the arrival of new players like Banks, Mobile Operators or third parties, depending on the chosen business model.

Alternatively, transport operators can choose a location-based ticketing model (Bohm et al. 2005; Ferreira, Nóvoa, et al. 2014), where travellers don't need to buy tickets, they just need to check-in when starting a trip and check-out at the end of the trip. Then the system starts to determine the route within the public transport infrastructure, calculates the price of the trip and presents the account to the customer. In this specific case, there is no need of ticket vending machines or ticket readers, or even gates. Besides, PTOs can benefit from the perception of tickets stored in phones as environmentally friendly, and from the reduction of customer service issues with lost paper tickets.

Operational and productivity gains may also be achieved, by increased throughput in closed gate systems and improved bus boarding times. Transport Operators will be more able to deal with under occupied and overcrowded vehicles, through the use of differentiated fare policies that enable automatic fare modification (Global Platform 2009). Cloud-based mobile ticketing systems (Ferreira, Dias, and Cunha 2014) delivers data on actual usage of the public transport in real time. This would allow a transport operator to proactively act or quickly react to situations such as accidents or bottlenecks.

Mobile ticketing can also reduce fare evasion through fake-proof mobile ticket design. A significant number of free riders are people who arrive late to the transport and do not have time to buy a regular ticket (GSMA 2011). By reducing obstacles to ticket acquisition, mobile ticketing can bring additional benefits, such as increased the use of public transport services and mobile ticketing adoption, thus reducing pressure on physical ticket acquisition means. It also allows the implementation of flexible fare structures, varying according to the transport mode, time of the day, demand and individual use of public transport services.

Mining on the public transport data collected through the mobile ticketing system provides valuable information on network usage and travel patterns which could be used for planning, operation and marketing purposes. Transport operators will, for instance, be able to (Mezghani 2008):

- Monitor capacity utilisation and loading on different routes
- Monitor bus headways and punctuality
- Monitor boarding and alighting at stops and estimate passenger volumes at stops
- Estimate ridership per operator and ticket types
- Analyse travel patterns for different groups of passengers, introduce incentives
- Estimate O-D, time, cost, modes, transfer information, related to any journey.

Mobile phones also allow PTOs to provide additional services, enhancing customer experience and satisfaction. Hence, PTOs can benefit from new revenue streams, such as publicity in mobile apps or complementary retail purchases. Additionally, this closer interaction with customers will allow PTOs to know their customers' travel behaviour, and manage a vast and important database. This patterns and preferences expressed by customers can later be used to set up enhanced loyalty schemes, for instance, to advise customers of fares that suits better their travel profile or to create personalised journey plans to enhance the travel experience. Transport operators would also have the opportunity to contract providers of other transport services that are used in the mobility chain of their customers, such as parking, taxi and bike or car rental. Along the same lines, the solution could also be used as a "city service solution," covering a wide range of offerings such as libraries, museums, events and public services (Ferreira and Dias 2015).

2.5 Mobile Ticketing Challenges

Despite its clear advantages and the technological evolution, a large number of mobile ticketing initiatives fail before they even reach their intended end-users. At the moment, it is difficult to predict when and how mobile payment services will reach mass markets in developed economies (Dahlberg, Guo, and Ondrus 2015). Several factors are hindering the expansion of mobile ticketing services worldwide.

The implementation of mobile ticketing solutions requires the combination of different services (payment, transactions, identification, etc.), which are usually provided by different organizations or even industries. Therefore, mobile ticketing is complex as it requires the establishment of a full ecosystem involving many different stakeholders (Little 2014). They include passengers, transport operators, transport authorities, mobile network operators, financial services firms, software and technology providers, as well as the government. All of these stakeholders have their own personal interests that may collide with each other. Major efforts are required to merge actions and expectations of these rather heterogeneous actors in order to resolve their conflicting interests in terms of revenue sharing, customer ownership and support issues. Discussions are ongoing about future business models (Sang, Chae, and Hedman 2015; Juntunen, Luukkainen, and Tuunainen 2010; Pousttchi, Schiessler, and Wiedemann 2008), however achieving consensus and finding the right business model has revealed to be a herculean task. Most of the times mobile ticketing solutions fail to be implemented because it is not possible to reach an agreement. A study conducted by Ondrus, Lyytinen, and Pigneur (2009) summarize the current state of the art and analysed three failed mobile ticketing projects in Switzerland, concluding that the first necessary step for a successful mobile payment implementation is to develop inter-organizational relationships.

The implementation of mobile ticketing services also require a considerable amount of investment, including the need to establish, operate and update a mobile ticketing platform, upgrade of ticket vending machines, training of sales and train personnel, as well as the upgrade or replacement of existing ticket validation systems (Niegel and Schättgen 2014). Naturally, a mobile ticketing service also generates ongoing operating and maintenance costs, as well as clearinghouse costs. These need to be carefully estimated prior to the implementation of the system.

Furthermore, mobile ticketing solutions allows to collect much more data regarding the use of transport services. This data is useful to know better the passengers, provide customized services offerings and improve the service delivery process. However, it represents an additional challenge in terms of Big Data analysis (Cerruela García, Luque Ruiz, and Gómez-Nieto 2016) and raises privacy concerns.

Customers now are more sensitive to security and privacy issues. In fact, customer security has revealed to be a crucial factor in a successful mobile payment implementation (Silic, Back, and Ruf 2014). As a provider of the system, transport operators need to assure user data security and protection. If customers perceive that mobile ticketing potentially involves loss of privacy or insecure transactions, they will not accept it (Smart Card Alliance 2007). Also, "who owns user data" is object of much debate. If transport operators want to collect user personal data, users should be allowed to opt in as they are the primary owners of it. Besides that, at the planning stage of the mobile ticketing it should be agreed on all parts who should own the user data.

The introduction of a new ticketing media does not eradicate the existence of other media, such as travel cards. This means that transport operators will have to continue to provide multiple ticketing media to address different passenger segments. These ads complexity to the ticketing model since there will be a mix of smartphone applications using various transmission technologies for the ticket information and of contactless card solutions. Transport providers need to look at the mobile ticketing not as "another ticketing option" that fits the current service model (which may be a recipe for the failure of the mobile ticket solution), but as an opportunity to rethink and redesign their service model and make it more user-centric and effective.

Several studies show that customers are interested in using the mobile phones to make payments (Smart Card Alliance 2007a; Fontes et al. 2017). To take advantage of passengers' willingness to use new payment methods, transport operators must offer convenient and easy-to-use solutions. Customers are aware that they have alternatives, hence mobile ticketing services must deliver a clear value proposition that incentivizes customers to make the switch (Card, Transportation, and White 2012).

2.6 Mobile Ticketing Ecosystem

From a biology perspective a service ecosystem may be described as a system that includes all living organism in an area, as well as its physical environment, functioning together as a unit through interactions (Odum and Barrett 2005). In the context of services, a Service Ecosystem can be defined as "a spontaneously sensing and responding spatial and temporal structure of largely loosely coupled, value-proposing social and economic actors interacting through institutions, technology, and language to co-produce service offerings, engage in mutual service provision, and co-create value" (Vargo and Lusch 2010).

The widespread deployment and adoption of mobile payment solutions requires action from complex ecosystem of organizations, such as passengers, transport operators, transport authorities, banks, mobile network operators, third parties to create a mobile payments service solution (Ezell 2009). Each entity desires to have the leading place in the mobile payments ecosystem and a dominant role in the value chain. Mobile payments entail a complex, system-interdependent ecosystem whose success is dependent on joint action by all the players together at the same time. Because of this, only a few nations, notably Japan and South Korea, have been able to coordinate the complex ecosystem required to extensively deploy a widely used mobile payments system. In contrast, most other nations, including the United States and Europe, lag far behind. For lagging nations to take full advantage of the opportunities of mobile payments, they will need to develop and adopt national mobile payments strategies. This subsection presents the main players involved in this complex ecosystem, as well as their key drivers and concerns.

2.6.1 Customers

The introduction of mobile ticketing services in public transport involves a significant change in customer experience. Remote and ubiquitous access to payment, queue avoidance and lack of need to carry cash and coins are advantages often mentioned by passengers (Mallat 2007). Convenience, usefulness, ease of use and access to additional services beyond payment are also advantages usually referred by customers (Ferreira, Fontes, et al. 2017). Despite its clear advantages, few customers were able to experience mobile payments, and a large number of mobile payment initiatives failed before they even reached their intended end-users (Dahlberg, Guo, and Ondrus 2015). Therefore, it is important to understand which are the main factors that may influence the adoption of mobile ticketing services in public transport. In this subsection the customer experience concept is introduced, followed by the presentation of technology acceptance theories. Finally, mobile ticketing adoption in public transport studies are presented.

Customer Experience

Pine II and Gilmore (1998) introduced the term "Experience Economy", considering customer experience as the next competitive battleground, as a way to obtain competitive advantages over competitors. Customer experience can be defined as the internal and subjective response customers have to any contact (direct or indirect) with a company (Meyer and Schwager 2007). This is a holistic concept that encompasses every aspect of a company's offering (Zomerdijk and Voss 2010). Additionally, Vargo and Lusch (2004) argue that the customer experience is not designed, rather it is co-created through customer interactions with the several service elements. In fact, the role of customers has evolved from a traditional passive audience to active players creating and competing for values (Prahalad et al. 2000).

The use of customers' mobile devices to make payments allows customers to be active participants in the value-creating process. Even if the benefits of the implementation and deployment of mobile ticketing are evident, it is first important to understand whether people are willing to use this type of service. Indeed, uncertainty is an important obstacle to the adoption of innovations (Di Pietro et al. 2015).

Several studies have focused on the factors that influence the adoption of mobile payments in general and some less in mobile ticketing adoption in public transport. Experience factors can be defined as "customer perceptions of all aspects of a product or service that contribute to the customer experience" (Patricio, Fisk, and Falcao e Cunha 2008). Experience factors can be used by designers to define the clues, affordances or signifiers that companies can orchestrate to collectively meet customer needs and expectations (Berry and Carbone 2002).

Technology acceptance theories

A variety of research models have been introduced to explain innovation usage. The Technology Acceptance Model (TAM) is one of the first and the most influential research model to explain users' IT adoption behaviour (Davis, Bagozzi, and Warshaw 1989). TAM originates from Theory of Reasoned Action (TRA), which depicts user behaviour from a social psychology's point of view

(Fishbein and Ajzen 1975). According to TAM, the intention to use a particular system is determined by two major variables: perceived usefulness and perceived ease of use. Perceived usefulness is defined as the degree to which a person perceives that adopting the system will boost his job performance. Perceived ease of use is defined as the degree to which a person believes that adopting the system will be free of effort. These two beliefs determine the attitude towards using the system and that attitude, together with perceived usefulness, determines the use intention. Use intention then predicts the actual system use.

Although TAM was originally intended to predict IT systems usage in the workplace, this model was also applied to predict consumer acceptance in a variety of settings, including, wireless LAN usage (Yoon and Kim 2007), acceptance of handheld Internet devices (Bruner II and Kumar 2005), adoption of internet banking (Lee 2009), and attitudes towards self-service solutions (Dabholkar and Bagozzi 2002). TAM was also used as a baseline of several studies about factors influencing mobile payment adoption (Kim, Mirusmonov, and Lee 2010a), (Schierz, Schilke, and Wirtz 2010), (Kim, Mirusmonov, and Lee 2010a).

Another multidisciplinary theory frequently applied in IT adoption research is the Diffusion of Innovations (DOI) theory developed by (Rogers 1995). According to this theory, users are only willing to accept innovations if those innovations provide a unique advantage compared to existing solutions. The theory determines five characteristics that affect the adoption of the innovation: relative advantage, complexity, compatibility, trialability, and observability. According to (Tornatzky and Klein 1982), especially the relative advantage, complexity and compatibility, appear as constant determinants of technology adoption decision, and are therefore deemed as valid predictors for mobile payments adoption as well (Mallat 2007).

(Moore and Benbasat 1991) propose the Perceived Characteristics of Innovating (PCI) theory capable of measuring the individual perceptions associated to the adoption of an IT innovation. They used a set of eight attributes, three of which were borrowed from Rogers' DoI theory. The other five attributes are voluntariness, image, and ease of use, result demonstrability, and visibility.

(Venkatesh et al. 2003) present the Unified Theory of Acceptance and Use of Technology (UTAUT) which is based on four determinants of usage intention and behaviour: performance expectancy, effort expectancy, social influence, and facilitating conditions. The performance expectancy in UTAUT is the same as TAM's perceived usefulness, and is defined as ''the degree to which an individual believes that using the system will help him or her to attain gains in job performance." Like perceived ease of use in TAM, effort expectancy refers to ''the degree of ease associated with the use of the system." Unlike TAM, UTAUT introduces moderating constructs (gender, age, experience, and voluntariness of use) which are posited to moderate the impact of the four key constructs on usage intention and behaviour.

A number of mobile payments adoption factors studies have been based primarily on the TAM, with additional constructs adapted for the study of mobile payment such as cost, mobility, convenience, personal innovativeness, mobile payment knowledge, privacy, perceived risks and trust (Mallat 2007) (Wu and Wang 2005) (Siau et al. 2004) (Schierz, Schilke, and Wirtz 2010) (Kim, Mirusmonov, and Lee 2010b) (Yang et al. 2012).

Mobile ticketing adoption in public transport

These above-mentioned publications are evidences to confirm that despite the presence of numerous studies on mobile commerce and mobile payment adoption, notably, very few studies on the mobile ticketing services adoption have been undertaken. In this sub-section five studies are highlighted and summarized in Table 3.

Mallat et al. (2008) studied the factors that influence the adoption of a mobile ticketing service based on SMS in the Helsinki's public transport. The proposed research model was based on TAM (Davis, Bagozzi, and Warshaw 1989), DOI theory (Rogers 1995) and trust theories, which are augmented with concepts of mobile use context and mobility. Their findings corroborate the TAM model, where ease of use and usefulness had a statistically significant effect on the adoption decision. The effect of both factors was, however, relatively weak compared with other studied factors. Interestingly, cost was not a significant determinant of mobile ticketing adoption. The strongest predictors for use intention were prior experience on mobile ticketing service and compatibility of the mobile ticketing service with a person's use of public transportation, use of mobile phones, and general habits. Consumers who perceive mobile payments as compatible with the way they use both public transportation and mobile phones, are most likely to adopt the mobile ticketing service. Mobility and contextual factors, including budget constraints, availability of other alternatives, and time pressure in the service use situation were also found to have a strong effect on the adoption decision. The effect of these factors on the adoption of different types of mobile services is plausible, given the contextual and ubiquitous nature of the mobile services use in general.

Based on the same survey of Mallat et al. (2008), Mallat et al. (2009) present another paper focusing on the impact of user context on mobile ticketing services acceptance. This construct mediated the effect of mobility and usefulness on use intention, implying that users valued the benefits of the mobile ticketing service in situations where they were in a hurry, where other ticketing alternatives were not available, when the need for a ticket was unexpected, or where there were queues at points of sale.

Cheng and Huang (2013) examines Taiwan high speed rail (HSR) passengers' acceptance of mobile ticketing services. The implemented mobile ticketing services is based on QR Codes that are used for payment and gate entrance. The theoretical framework proposed by the authors is based on TAM (Davis, Bagozzi, and Warshaw 1989) and mental accounting theory (Moore and Benbasat 1991). Drawing on mental accounting theory, mobile ticketing adoption is influenced by the potential loss (perceived risk) and benefit (perceived ease of use and perceived usefulness) of the mobile ticketing service. The findings demonstrate that personal innovativeness has a positive effect on mobile ticketing services adoption. Although perceived risk, perceived usefulness, and perceived ease of use all influence QR code adoption, mobile access adoption is not directly affected by perceived risk or perceived ease of use. The analytical results demonstrate that potential loss (perceived risk) not only affects HSR passengers' mobile ticketing adoption but also offsets the influence of the positive construct (perceived ease of use and perceived usefulness) on the HSR passenger's adoption. Indeed, perceived risk is a deterministic factor that affects an HSR passenger's mobile ticketing adoption.

Kapoor, Dwivedi, and Williams (2015) studied the experience factors that determine the adoption of the Indian Railway Catering and Tourism Corporation Limited's (IRCTC) mobile ticketing service in India, based on 3G/4G technologies. The model comprises four attributes from the DOI (Rogers 1995), four from the PCI theory (Moore and Benbasat 1991), and four from

Tornatzky and Klein's meta-analysis (Tornatzky and Klein 1982). The results showed that compatibility, relative advantage, cost, social approval, demonstrability, voluntariness and riskiness were the strongest predictors of adoption intention. Only complexity failed to influence use intentions. Also, riskiness strongly predicted the actual adoption. The authors suggest that service providers of mobile ticketing solutions should place more emphasis on its ubiquitous feature making it usable on-the-go, ensure clear demonstration of the benefits and ease involved with its use, highlight the cost-effectiveness of the service, assure users of the service being a low-risk technology, and make efforts in increasing consumer awareness to attract more users, wherein, the potential adopters will be attracted towards its use upon watching the adopters savouring its benefits and spreading a positive word on its use.

TABLE 3. MOBILE TICKETING ADOPTION STUDIES

Reference	(Mallat et al. 2008)	(Mallat et al. 2009)	(Cheng and Huang 2013)	(Kapoor, Dwivedi, and Williams 2015)	(Di Pietro et al. 2015)
Country (city)	Finland (Helsinki)	Finland (Helsinki)	Taiwan	India	Worldwide
Sample	360	360	262	375	439
Ease of Use	✓	✓	✓		✓
Perceived Usefulness	✓	✓	✓		✓
Relative Advantage				✓	
Complexity				✓	
Compatibility	✓	✓		✓	✓
Trialability				✓	
Observability				✓	
Cost	✓			✓	
Risk	✓		✓	✓	
Social Approval				✓	
Communicability				✓	
Voluntariness				✓	
Visibility				✓	
Image				✓	
Result Demonstrability				✓	
Social influence	✓				
Behavioural intention			✓	✓	✓
Mobility	✓	✓			
Use Context	✓	✓			
Attitude	✓				✓
Prior experience	✓				
Trust	✓				
Personal Innovativeness			✓		
Security					✓

Di Pietro et al. (2015) examines the users' acceptance and usage of mobile ticketing technologies applied in the public transport context. They proposed a model, called the Integrated Model on Mobile Payment Acceptance (IMMPA), based on TAM (Davis, Bagozzi, and Warshaw 1989), DOI (Rogers 1995) and UTAUT (Venkatesh et al. 2003) theories. It was developed by mixing the variables of the existing models and adding new ones tailored to the mobile ticketing framework. The results show that the intention to use a technology is affected by the Usefulness, Ease of use and the Security of that technology. Moreover, the Usefulness is simultaneously influenced by the Ease of use, the Compatibility with users' values and needs and their Attitude towards mobile services. Furthermore, the model confirms the direct relation between the intention to use a technology and its actual usage. The new predictor, that is the Attitude towards mobile services, includes those requirements that every mobile ticketing payment must address in this context: complete information, further information about time and delay, speed of use, intuitive interface, and path customization. Another new construct detected is the Security, in reference to mobile payment. Because it could represent an obstacle to mobile ticketing distribution, it must be considered by market operators.

Finally, other studies try to forecast the adoption of mobile ticketing services in public transport. Brakewood et al. (2014) performed a stated preferences analysis through an on-board survey on two commuter rail lines (Worcester and Newburyport/Rockport) in the greater Boston area. From the application of a binary logit model they concluded that 26% of commuter rail passengers in Boston are very likely to adopt mobile ticketing. (Fontes et al. 2017) applied a survey to two different cities: Porto (Portugal) and Beijing (China). Although the high differences between the ticketing systems in both cities, Chinese and Portuguese have a similar opinion about the systems implemented in their cities. Still, Chinese reveal a higher motivation to adopt the new mobile ticketing system. In general, such system is greatly accepted by the respondents and the potential market is expected to be high (Porto: 30%; Beijing: 68%).

2.6.2 Transport Operators and Authorities

Service encounters are critical moments of truth in which customers often develop indelible impressions of a firm (Bitner, Brown, and Meuter 2000). Each encounter is an opportunity for a firm to sell itself and to satisfy the customer, but also an opportunity to disappoint. Several studies have been conducted in order to explore customer satisfaction with public transport services. Researchers studied the impact of frequency of negative critical incidents on overall satisfaction (Friman and Gärling 1999), the reasons behind poor experiences in public transport services (Hutchinson 2011) and the customer travel experience from a holistic point-of-view (Carreira et al. 2013).

In this sector, the infusion of technology also revolutionized the overall service offerings. Formerly, the tickets were sold in physical stores, and they had to be presented to the bus driver or to the inspector. Then, ticket vending and reader machines appeared, improving efficiency and productivity. More recently, the evolution of mobile devices allowed the emergence of new forms of ticketing such as mobile ticketing. This new channel also allows to offer journey related services, such as journey planner, real time traffic information, and customized alerts and information.

The deployment of a mobile ticketing solution depends, not only on customer acceptance, but also on the willingness of transport operators to turn it into reality. There are several reasons for considering mobile ticketing, namely: streamline the fare payment and deploy real-time information and other features as part of the fare payment app (Quigley et al. 2016), attract and retain customers (Puhe, Edelmann, and Reichenbach 2014), offer different payment methods and more flexibility with the types of tickets that can be purchased (Juntunen, Luukkainen, and Tuunainen 2010), technology obsolescence of existing equipment, fraud prevention and increase of boarding speeds (Mezghani 2008), reduce cash handling costs and improve passenger convenience (GSMA 2012).

Despite its clear advantages, there are several concerns that haunt transport operators' decisions, which are presented below.

Cost

In a study conducted by Quigley et al. (2016), cost of the mobile ticketing system is the most important piece of information that transit agencies examine to make decisions about mobile ticketing options. The cost of the mobile ticketing solution comprises software development costs, equipment acquisition costs (e.g. NFC readers, QR code readers), maintenance costs, fee per transaction and processing costs. Therefore, it is important to request proposals from different vendors and compare them. This comparison may not be easy and straightforward, since some vendors may only charge a percentage of the final sale value of each mobile ticket purchased through the app, others charge the equipment (production and installation), software development and a small fee per ticket sold. Others charge a fixed amount for the entire project plus a value per hour if any customization and specific features is requested by the transport operator.

Marketing costs need to be considered as well. Mobile ticketing requires extensive marketing activities in order to be successful (Quigley et al. 2016). It is important to inform the public about the availability of mobile ticketing and to educate individuals on how the mobile app is used. Internal training should also be considered. Training sessions with drivers and fare inspectors should be conducted for them to understand how to identify active mobile tickets and answer customer questions about mobile ticketing.

Fear of outsourcing

The fear of outsourcing expertise and responsibilities in ticketing to third-party suppliers remains a worry to public transport operators (Turner and Wilson 2010). Some smaller operators do not want to lose control or fear a reallocation of their funding to larger entities. Investing in a technology bears the risk of sticking to this particular technology or contract, which could prove to be the market loser in the long run (Turner and Wilson 2010).

Existing infrastructure

The existing infrastructure also influences the decision about the mobile ticketing final solution and technology. If the readers installed in the transport network read RFID contactless cards it is likely that transport operators opt for a NFC mobile ticketing solution. If there are no equipment on board the vehicle or station, neither wireless connection available it is likely that, in a first stage, they opt for visual validation of mobile tickets using animations, countdown, or a "colour-of-the-day" to prevent users from creating fraudulent electronic tickets through screenshots or other means. Of course, all of these decisions depend on the budget available.

Customer data

Mobile ticketing systems are capable of colleting an increased amount of data and the ownership of data is a major concern for transport operators. Usually the passenger's name and address, age, gender and bank details are recorded, as well as accurate data on the passenger's travel behaviour (e.g., boarding times and dates, locations, route profiles, frequencies and preferences). If the ownership of data is on the side of the suppliers, transport operators will be subject to restrictions imposed by them, for instance need for permissions to access data or access to aggregate instead of disaggregate records. If owned by operators they benefit from more flexibility in accessing, analysing and sharing the data (Quigley et al. 2016).

In this context data, privacy concerns arise as well. Concerns relate to the risk of the misuse of personal data. The Urban ITS Expert Group, which was set up by the European Commission to promote the deployment of ITS (Intelligent Transport Systems), has proposed guidelines for smart-ticketing applications (Urban ITS Expert Group 2013). There is general agreement that sensible and detailed personal information – which could potentially be gathered and used by participating operators or third parties – has to be protected. Therefore, transport operators should keep passengers' privacy in mind and be transparent with them about what type of data in being collected and how it is used. More recently, European Union proposed and carried out a data protection reform through the General Data Protection Regulation (GDPR) to regulate data privacy and reshape the way in which data is handled across every sector (European Union 2016). This regulation is based on five fundamental pillars (European Union 2018): clear language, consent from user, more transparency, stronger rights, and stronger enforcement.

Fraud

Another major concern regarding the deployment of mobile ticketing solutions is fraud. In terms of revenue loss, the main system fraud are individuals that enter and exit the system without paying. Transport operators are looking for solutions to decrease fraud, or at least to maintain the same levels. It is expected that new mobile ticketing systems are robust against fraud, by discouraging people from having fraudulent actions, allowing drivers and inspectors to easily recognize that a passenger is travelling with a valid ticket, and preventing identity transmission and irregular ticket validation procedures.

Consistency with existing practices

Finally, and since the mobile ticketing system will have to coexist with traditional systems, transport operators are looking for solutions that are compatible and consistent with existing practices and already implemented rules. If, nowadays, passengers need to tap the smartcard on the reader in front of the bus driver, the new mobile ticketing system has to be consistent with this practice, and somehow show the driver and other passengers he/she is travelling legally.

2.6.3 Government and Other Authorities

Government authorities usually aim to provide a public transport network that is affordable, accessible and integrated, and purely economic reasoning would in most cases not justify the operation (Assessment and Parliamentary 2014). Traditionally, the purpose of public transport has been to provide mobility for everyone, including those groups having no alternative to public transport. In many European countries, public services in transport are publicly planned, owned and operated (Arthur Gleijm 2003). Government subsidies together with passenger fares are usually the largest sources of revenue for public transport operators.

Strong governmental support has proved to be important for institutional coordination of integrated ticketing schemes in the Netherlands and the UK (International Transport Forum 2012). The extremely successful card systems in Hong Kong and Singapore have been set up with strong, centralised government control as well. Therefore, Government has a facilitating role in order to push initiatives forward. Setting up a platform for cooperation among stakeholders, financing pilot projects and subsidising installation are important (Yoh et al. 2006). Governments expect some positive indirect effects for the national economy and the environment. Knowledge and technical expertise gained in the smart card system could be applied and transferred to other sectors, and could create a positive economic climate for companies (Cheung 2006). Regarding the positive effects for the environment, it is assumed that mobile ticketing could increase public transport usage at the expense of car usage (Assessment and Parliamentary 2014). A closer collaboration between Government and local authorities is also important in order to successfully implement new ticketing schemes.

A conscious role for government to guide mobile payments ecosystems and a corporate business climate oriented towards longer-term investment strategy and receptive to collaborative public private partnerships, appear to play an indispensable role in explaining countries' mobile payments leadership (Ezell 2009).

2.6.4 Financial Institutions

Financial industry is composed by two main players: banks and credit-card institutions. The relationships they establish with each other is usually called a network joint venture (Evans and Schmalensee 1999). This kind of joint venture relates to banks with card issuing institutions, such as Visa or MasterCard. Each bank that joins the network must be able to conduct transactions with other banks within the network. Since one of the banks' core businesses is payment intermediation, it is clear that banks have the capability and experience to manage global payment transactions. Furthermore, mobile payments allows them to replace small cash transactions that until now were off the banking circuit.

During the last decades, banks have established a strong brand image and earned the trust of their customers (Ondrus, Pigneur, and Ecole 2005). When compared to Mobile Network Operators (MNOs), banks are perceived as more reliable mobile payment service providers (Dahlberg and Mallat 2002). Until now, banks had control over an exclusive resource that can be used in mobile payment solutions: bank accounts. Bank accounts contain privileged and confidential information about customers and can be plugged and integrated directly with payment solutions in order to facilitate the settlement of payment(Gaur and Ondrus 2012). This great advantage is being menaced by introduction of the "Open banking" in January 2018 by European countries (Doyle et al. 2017). Under the new rules, the ownership of financial data will be transferred to the customers, meaning that account holders will be able to give companies, other than their own bank, permission to access their details, and financial institutions must let customers share their data easily and securely. This opens the way for the entrance of new players, who can benefit from the advantages that until now belong only to the banks.

There are two types of mobile payment system that may be implemented by financial institutions:

- Wallet system or a bank account-based system. The bank acts as acquirer, issuer and trusted network. Banks deploy mobile payment applications or devices to customers and ensure merchants have the required POS acceptance capability. Payments are processed over the existing financial networks with credits and debits to the appropriate accounts. Banks manage end-to-end solution and completely assume risk involved on the transaction. In this development, banks cooperate with mobile device manufacturers. Banks contribute their financial services and risk-management experience in payment systems, and mobile device manufacturers develop a wallet feature for handsets. Other actors such as MNO have a marginal or non-existent role by simply providing communication and/or hosting facilities.
- Card-based system. With this system, customers may initiate a remote payment on their credit cards through a mobile connection. Credit-card institutions provide a payments platform where customer pays through a platform based rechargeable virtual account or through credit transactions. This entity performs bank settling but banks are still responsible for credit risks (and keeping associated revenue). MNO simply provide communication and/or hosting facilities. Veturi[9] train tickets (Helsinki) may be purchased through the mobile phone and paid by credit or debit cards. The tickets are then send to the customer by SMS and email. METRO[10] customers (Houston) may also purchase travel tickets using a mobile application and pay by credit or debit cards.

2.6.5 Mobile Network Operators

Mobile Network Operators (MNOs) provide the infrastructure for the mobile network, and offer services to mobile market. They have been dealing with payments and customer relationship management since mobile communications were launched onto the market. They play an active role in implementing their best practices as a foundation for mobile payments (Lim 2008). MNOs may implement operator centric models, where MNOs intermediate payment transactions, for example, information services, premium services, and SMS services. These systems can be either a prepaid system using over-the-air (OTA) connection or a post-paid system. The payment services are not necessarily provided by the service provider. In fact, the MNO acts only as the payment service provider, who forwards the payment to the next party and receives a fee for the services provided. Netsize[11], from Gemalto Company, is an example of a mobile ticketing solution based on SMS. The passenger sends a ticket order by SMS, and then Netsize works with the customer's mobile operator to handle payment through the mobile company's existing billing system, and any additional checks the mobile operator requires. At the same time, Netsize sends details of the sale to the transit network operator, ensuring it knows the ticket is valid. Helsinki in Finland and Italian cities such as Spezia, Pisa and Mantova have implemented this solution (Netsize 2015).

Despite an operator centric model being interesting to micro-payments (less than €10) since MNO can provide transaction services at lower fees, where banks are not efficient enough, it is

[9] https://www.vr.fi/cs/vr/en/osta_mobiilikaupasta_mobiili_en
[10] https://www.ridemetro.org/Pages/MobileTicketing.aspx
[11] http://www.netsize.com/

likely to find limited acceptance in the fragmented payment industry (Capgemini 2011). The lack of relationships between MNO and merchants, limited incentives to cooperate, and the complexity of negotiations may hinder the adoption of this model.

In what concerns NFC based mobile payments, MNOs may play a more important role. If the UICC is used as a secure element, the MNO functions as a secure element issuer and can benefit from controlling the UICC. In this case, the operator can rent the space on the secure element to the service provider who wish to place their applications there (Juntunen, Luukkainen, and Tuunainen 2010). MNOs also benefit in another way. When a subscriber wishes to switch from one MNO to another, he/she has to change the UICC to a new one, and transfer all the applications between the UICCs. Unless this can be done in a very convenient manner, the users may find it less attractive to change operators, possibly reducing churn for the MNOs. Therefore, it is expected the NFC-enabled ticketing result in additional GSM/UMTS transactions and additional services generated by NFC technology attract and retain customers (Assessment and Parliamentary 2014).

2.6.6 Mobile Device Manufacturers

Mobile device manufacturers provide the mobile phones used in mobile payment services. The manufacturers can sell the handsets directly to end users, or they can sell them to MNOs, who subsidize the handsets and sell them as a bundle together with a subscription to their customers. These subsidies by the MNOs are a common practice in most major markets, and thus the MNOs are important customers of the handset manufacturers. Besides their close relationship to MNOs, handset manufacturers try to create a mutually-beneficial relationship to another actor in the NFC ecosystem – the Financial Institutions (Lim 2008). In many ways, the handset manufacturers engage in a balancing act between the financial industry and the MNOs and try to collaborate with both parties.

The handset manufacturers are also a part of numerous consortia, which allows them to influence the standardization process. This collaborative behaviour is part of these manufacturers' strategies. Manufacturers promote standards which allow the production of flexible handsets, which can be used in different ways in different markets, based on the business needs of the specific situation (Juntunen, Luukkainen, and Tuunainen 2010). Thus, the handset manufacturers tend to favour, for example, having multiple choices for a secure element (e.g. NFC chip). This may threaten the role of MNOs, since mobile ticketing providers may choose the NFC tag as the secure element instead of the UICC, becoming independent from the MNOs.

2.6.7 Fare System and Technology Vendors

The use of mobile phones in public transport will have serious implications on transport operators' supply chain (Ferreira et al. 2012). Nowadays, the most common public transport suppliers are ticketing companies, ticket vending machines and ticket reader machines suppliers. Depending on the technology chosen for mobile payments, it may be necessary to adapt the existing infrastructure or even to replace it. Vendors that sell NFC ticketing readers, QR-Code readers, beacons and antennas are the new suppliers.

Technology based companies are also important suppliers entering the scheme. It is necessary to develop software, back office systems and mobile applications before deploying a mobile ticketing solution. Masabi[12], Cubic[13], Passport[14] and Unwire[15] are examples of vendors of such solutions. They offer rapid time to market solutions with low (or no) capex rollout (visual validation).

The primary compensation mechanism for the contracted mobile ticketing vendor will be via a transaction-based fee. For instance, this transaction-based fee could be a percentage payment for all mobile ticketing transactions (such as is done by Passport at COMET – Columbia USA) or a flat fee based on an estimated number of mobile ticketing transactions (such as is done by Masabi at NICE) (Quigley et al. 2016). There could also be fixed upfront costs for the initial development of the mobile ticketing system, if vendors responding to the solicitation do not have turnkey systems available that meet the agency's needs.

For instance, NICE pays Masabi a fixed annual fee of approximately $80,000 per year for maintenance of the mobile ticketing system. And COMET paid Passport the start-up fee of $150,000 plus 10% of gross mobile app ticket sales (Quigley et al. 2016).

Quigley et al. (2016) also leave some advice to transport operators on the choice of the vendor: check for references of the vendor, since many of them are new in the industry, and evaluate the vendor's ability and willingness to make changes to the mobile apps, such as including new features and integrate with other systems in the future.

2.6.8 Universities

Service innovation involves a new process or service offering that creates value for one or more actors in a service network (Patrício, Gustafsson, and Fisk 2018). Actors can be customers, organizations, and other elements such as technology that participate in the value creation process. As every new service, previous research work needs to be done. Universities play a key role in mobile ticketing ecosystem, by bringing innovative ideas to life, understanding customers and their context, envisioning future service solutions, and prototyping them.

Researchers contribute with their knowledge, technologies, previous experiences and design skills. They bring in applicable domain theories, background knowledge and literature on theories which can guide and/or inspire the design of mobile ticketing solutions. Often the pressure to launch a service and reduce time-to-market, drives companies to make hasty decisions, and skip fundamental steps in designing a successful solution. Therefore, researchers play a large role in knowledge development, idea generation and concept development, by providing proper methodologies and tools and ensuring that important steps are not ignored.

Researchers play also a facilitator role. Designing mobile ticketing services in complex ecosystem context requests a participatory and pluralistic approach based on the belief that systems

[12] http://www.masabi.com/
[13] https://www.cubic.com/
[14] https://www.passportinc.com/
[15] https://www.unwire.com/

cannot be completely understood or designed, but that they can be interpreted via a collaborative process. The mobile ticketing ecosystem encompasses multiple actors with, sometimes, conflicting interests that hinders decision making. Thus, an agnostic entity with no commercial interests is necessary to establish a consensus between the various actors. Researchers play a facilitator role in bringing together these different perspectives into a new service solution.

2.6.9 Third Parties

Recently, technology companies such as Google, Paypal, Apple and AliBaba have also shown interest in joining the mobile payment market. These companies are taking advantage of NFC mobile devices and their customers' database to offer mobile payment services. Since 2007, the number of mobile devices that include this technology has increased dramatically. Currently, three out of four smartphones made incorporate NFC (Cerruela García, Luque Ruiz, and Gómez-Nieto 2016) and also most tablets, although Apple has decided to block the NFC function on their devices so they can only be used for mobile payment operations with Apple Pay.

The introduction of NFC technology in smartphones added new functions to it, such as the emulation of a contactless card. Host Card Emulation (HCE) (Alattar and Achemlal 2014), provides a secure channel of communication between the NFC reader, a mobile application installed in the device and the payment terminal. This development frees the mobile payments ecosystem from the dependence of Secure Element chips, such as the SIM card, and allows the entrance of new players.

Unlike mobile ticketing, this type of fare system can require substantial capital investment and new infrastructure. Similar to a retail point-of-sale (POS) mobile transaction, a fare validator calculates payment for each trip when the commuter taps his NFC mobile wallet at the reader. Both Chicago's Ventra and Utah Transit Authority (UTA) fare systems accept mobile NFC wallets and contactless credit/debit cards. However, actual use of these payment methods remains low (less than 1 percent) primarily due to the limited availability/adoption of NFC-enabled smartphones and contactless cards (Tavilla 2016).

Although NFC contactless mobile payment transaction volume is low, it is expected to increase with broader availability of NFC-enabled phones and increased consumer awareness of mobile wallets such as Apple Pay, Google Wallet, and Softcard. Interestingly, since Apple Pay's release in October 2014, more Android smartphone users have downloaded the Softcard and Google Wallet apps for the first time, and existing wallet customers have used these mobile wallets more frequently (Tavilla 2015). Customers can use NFC mobile wallets to pay for purchases, including in public transport. London (UK), Salt Lake City and Chicago (USA) passengers with NFC phones can pay their fares with Apple Pay, Google Wallet, and Softcard.

2.7. Chapter Summary

This chapter frames the mobile ticketing landscape. First, general concepts of the public transport context are introduced, such as pricing, ticketing, open gate and close gate solutions, automated fare collection systems and electronic ticketing schemes. Then, the mobile ticketing definition considered in this dissertation is presented as “the use of a mobile device to purchase and/or validate a travel ticket or to initiate a journey”.

There are several technologies available in mobile devices that can be used to implement mobile ticketing solutions, such as SMS and phone calls, Wi-Fi and 3G/4G, RFID, NFC, BLE, and QR Codes. These technologies are described, their main advantages and disadvantages are identified and examples of implementation are provided.

Mobile ticketing advantages such as remote and ubiquitous access to payment services, avoiding queues, and decrease the need of tickets production, vending machines maintenance and cash handling are presented. However, the development of mobile ticketing services also face challenges, which are explored in this chapter.

Mobile ticketing is complex as it requires the establishment of a full ecosystem involving many different stakeholders, with sometimes conflicting interests. Mobile ticketing solutions usually fail to be implemented because it is not possible to reach an agreement. To better understand the actors of this complex ecosystem, key stakeholders are identified as well as their interests and concerns regarding mobile ticketing solutions. The first necessary step for a successful mobile ticketing implementation is to develop inter-organizational relationships. This fact frames the contribution and innovative features of the methodology proposed in Chapter 3.

3. The DMTS (Designing Mobile Ticketing Services) Methodology

Markets in developed countries have witnessed the launch of a number of mobile payment initiatives over the last years. Even though the emergence of mobile ticketing may still hold high promises, many these initiatives have seen stagnation or failure (Gaur and Ondrus 2012). The widespread deployment and adoption of mobile ticketing solutions requires action from a complex ecosystem of organizations, such as passengers, transport operators, transport authorities, banks, mobile network operators and third parties (Ezell 2009). Each entity desires to have the leading place in the mobile ticketing ecosystem and dominant role in the value chain. Mobile ticketing entail a complex, system-interdependent ecosystem with many actors whose success is dependent on joint action by all the actors together at the same time. However, the struggle for these inter-dependent firms to form coalitions just hindered the emergence of successful mobile ticketing platforms.

The infusion of technologies into services enable new and smarter offerings that enhance customer experience. The traditional dyadic relationship between customers and service providers has changed to dynamic and many-to-many relationships (Pinho et al. 2014). Services are now offered through complex service systems and value networks, and value is co-created through interactions among a set of interrelated actors. From a service-dominant logic point-of-view, value is co-created collaboratively, being an "interactive process that takes place in the context of a unique set of multiple exchange relationships" (Vargo and Lusch 2010).

When addressing more complex service systems, such as public services, service design engages customers and other network actors, considering their experience as a fundamental resource to envision new services. Codesign in this context seeks to create better solutions but also to promote more inclusive processes to enhance multiple actor engagement. In spite of previous efforts, further research is needed to better understand when and how to involve customers and other actors during the process of designing services (Patrício, Gustafsson, and Fisk 2018), and how do keystone actors in an ecosystem establish their position (Vargo and Lusch 2017).

In complex value networks, such as mobile ticketing, a holistic design approach is necessary to create an integrated service for different actors that co-create value among them. This chapter presents the DMTS (Designing Mobile Ticketing Services) methodology which represents a holistic approach to design mobile ticketing services. The proposed methodology has been derived from empirical work on designing, developing, implementing and testing four different mobile ticketing service solutions, and is grounded on concepts and models presented in the next sub-section. The DMTS methodology is detailed in sub-section 3.2, being accompanied by concrete examples of its application during the design of the four different mobile ticketing service solutions. Finally, sub-section 3.3 presents the main contributions of the DMTS methodology.

3.1 DMTS Methodology Components

The DMTS methodology is focused on value co-creation among stakeholders during the design process of mobile ticketing services for urban passenger transport, and combines contributions from different perspectives.

This sub-section describes briefly the main approaches that were useful for the establishment of the DMTS methodology:

1. Value co-creation;
2. Participatory design;
3. User-centred design;
4. Interaction design;
5. Service design;
6. Software engineering.

3.1.1 Value co-creation

The concept of value has evolved over time. Holbrook (1996) defined value as an "interactive relativistic preference experience", which means that the value to the customer is defined by the experience and not by the purchase. More recently, Vargo and Lusch (2008) introduced the service-dominant (S-D) logic, which claims that value is always determined by the beneficiary and is co-created through joint and reciprocal interactions between providers and beneficiary integrating resources. According to this paradigm, the customer assumes an active, connected and informed role on the value creation process. This paradigm opposes to the traditional goods-dominant (G-D) logic that considers customers as passive consumers, where goods are created by firms and distributed to consumers (value destroyers) (Vargo and Lusch 2010).

According to G-D logic, firms create value-in-exchange, i.e. value occurs when the goods produced by the firm are exchanged in the marketplace. In S-D logic, value is co-created with customers as value-in-use. Irrespective of the degree of intangibility involved in a given offer "the customer is always a co-creator of value" (Vargo and Lusch 2008). Grönroos (2008) goes further, arguing that if the value creation is characterised by value-in-use, logically the customer is always a value creator, not a co-creator. And because value-in-use implies that it is realised during consumption, the development, design, manufacturing, and delivery processes of the provider merely facilitate value creation (Grönroos 2008). The author still maintains that co-creation exists, but only through the interaction between customer and the firm.

From a value network (system of service systems) perspective, value co-creation goes beyond the firm and customer dyadic interaction to a broader perspective where all participants (companies, customers, suppliers, employees, stockholders, and other network partners) contribute to creating value for themselves and for others (Vargo and Lusch 2008). Thus, value creation is no longer only within firms' boundaries but value is co-created among various actors within the service network. Also, the interactions between actors offer opportunities to facilitate value creation experiences for and with each other (Grönroos 2008). Previous research has mainly adopted a perspective centred on a service or a company (Tronvoll et al. 2011). However, in this new environment, it is critical to shift from a single supplier and single customer dyadic perspective to a many-to-many perspective where customer networks interact with supplier networks (Pinho et al. 2014).

Value co-creation happens during use, as a result of service interactions, but it also happens during design (Holmlid 2012), via a set of participatory methods and approaches to engage actors in co-design. Design for Service, introduced by Wetter-Edman et al. (2014), focuses on developing different and new ways to engage people in design processes and to learn about their experiences and stories to inform reconfigurations of a service system. In Design for Service, this is called co-design, where resources are reconfigured in a collaborative and creative way by the involved actors for future integration in use. The process of co-designing leads to actual value co-creation during the design process, which is called value co-creation in designing. In this line, design integrates attention to and evaluation of value co-creation in use (present) with a focus on the role of value co-creation in designing, by engaging stakeholders in the co-creation (via co-design and prototyping) and negotiation of future service configurations (Wetter-Edman et al. 2014).

Customers of public transport have traditionally been considered as passive consumers (Lovelock, Lewin, G., Day, and Bateson 1987), rather than active participants in the value-creating process (Vargo and Lusch 2008). Public transport operators create value-in-exchange, functioning through an internal cost orientation rather than an external market orientation (Gebauer, Johnson, and Enquist 2010). The emergence of the S-D paradigm, altered the traditional premise of value-in-exchange as the basic principle of public transport. In its place, S-D logic posits the co-creation of experience as the essential basis of value, with individual customers assuming a central role in the co-creation of such experiences. These heterogeneous interactions lead to the personalization of the co-creation experience in using public transport (Gebauer, Johnson, and Enquist 2010).

3.1.2 Participatory Design

Participatory design has had a long tradition in Scandinavia (Greenbaum and Kyng 1991; Schuler and Namioka 1993). During the 70s and 80s the rationale for user participation was based on the fact that system developers mostly met the managers or the technical personnel, who were not the end-users of the system. With participatory design end-users were given the opportunity to participate in and contribute to the design together with the developers. As participatory design evolved, workers as well as managers were involved in the projects (Bødker 1996).

The rationale behind participatory design is that people are considered precious resources and experts of their own experiences having the potential to contribute as co-designers (Visser et al. 2005). Users and other stakeholders are engaged and encouraged to share and use their experiences as a way to imagine and co-construct possible futures. A participatory approach therefore co-creates value by supporting people to integrate these resources in the design process to generate more effective and meaningful solutions (Holmlid 2012).

Several techniques and methods have been used to promote participation in the design process. For example, users participate in building prototypes and mock-ups of systems and try them out in laboratory environments, bringing their knowledge into the design process. Storytelling and different forms of written and visual narratives have been used as means to elicit reconstructions of what happened in the past (Bate and Robert 2007). Visualizing and sharing these stories in the forms of films, video sketches, stories, blogs, or emotional journeys have also the capacity to engage people in co-design processes (Kankainen et al. 2012). But there are also certain limitations. Despite all stakeholders participate in the design process, it usually takes place in controlled environments different from the real context, distancing people from how they would behave in a real situation. Designers should be aware of such limitations and try to monminimize them.

3.1.3 User-centred design

In general, three fundamental activities are common to every design process (Sharp, Rogers, and Preece 2007): understanding the requirements, producing a design that satisfies those requirements, and evaluating the design. User-centred design approaches comprise these activities and focus attention on users and their goals, involving them from early design stages. In the past, developers would interact mainly with managers and proxy users (people who would role-played as users during requirements elicitation). While a proxy user can provide useful information, he/she will not have the same perspective as someone who performs the task daily, or who will use the final service on a regular basis. Therefore, it is important to involve real users throughout all design stages, in order to achieve a successful solution.

The degree of user involvement in the design process may vary. Users may work with the design team and developers in a full-time basis or in a part-time basis, by participating in workshops, focus groups and evaluation sessions. Less participative approaches include updating users through regular newsletters and other channels of communication and events to keep users informed about the evolution of the development process. Involving users in the design process requires that designs and potential solutions are communicated in an effective and simple way. Producing a series of sketches, drawing diagrams and building prototypes are examples of artifacts that may be produced to help capturing and expressing a design in a simple format.

Recently, the term human-centred design has emerged in the literature. This approach favours the term human in detriment of user, since it considers the importance and role of a larger network of actors, not only users, who are directly or indirectly involved in the service provision and use (Wetter-Edman et al. 2014). According to Meroni and Sangiorgi (2011), a human-centred design approach consists on the capacity and methods to investigate, understand, and engage with people's experiences, interactions, and practices as well as their values and dreams. This understanding is the starting point of a service innovation process. Experiences and interactions can be related to the service delivery and use, but they can also refer to a staff's work practices and experiences or more general interactions and experiences of stakeholders interacting with each other to provide the solution (Wetter-Edman et al. 2014).

On another level, a human-centred design approach refers to the capacity and methods of engaging people in the design and transformation processes, which can vary from the adoption of participatory design techniques where users and staff become co-designers, to co-creation approaches, where users become conscious and active participants in service delivery processes (Meroni and Sangiorgi 2011). This dual interpretation of human-centred design, as understanding and engaging people, suggests the relevance of both actors' experiences and participation as key concepts for value co-creation in design (Wetter-Edman et al. 2014).

3.1.4 Interaction Design

The field of human-computer interaction (HCI), has had a rapid development during the last 40 years (Holmlid 2007). HCI evolved from developing general theories, based on cognitive psychology concepts (Norman and Draper 1986), to a multi-disciplinary field, covering different perspectives, such as engineering, participative, contextual and design (Holmlid 2009). Engineering perspective is institutionalised through a set of ISO standards and has proponents such as Jakob Nielsen (J. Nielsen 1994) with usability engineering and Deborah Mayhew (Mayhew 1999) with a usability engineering lifecycle perspective. The participative perspective has its roots in Scandinavia (Ehn 1988) and took as starting point a high degree of user involvement in design and change processes. The contextual perspective emerged from the engineering perspective as well as some of the shortcomings of that perspective (Wixon, Holtzblatt, and Knox 1990; Beyer and Holtzblatt 1998). Finally, the design perspective started to become important during the 90s, when interaction design was established alongside experience design as central design disciplines in the development processes of digital artefacts (Holmlid 2009). During this period and the early 2000s the use of the World Wide Web for business purposes was initiated and grew rapidly. Designers started to work on the design of online banking, community based shopping, travel arrangements and other businesses. In fact, these designers were participating in the design of services, focusing on the online presence and the user-interface component of a self-service channel. Due to this fact, some authors (Miettinen 2009; Löwgren and Stolterman 2005) argue that interaction design should be referred to as digital interaction design.

Sharp, Rogers, and Preece (2007) propose an interation design process involving four basic activities: i) identifying needs and establishing requirements for the user experience; ii) developing alternative designs that meet those requirements; iii) building interactive versions of the designs; and iv) evaluating what is being built throughout the process and the user experience it offers. These activities are intended to inform one another and to be repeated (see Figure 2). Iteration allows design to be refined based on feedback. This is particularly important when designing innovative services, since innovation takes time, evolution, trial and error.

Users' involvement and participation has been one of the fundamental issues within interaction design. Ethnographic methods have been used and adapted for user research and for interacting with users. Also, additional experimental design methods and techniques have been developed to complement traditional design techniques. Experience prototyping is an example of such a technique developed by Dahlbom (2002), which allows users and designers to experience an imagined future situation, instead of watching a demonstration of the experience. Iacucci and his colleagues (Iacucci, Kuutti, and Ranta 2000) apply role-playing and Situated and Participative Enactment of Scenarios (SPES) to design mobile services and devices. Other techniques are continuously being developed and updated, such as bodystorming (Oulasvirta, Kurvinen, and Kankainen 2003), playacting and focus troupes (Sato and Salvador 1999), place storming (Anderson and McGonigal 2004), storytelling (Sandra and Tuuli 2010) and design games (Vaajakallio and Mattelmäki 2014). Personas, scenarios and storyboards are also techniques that have been used in the design.

Interaction design is closely linked to user-centred design. Different ways of involving users, and more recently other stakeholders, have been developed and implemented. Diaries are such an example that allow users to document day-to-day practices using paper (Wild et al. 2010) or a mobile recording device, such as digital camera or mobile phone (Hagen, Robertson, and Gravina 2007). Diaries can also be generated by a mobile device, which logs the activity of the user through GPS, accelerometer and other sensors (Montini et al. 2014). Additionally, Löwgren (2004) propose the use of animated sketches as a design representation technique, which allows expressing important scenarios in the intended use of the future artefact through animated movies.

With the proliferation of mobile and social computing, Forlizzi and Zimmerman (2013) argue that the current interaction design approaches, inspired by user experience and user-centred design, are insufficient to appropriately take on these new challenges. They propose that designers consider a service design framing to complement what is already being done in the field. Service design offers a systemic approach that better address the complex stakeholder relationships, yields outcomes in the form of product-service systems, and focuses on how value can be co-created between customers and stakeholders.

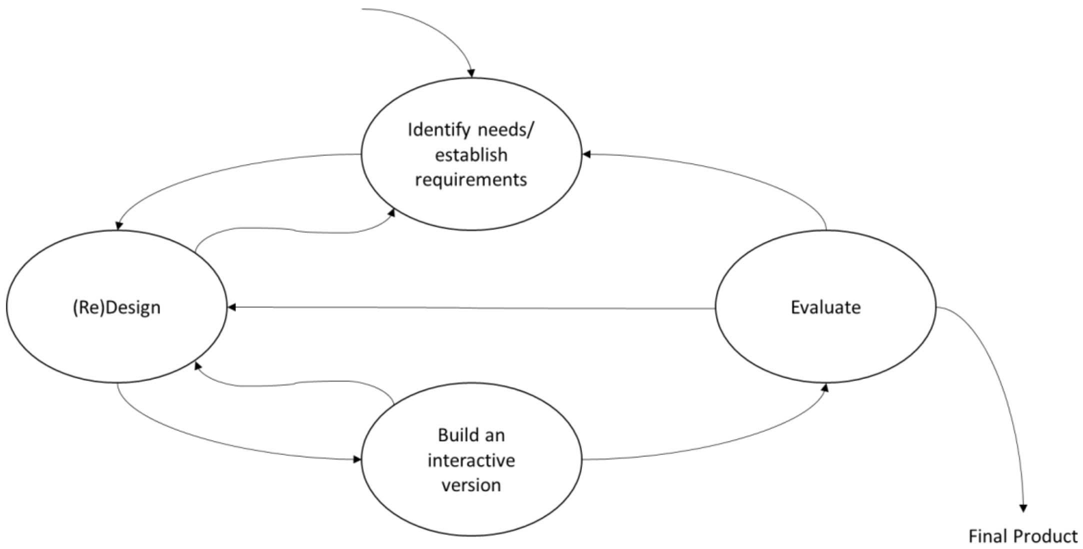


FIGURE 2. INTERACTION DESIGN LIFECYCLE MODEL (ADAPTED FROM SHARP, ROGERS, AND PREECE 2007)

3.1.5 Service Design

Service design represents a human-centred, reflective learning, iterative approach to the creation of new service offerings (Storey and Larbig 2018). It involves a deep understanding of customers and service providers, their context and social practices, and translating this understanding into the development of evidence and service systems interaction (Holmlid and Evenson 2008). The service logic perspective argues that value is not created by the firm, rather value is co-created by the interaction between the service provider and the customer (Lusch and Nambisan 2015). Therefore, the capability to collaborate with customer during service development transforms the customer into an operant resource which increases the firm's innovation capabilities (Ordanini and Parasuraman 2011).

As a growing field, service design methods and tools have been developed over the last years. Brown, the CEO and president of the innovation and design firm IDEO, is a leading proponent of design thinking, described as a method of meeting people's needs and desires in a technologically feasible and strategically viable way (Tim Brown 2008). According to a design thinking approach, a service design process involves three phases: 1) inspiration, 2) ideation, and 3) implementation (see Figure 3). Inspiration consists of identifying the circumstances (be they a problem, an opportunity, or both) that motivate the search for solutions. Ideation is related to the process of generating, developing, and testing ideas that may lead to solutions. Finally implementation leads to planning, implementing and reviewing the changes necessary to put into practice the new service concept and offer it to customers. The design thinking process will loop back through these phases, particularly the first two, more than once as ideas are refined and new directions taken.

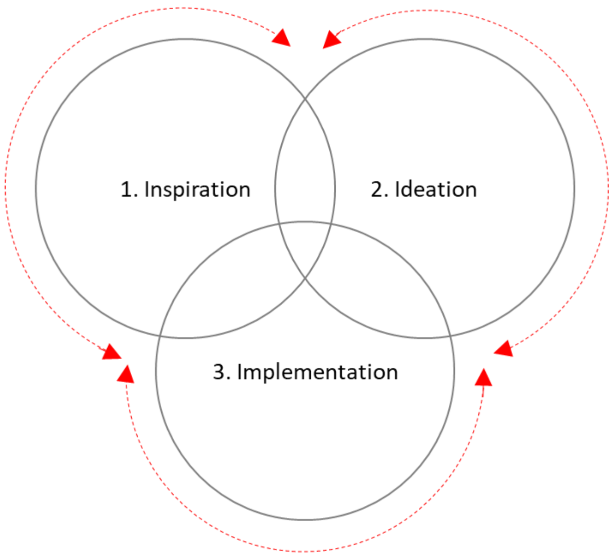


FIGURE 3. DESIGN THINKING APPROACH (ADAPTED FROM BROWN 2008)

Service Design integrates multiple contributions from service research fields such as service management, marketing, and operations as well as from technology-related fields, such as information systems and interaction design. Contributions from service management are focused on designing value propositions and orchestrating multiple interfaces and actors to enable value co-creation and seamless customer experiences. Models based on this perspective focus on the service delivery process, with the service blueprint (Bitner et al. 2008) or have a network structure, such as the Customer Value Constellation (Patricio et al. 2011) or Actor Network Map (Morelli and Tollestrup 2006). However, these models do not address in detail the aesthetic and technological aspects of the service experience, such as the environment in which the service takes place, the interaction between actors and technologies, or the service attractiveness and atmosphere (Grenha Teixeira et al. 2016).

According to Forlizzi and Zimmerman (2013), service design has several limitations that are important to be aware of. First, while service design offers advantages on how to address more complex sets of stakeholders, it still relies on a rather simplistic framing of customer and service provider. This is a "huge opportunity for research and for the development of new tools that can advance our ability to more effectively address and design for complex stakeholder relationships" (Forlizzi and Zimmerman 2013). Second, service design methods and practices are optimized towards the innovation of current services, which do not work nearly as well to create entirely new services. Interaction design has grown up with a strong focus on novelty and the creation of things no one previously imagined, demanding new service design processes that support the rapid creation of new services. Third, service design seems timid in its approach to using technology. While technology often drives service innovation, it is often the adoption of well-known and well-understood technology. Interaction design, on the other hand, has a tradition of pushing new technical systems into the world and waiting to see how users appropriate this technology and invent entirely new uses for it.

Interaction design is mostly concerned with the front stage interaction and experience with the technology. It provides a richer view of the context surrounding service provision, a critical feature to understand the perception of value propositions (Vargo and Lusch 2016). It is also less structured, more emphatic, and well suited for creative exploration. Service design lacks integrated, cross-disciplinary models and frameworks (Ostrom et al. 2015), that could support the design of technology-enabled services.

3.1.6 Software Engineering

The main objective of software engineering is to improve organization production and quality by selecting the right methodology, technologies and practices during software development (Sabri and Alfifi 2017). First software engineering methodologies emerged in the 70s with the waterfall model (Winston W. Royce 1970). This is a sequential development approach, in which development is seen as flowing steadily downwards (like a waterfall) through several phases (see Figure 4). The model starts with the specification and analysis of the requirements, moves to the design, coding, implementation, testing and, finally, maintenance. According to this model each phase must be completed before the next stage starts. This lack of flexibility has been criticized, giving rise to other, more iterative, approaches.

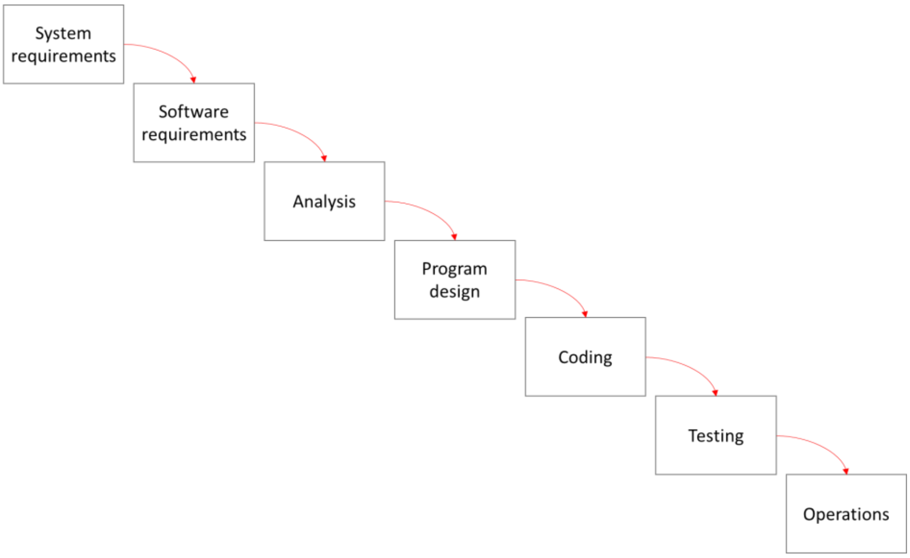


FIGURE 4. WATERFALL MODEL (ADAPTED FROM WINSTON W. ROYCE 1970)

The spiral lifecycle model (Boehm 1988) introduces iteration in the software development process and adds two complementary stages: risk analysis and prototyping. According to this model, ideas and progress can be repeatedly checked and evaluated, as shown in Figure 5. Therefore, unlike the waterfall approach, the spiral model explicitly encourages alternatives to be considered, and stages in which problems or potential problems are encountered to be readdressed.

More recently, agile development methods have emerged. These aim to react to change quickly by embedding principles of iteration, communication and feedback. Agile processes incorporate tight iterations and continuous feedback to successively refine and deliver a software system. There are several agile methodologies such as eXtreme Programming (XP) (Beck and Andres 2004), Scrum (Schwaber 2004) or Adaptive Software Development (ASD) (Highsmith 2000). For instance, in XP, the work is divided into actions that need to be delivered at the end of each iteration (lasting between one and three weeks). Also, XP stipulates that customers should work closely to developers, which in practice is rarely achieved (Sharp, Rogers, and Preece 2007). In Scrum, iterations (sprints) last 30 days or less (most commonly two weeks) and track progress and re-plan are made in 15 minutes stand-up meetings (scrums). The ASD method embodies the principle of continuous adaptation of the process to the work at hands, replacing the traditional waterfall cycle with a repeating series of speculate, collaborate, and learn cycles. Each cycle is iterative, timeboxed, risk driven and tolerant.

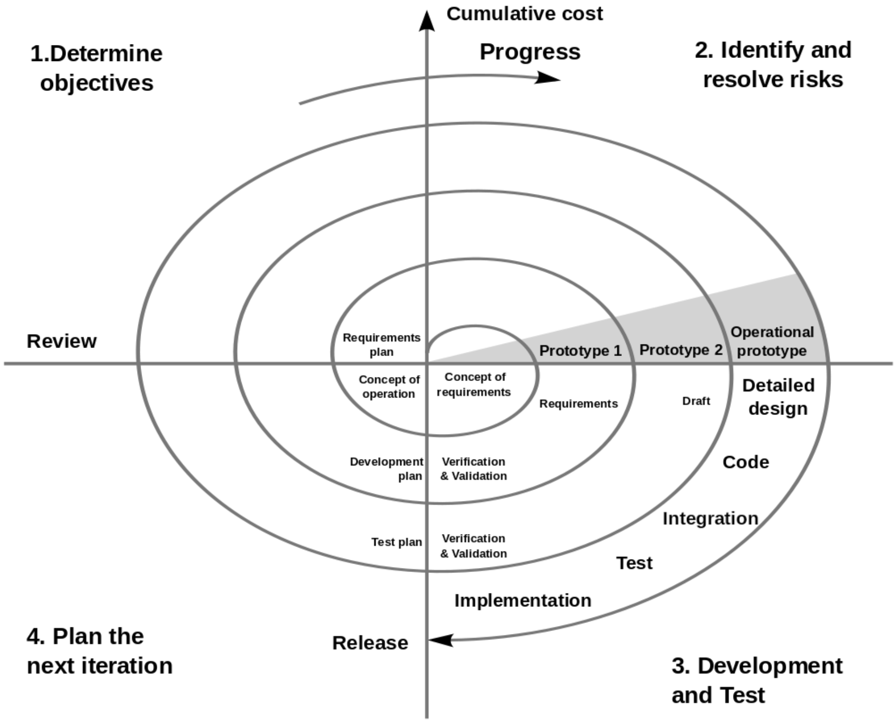


FIGURE 5. SPIRAL LIFECYCLE MODEL (ADAPTED FROM B. Boehm 1988)

Software engineering has gradually changed to include a more iterative and user-centred point-of-view. Though, it encompasses methodologies very focused on software development and designing mobile ticketing services is much more than developing software. Therefore, software engineering approaches are not sufficient per se and must be combined with other perspectives.

Summing up, the DMTS methodology combines contributions from the different perspectives presented above leveraging the best of each and filling the remaining gaps. Service design principles are used to address complex stakeholder relationships, overcoming the inability of interaction design approaches to take on this challenge. However, despite its superiority to interaction design in this subject it still relies on a rather simplistic framing of customer and service provider. Therefore, the DMTS methodology tackles this issue by addressing more effectively the design of ticketing services in complex ecosystem environment. It follows a user-centred design approach, using participatory design techniques to actively involve all stakeholders in the value co-creation process.

Interaction design is used in the DMTS methodology for creative exploration. Compared to service design it is less structured, more emphatic and has a tradition of pushing new technological systems into the world. Mobile ticketing is about disruptive solutions and cannot rely on the adoption of well-knownth and well-understood technologies, as does service design. Finally, more structured models from software engineering are used in the DMTS methodology to fill the gap in specification and development of the mobile ticketing solution that other perspectives are not capable of.

3.2 Detailed Presentation of the DMTS Methodology

In complex value networks, such as mobile ticketing, a holistic design approach is necessary to create an integrated service for different actors that co-create value with each other. The DMTS methodology has its roots in participatory design, software engineering, interaction design and service design methods and derived from empirical work on designing, developing, implementing and testing mobile ticketing service solutions, in the scope of four projects: MobiPag, MobiPag STCP, Seamless Mobility and Anda. Although these projects are presented in more detail in Section 4, the description of the methodology is accompanied by examples of practical application of the methodology to the design of the mobile ticketing services. Figure 6 shows the distribution of these projects over time.

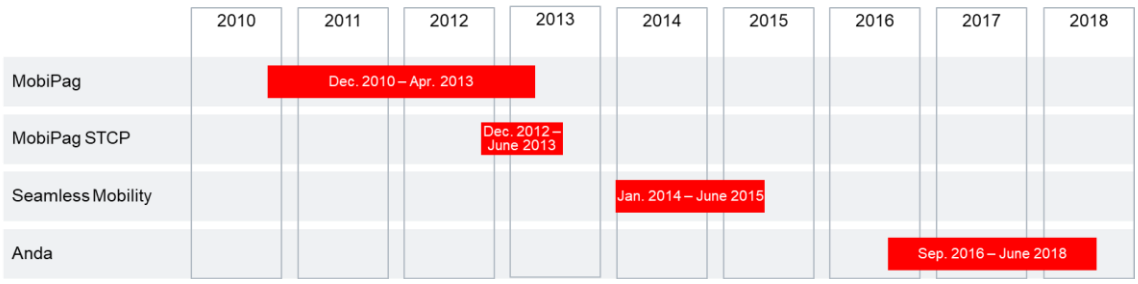


FIGURE 6. TIMELINE OF THE PROJECTS DEVELOPED

Mobipag was a 2,5-year project (December 2010 – April 2013), which main objective was to design, develop, implement and test, in real environment, a solution of dematerialisation of payments with the use of personal mobile devices as an automatic payment terminal. The final solution comprised a universal mobile payments and services platform that was demonstrated through the development and deployment of two mobile payment applications (customer and merchant) based on NFC.

MobiPag STCP was a 6-month project (December 2012 – June 2013), developed under the MobiPag project and results from the partnership between FEUP, OPT and STCP. The main aim was to design, develop, implement and test, in a real environment, a mobile ticketing solution based on the passengers' mobile devices, requiring no interaction with transport operators' infrastructure. The final solution allowed to purchase and validate travel tickets over-the-air, using wireless technologies (3G/4G and Wi-Fi), as well as access to the tickets balance, travel history and account movements.

Seamless Mobility was an 18-months project (January 2014 – June 2015), which main objective was to design, develop, implement and test, in a real environment, a mobile ticketing solution based on QR Codes. This mobile service solution allows the dematerialization of transport tickets and provides advanced information to the public in real time, leveraged by the concept of social network.

Anda was a 22 months project (September 2016 – June 2018), which main objective was to design, develop, implement and test, in a real environment, a mobile ticketing solution based on BLE and NFC technologies that allows the dematerialization of travel tickets. This solution was launched in the market, in the Metropolitan Area of Porto (MAP), in June 29th 2018.

The proposed DMTS methodology, which was tested and refined throughout the four projects, consists of 4 main phases that can be detailed into 9 iterative design stages (see Figure 7), and are presented in detail below:

Phase 1 – Conceptualization:

Stage 1: Identifying the problem and defining the objectives;

Stage 2: Mapping the stakeholders ecosystem;

Stage 3: Identifying the needs and establishing the requirements;

Phase 2 – Exploration:

Stage 4: Co-designing the service;

Stage 5: Evaluating the artifacts;

Phase 3 – Convergence:

Stage 6: Redesigning and developing the service solution;

Stage 7: Evaluating the service solution in a real environment;

Phase 4 – Launch:

Stage 8: Preparation;

Stage 9: Deployment.

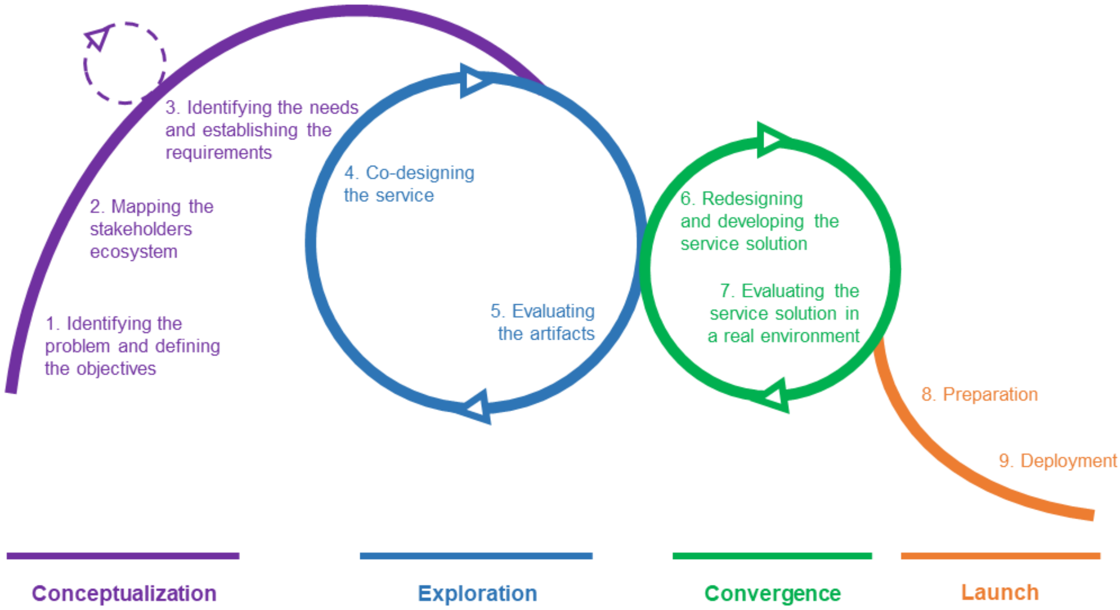


FIGURE 7. STAGES OF THE DMTS METHODOLOGY

Stage 1: Identifying the Problem and Defining the Objectives

This stage consists of identifying the problem and justifying the need for a solution. Before deciding about a mobile ticketing solution, decision-makers (e.g. Transport Operators, Authorities, or Governments) must think about the reasons that would lead to the introduction of a mobile ticketing solution and about the added value of such solution to the transport system. The problem or the opportunity that the new ticketing system is going to solve must be clear and well-founded. Examples of problems or opportunities can be: the high complexity of tariffs and transport networks topology, the current ticketing systems and infrastructure obsolescence, or to improve customer value and broaden the customers' basis. It is useful to define the problem conceptually so that the solution can capture its complexity. Justifying the value of a solution motivates the stakeholders to pursue the solution and helps to understand the reasoning behind the problem.

From the problem definition and knowledge of what is feasible, it is possible to infer the objectives. The objectives can be quantitative, such as predicting sales volume and customer attraction through the new ticketing channel, or qualitative, such as a description of how the new artifact is expected to support solutions to problems not yet addressed.

> Example 1: Seamless Mobility Project
>
> The Seamless Mobility project aimed to solve a problem that people face every day, especially occasional passengers, of knowing how to travel from point A to B: which is the best combination of transport modes? How and where to change mode of transport? And what type of ticket to buy? Following this problem, four main objectives were identified: 1) promote transport intermodality; 2) Promote the dematerialization and intermodal homogenization of transport tickets; 3) Improve the experience of using transport alternatives to private cars; and 4) Create a channel to exchange information between passengers and transport operators.

Example 2: Anda Project

The Anda project aimed to solve the problem of the complex fare system and transport network of the city of Porto, Portugal. The main objective was to design a mobile service solution that simplifies and enhances the customer experience when travelling in public transport services. The idea is that passengers do not need to pre-purchase tickets before travelling, neither to know which type of ticket should be purchased to perform a certain journey.

Stage 2: Mapping the Stakeholders Ecosystem

From a S-D logic perspective, value creation is no longer only within firms' boundaries but value is co-created among various actors within the service network. Actors need to engage in dialogue, conversations, interaction and interactive value creation (Ekman, Raggio, and Thompson 2016). As shown by Jaakkola and Alexander (2014) actors not only try to affect the actor that offers a service, but also try to influence other actors in the network. Therefore, it is important to adopt a many-to-many perspective to identify all relevant stakeholders that should be involved in the design of the solution.

The DMTS methodology defines the stakeholders' ecosystem mapping according to four tasks:

Task 1 – Value network constellation map: consists of identifying relevant actors and their relationships using the value constellation concept from Normann and Ramírez (1993). The value constellation can be viewed as a system of service systems and represents the network of actors and their relationships that jointly create an offering. A firm can upframe its perspective by understanding the firm's offering as an input into creating customer value while also considering the inputs offered by other firms. The value network is dynamic and evolutionary. During the design process more actors may be identified and introduced in the value network, as well as relationships may change. Figure 8 presents a proposal of a value network constellation map for the mobile ticketing ecosystem. The actors involved can be adapted to the reality that is being addressed, as well as the relationships among them.

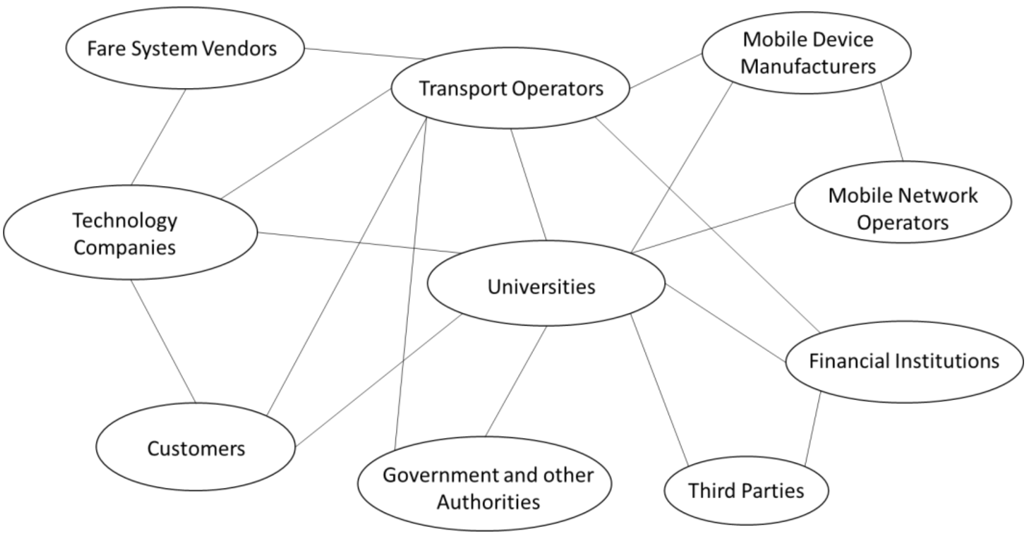


FIGURE 8. MOBILE TICKETING VALUE NETWORK CONSTELLATION MAP

Task 2 – Contributions and expected benefits from different actors: consists of a checklist of motivations, benefits and contributions from each stakeholder's point-of-view to the design and development of the ticketing solution. Filling up this information forces to actively reflect upon each actor's relation to the whole system and to coordinate roles and expectations. This allows to understand why the various actors should participate or contribute to the system, which is a fundamental step in deciding and organising their role and input. Table 4 exemplifies the contributions and expected benefits from different actors of the mobile ticketing ecosystem. The table clarifies what each actor brings to the project (competitive advantages and potential contributions) and what each actor gets from the project (expected benefits).

TABLE 4. MOBILE TICKETING ACTORS' CONTRIBUTIONS AND EXPECTED BENEFITS

Actor	Contribution	Expected Benefits
Transport Operators	- Market expertise - Ticketing expertise - Customers database - Operations expertise - Frontline interactions with customers	- To complement the present service offering - To better satisfy customer needs
Universities	- Methodological approaches - Research studies - Know-how (e.g. technologies, algorithms, usability, qualitative and quantitative studies)	- To open and finalise research in mobile ticketing field - To develop expertise in mobile ticketing - To disseminate the results
Customers	- "Experts of their own experiences"	- To access new, innovative and convenient services
Technology Companies	- Software development expertise - Mobile applications development expertise - Technology expertise	- To expand the service portfolio - To develop expertise in mobile ticketing solutions' design and development
Fare System Vendors	- Hardware and fare machines expertise - Technology expertise	- To expand the service portfolio
Government and other Authorities	- Institutional support - Financial support	- To support the launch of a new, innovative and convenient service
Financial Institutions	- Payments expertise - Secure financial transactions expertise	- To extend the offering to new contexts
Mobile Network Operators	- Mobile communications expertise - Payments expertise - Network signal infrastructure	- To extend the offering to new contexts
Mobile Device Manufacturers	- Knowledge about mobile devices capabilities and limitations	- To develop expertise in mobile ticketing
Third Parties	- Payments expertise	- To extend the offering to new contexts

Task 3 – Actor's roles: the competitive advantage of each actor reflected in their potential contribution allows to define their roles and inputs during the design process. The objective is to identify and assign the major tasks to each actor, taking into consideration their responsibilities and skills. Clarifying roles and defining tasks is important to ensure that all stakeholders are aware of their responsibilities and efforts needed, and that all tasks required to develop the solution are assigned. Table 5 suggests the actor's roles and main tasks are defined in taking into consideration their know-how and potential contribution.

TABLE 5. MOBILE TICKETING ACTOR'S ROLES

Actor	Role
Transport Operators Representatives	- Manage and coordinate the project - Interact with all stakeholders
Transport Operators Staff	- Provide feedback from interactions with customers - Receive and give training
Universities	- State-of-the-art studies - Methodology and methods - Technology tests - Usability tests - Interaction with customers and provide feedback regarding the interaction - Give training to customers and staff
Customers	- Participate in tests and give their opinion
Technology Companies	- Mobile application development - Frontend and backend development - Install hardware
Fare System Vendors	- Hardware development and production - Install hardware
Government and other Authorities	- Financial investment - Project dissemination
Financial Institutions	- Payments platform development
Mobile Network Operators	- Advisory
Mobile Device Manufacturers	- Advisory
Third Parties	- Advisory

Task 4 – Level of participation matrix: during the design process the level of participation of each actor varies according to the design stage. Levels of participation may vary from "no participation" to "very high" and are represented in a matrix form. By crossing the stakeholders and the design stage it is possible to assess the level of participation of each actor during each stage. Figure 9 presents the level of participation of each stakeholder during each design stage.

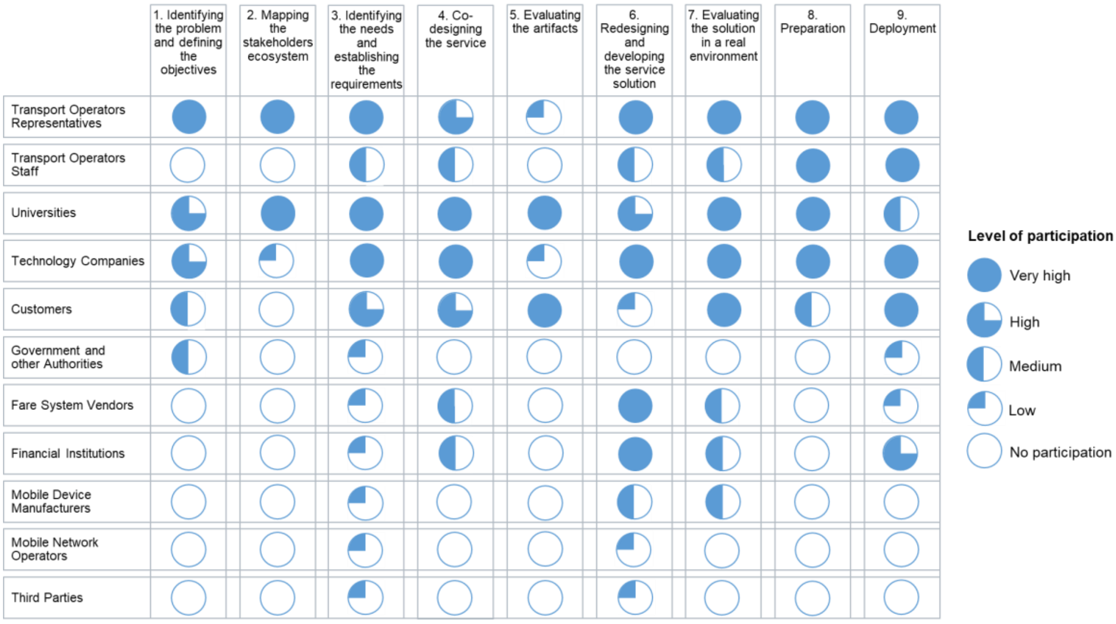


FIGURE 9. LEVEL OF PARTICIPATION MATRIX DURING THE DESIGN PROCESS

This stage contributes to literature by filling the gap referred by Dahlberg, Guo, and Ondrus (2015), who suggest that researchers should investigate about "(i) what the optimal roles of each stakeholder are; (ii) how to organize collaboration between stakeholders; and (iii) how to capture and measure the value each stakeholder is able extract from the participation to a mobile payment ecosystem". Additionally, it answers to the concerns raised by Patrício, Gustafsson, and Fisk (2018) who state that "further research is needed to better understand when and how to involve customers and other actors in the service design and innovation process as well as the impact on innovation outcomes".

Example 3: Anda Project

In order to exemplify the application of the value network constellation map model, the stakeholders' ecosystem map of the Anda project is presented below.

The value network constellation is represented in Figure 10 and identifies the actors involved in the design process of the Anda mobile ticketing solution and the corresponding relationships. The latter are represented by lines linking the various actors with whom they directly interacted with, during the design. In the first design stages it was not very clear all these interactions and actors. This representation has evolved over time. For instance, only during stage 7 (evaluating the service solution in a real environment) it was clear the need of technology companies to interact directly with mobile devices' manufacturers to understand the behavior of the Android operating system and mobile devices' restrictions when reading BLE beacons.

The map also shows that Transport Operators Representatives (TIP) interacted with all other stakeholders of the network. This happened because they were the promoters and coordinators of the project. It was also necessary to distinguish Transport Operators Representatives from Transport Operators Staff due to the configuration of the urban passenger ecosystem of MAP. Transport Operators Representatives (TIP) are the board of directors of the entity responsible for managing, collecting and distributing the ticket sales revenues to the 11 transport operators operating on MAP. Transport Operators Staff include all those involved on everyday operations, such as drivers, inspectors, security, customer service and sales operators. This is a very simplistic distinction since the urban passenger ecosystem of MAP is much more complex and could give rise to a map representing individual stakeholders. However, the value network constellation map intends to be a macro representation and so the stakeholders are not disaggregated individually.

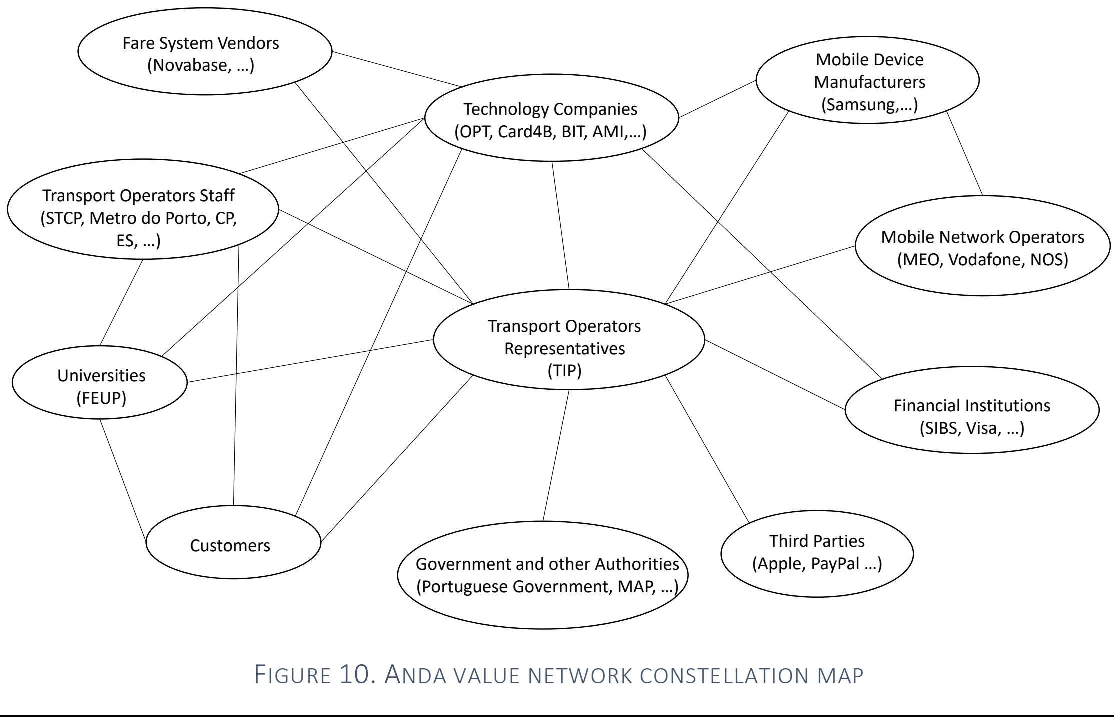


FIGURE 10. ANDA VALUE NETWORK CONSTELLATION MAP

Stage 3: Identifying the Needs and Establishing the Requirements

This stage consists of two main tasks:

Task 1 – Identifying the needs: consists of understanding as much as possible about stakeholders, so the service under development can support them in achieving their goals; and

Task 2 – Establishing the requirements: consists of producing a set of requirements that represent the decisions that were taken and form the basis to the design of the solution.

The task of identifying the needs is related to data gathering techniques that allow to collect information from the various stakeholders. Examples of such techniques include interviews, meetings, brainstorming, focus groups, questionnaires, and observation. The application of these techniques can be enriched with prototypes, storyboards, sketches, personas descriptions and other artifacts and props that may be developed. During this process, it is important to involve all stakeholders groups and thus the importance of the previous stage (mapping the stakeholders' ecosystem). Involving only one representative from each stakeholder may be not enough, since it is being collected its own perspective. This is especially important when the group is large. In this case, the representative of the group should ensure that he/she gathers different perspectives from the actors of the same group in order to expose them during the meeting.

Example 4: Mobipag Project

For instance, during the MobiPag project, regular meetings (at least once a month) were held between the co-promoters of the project (technology companies and universities). Presentation sessions and individual meeting with all members of the advisory board (composed of MNOs, banks and third parties) were also conducted to collect their opinion regarding the work that has been done, their expectations and position in relation to the MobiPag initiative and on the development of mobile payment solutions. A questionnaire was also applied to the academic community to solicit participants for a subsequent testing phase and to gather opinions on mobile payments, advantages, disadvantages and potential use cases. Results of the survey can be reviewed in MobiPag Consortium (2013)

Consultation of stakeholders should be complemented by literature research and benchmarking. Awareness of what is already implemented in other cities or countries and what is being proposed and investigated by other researchers, gives important insights about possible paths and allows to learn with others' experience.

The information gathered is then analysed, interpreted and decisions are made, leading to the extraction of requirements. Decisions regarding the technology to be used are also taken during this phase. Identifying needs and establishing requirements is an interactive activity in which the sub-activities inform and refine one another. Once starting analysing the data, it may be necessary to collect more data, including from different stakeholders and perspectives, in order to clarify and confirm findings.

Requirements can be classified as functional requirements, which capture what the system should do, and as non-functional (or experience) requirements, which define what constraints imposed to the system and to its development (Sharp, Rogers, and Preece 2007). Non-functional requirements can be refined into further categories such as look and feel, usability, performance, security and operational requirements (Robertson and Robertson 2013). Requirements evolve and develop as the stakeholders interact with the proposed designs. Making decisions and developing a set of requirements is an iterative process of evolution and negotiation, which needs to be carefully managed and controlled.

Stage 4: Co-designing the Service

The fourth stage of the DMTS is concerned with transforming the needs and requirements into a concrete view of the conceptual model. Data analysis and interpretation activities are followed by documentation. It is important to document the decisions and requirements, which will be the basis of the forthcoming stages. Requirements can be analysed and documented using data-flow diagrams, state charts, work-flow charts, class diagrams, activity and sequence diagrams, scenarios, use cases, among others. Also, more rigorous notations such as service blueprinting or UML (Unified Modelling Language) can be used in combination with less structured and more emphatic formats such as stories and prototypes.

Example 5: Mobipag Project

Figure 11 represents the diagram of the "Buy travel card" use cases and respective interactions with the actors. Figure 12 details the use case "Buy travel card with Human Mediator and POS" through a sequence diagram. Further details regarding MobiPag use cases specification may be reviewed in (MobiPag Consortium 2011).

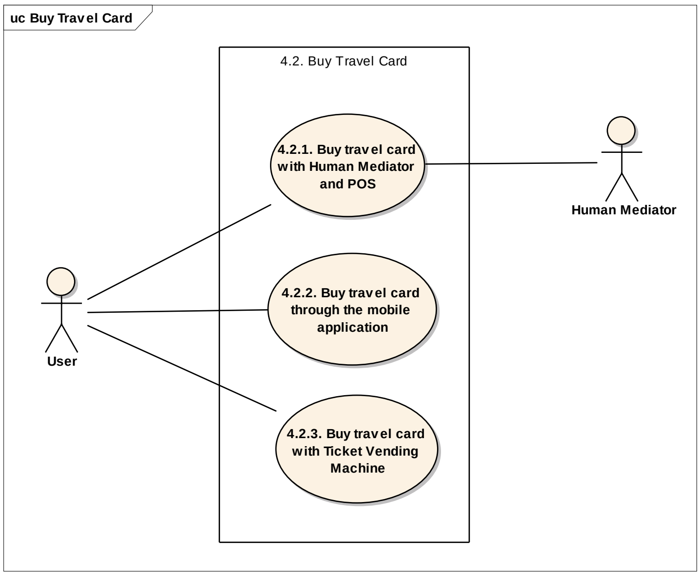


FIGURE 11. MOBIPAG "BUY TRAVEL CARD" USE CASES DIAGRAM

Example 5: Mobipag Project (cont.)

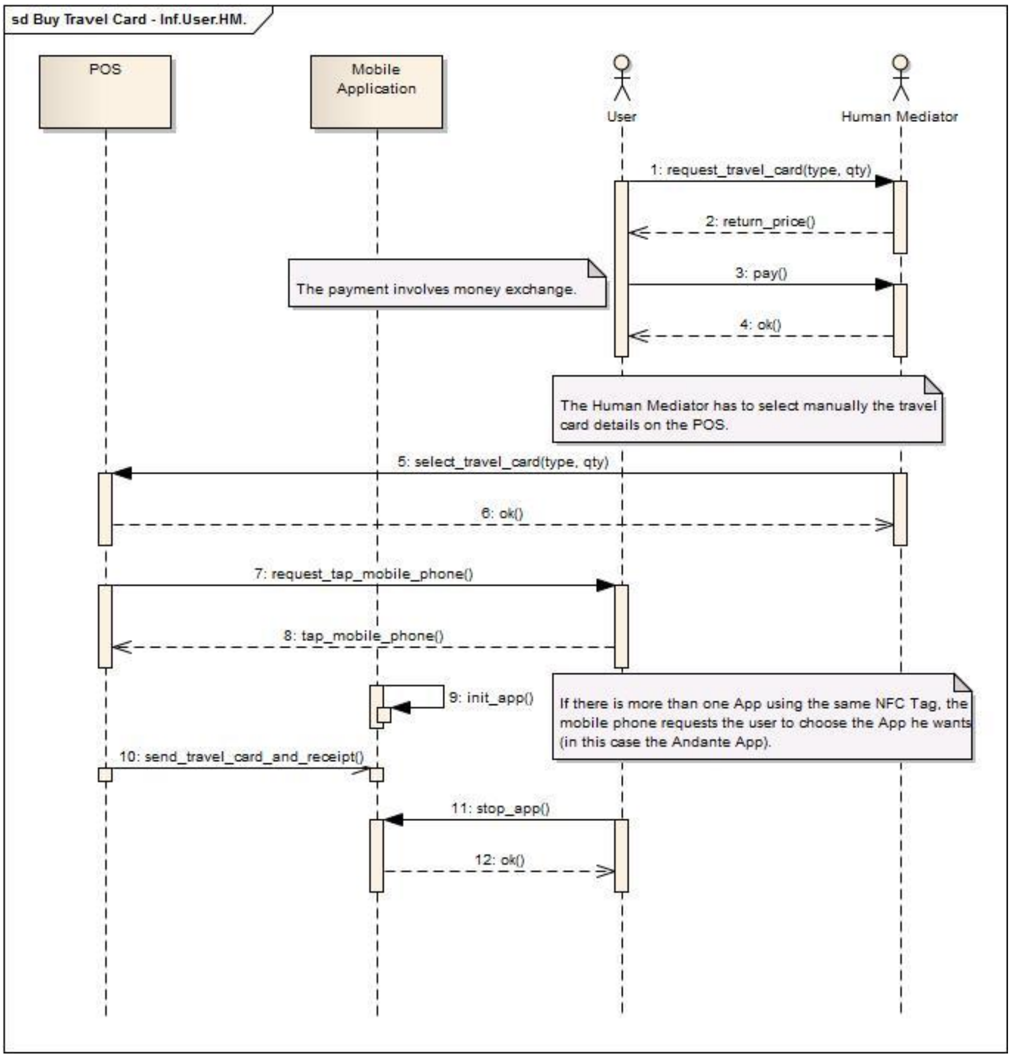


FIGURE 12. SEQUENCE DIAGRAM OF THE MOBIPAG USE CASE "BUY TRAVEL CARD WITH HUMAN MEDIATOR AND POS"

Example 6: Mobipag STCP Project

During the MobiPag STCP project, a story in video was produced to materialize the idea of the project and is accessible through the link: https://tinyurl.com/yby8rp83

Example 7: Seamless Mobility Project

During the Seamless Mobility project a story in form of video was produced to communicate the idea of the project and is accessible through the link: https://tinyurl.com/y9ektk6h

The participatory design approach is clearly evident in this stage. Users and stakeholders are engaged and encouraged to share and use their experiences to co-create the service. Artifacts are co-designed and discussed during meetings and focus group sessions. Informal evaluation involving users can be carried out by interviewing them and asking them to comment on early prototypes. This helps to deepen understanding and to expose all stakeholders to different aspects and get their perspectives on the design. Thus, the main objective is to evaluate if the users' requirements were correctly interpreted and properly embodied in the artifacts. The designs will be modified according to the feedback and new artifacts will be developed. Therefore, prototypes evolve during this stage, from low-fidelity such as sketches and paper screens, to high-fidelity using web tools to design the interaction with the service. When a stable and consensual prototype is reached, the DMTS method proceed to the next stage involving more formal evaluation approaches.

Example 8: Anda Project

In the Anda Project after several meetings between transport operators' representatives, researchers and technology companies, first mockups were produced and several questions and issues arose, being necessary to draw upon the experience of the customers. A focus group session with 6 potential customers was organized by researchers (see Figure 13). The session lasted about 2:30h, was audio recorded, fully transcribed and then analyzed following qualitative methods (Strauss and Corbin 1998). First, a questionnaire was applied to characterize the sample (see Appendix E.1), followed by a brief presentation of the project. They were then asked about their perception regarding the concept of paying their journeys with the mobile phone, the interaction with the BLE technology and the concept of optimizing the fares to be paid (see Appendix E.2). Then, each journey stage – start of journey, travelling and end of journey – was explored, with the help of the mockups and post-its. They were also encouraged to design their own mockup. The purpose of the mockups were not to test complete solutions but to explore user experiences and to understand how users cognitively and emotionally engage with service elements, processes, and experiences (Ferreira, Dias, and Cunha 2018). The objective was to understand the customers' needs at each stage and what kind of information and feedback they expect the service to provide.

FIGURE 13. FOCUS GROUP WITH POTENTIAL CUSTOMERS DURING EARLY DESIGN STAGES OF THE ANDA SOLUTION

Stage 5: Evaluating the Artifacts

Mobile services, including mobile ticketing services must be useful, easy to learn, effective, efficient, attractive and satisfying to use. Evaluation plays a fundamental role, enabling to assess if those requirements are fulfilled. Asking users and experts their opinions, observing users, testing users' performance and analysing users' interaction with the service are examples of methods used in evaluation processes.

In the previous stage, sketches and mockups were presented to potential customers to assess their opinion regarding the concept, the functionalities they would like the service to offer, and the information they wanted to have access to. In this stage the goal is to present the improved version of the mockups to experts and users before starting to develop the final solution. It usually involves the development of high-fidelity prototypes that preferentially will run on mobile phones, since the interaction with mobile phones is very different from the interaction with computer screens, keyboards or papers.

There are several approaches and methods that can be used to evaluate artifacts. Usability testing (Dumas and Redish 1999) is an example of an approach that can be used to evaluate the service. It consists in asking users to perform a set of tasks with the mobile service and measure their performance. Users are watched and/or videotaped and the time they take to complete each task is recorded as well as the number and type of errors they make. Questionnaires and interviews are also used to gather users' opinions. These tests may be done in laboratory environments, isolated from the normal daily interruptions, or in the field, with the aim of understanding what people naturally do and how the mobile ticketing service mediates their activities.

More analytical approaches may be used in the evaluation process, such as heuristics and walkthroughs. Heuristic evaluation (J. Nielsen and Mohlich 1990; Gómez, Caballero, and Sevillano 2014) is conducted by experts and is based on checklists and usability guidelines. Walkthroughs (Burghardt 2016) involve experts exploring scenarios with prototypes of the application to simulate a user's problem-solving process. Ideally, combining approaches is preferred to gain a broad understanding of the design effectiveness.

> Example 10: MobiPag STCP Project
>
> During the MobiPag STCP project, the evaluation of the mobile ticketing prototype was done using two different but complementary methods. The heuristic evaluation was performed by three experts (J. Nielsen 1992, recommends between three and five) and was useful to identify usability issues, such as inconsistency of words, complexity of information, and lack of undo and feedback buttons in certain screens. These usability issues were solved in order to prepare the next evaluation phase.
>
> The second evaluation method used was the usability testing. During this procedure the user interface design was evaluated by potential users who performed a list of tasks using the application prototype. The main objectives were to evaluate the user interaction with the prototype and how the information presented to the users was understood by them. A post-test questionnaire was administered to each user, to gather additional information regarding the usefulness of the solution and the acceptance of the idea of paying with the mobile phone. Each test took about thirty minutes to be completed. Data was gathered by videotaping the participants and recording their voice and the screen. Observers also took notes and recorded the execution time of each task. The test was divided into three parts: 1) Pre-test questionnaire; 2) User test with pre-defined tasks; and 3) Post-test questionnaire. Further details can be reviewed in (Ferreira, Nóvoa, and Dias 2013).

During this stage, technological issues are also investigated. Taking into account the technological decisions made in previous stages, it is necessary to carry out laboratory and field tests related with the technology. For instance, Bluetooth cover range, power transmission, radiation patterns are examples of important parameters that must be measured. This analysis enables to understand the technology restrictions and to define a specification of the technology that will be useful for supply competitions. Using different mobile devices (brands, models and operating systems versions) during the tests is also important to assess how different devices interact to the technology.

Example 9: Seamless Mobility Project

During the Seamless Mobility project laboratory tests were conducted to measure the reading process of the QR codes under different circumstances: i) Testing different QR codes sizes. Two sizes were tested, printed on white paper: 5.82 cm x 5.82 cm and 11.64 cm x 11.64 cm. These dimensions were used to fit existing infrastructures, such as buses or stops; ii) Testing the QR codes under different lighting conditions (high (~ 80 lx), medium (~ 20 lx) and low (~ 5 lx)); iii) Reading the QR codes at different distances (1m, 0.75m, 0.50m and 0.25m). Laboratory tests results revealed that a minimum illumination level (~ 4 lx) is required to the QR Codes be successfully read. This may constitute a challenge in bus stops at night, requiring an extra light source, such as the flash. Also, the correct position and distance to the QR Code has to be found while reading the codes. Further details can be viewed in (Couto et al. 2015) and (Ferreira, Fontes, et al. 2017).

Stage 6: Redesigning and Developing the Service Solution

Evaluation results from previous phases allow to identify the main issues concerning the design of the artifacts. These are improved taking into account the analysis of the results. The documentation produced can serve as a basis for market consultations with supplier companies. After choosing the technological companies that will develop the service more detailed information can be provided. The development of the solution requires a very close interaction among all hardware and software suppliers. Also, other stakeholders, such as financial institutions, mobile network operators, mobile device manufactures and third parties, play an important role, which can be an active role, such as developing and integrating services in the final solution or a less active role, such as a consultant.

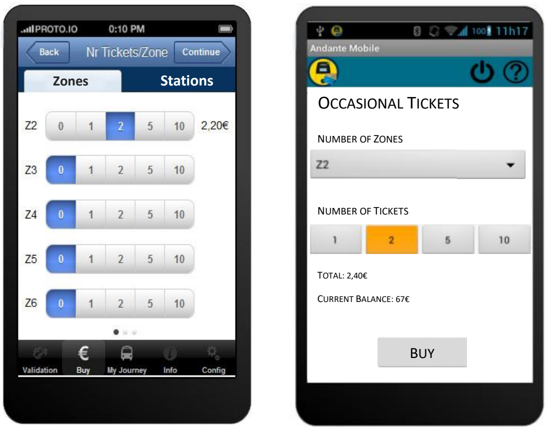
The transition between a mockup to a functional prototype and, finally, to a releasable service can be challenging. According to an evolutionary prototyping approach, the functional prototypes can eventually evolve to the final system, in such a way that it can be produced and distributed in large scale.

During this stage developers start the development of a functional prototype with an engaging user interface and user experience as close to the real service as possible. This is accompanied by the development of the backend service that will support the system and the front end services, if applicable. It may also be necessary to replace or upgrade ticketing equipment (e.g. ticket validators, ticket vending machines) in order to be able to interact with customers' mobile phones. In the end everything should work in an integrated way: mobile ticketing application, frontend, backend and hardware (if needed). Several tests are conducted during this stage, being the findings integrated in the iterative development process. When a stable solution is achieved, the DMTS method proceed to the next stage, which involves testing the developed solution in a real environment with real customers.

Example 11: MobiPag STCP Project

After the evaluation of the prototypes presented in Example 10, the results were analysed and an extensive discussion with all stakeholders prompted to the development of a functional prototype of the mobile application. This high fidelity prototype was developed for Android devices. The purchase of travel tickets screens of the prototype are shown in Figure 14, where a) corresponds to the initial design and b) corresponds to the final design. In the case of the MobiPag STCP solution, the passenger purchases the travel ticket OTA by selecting the type and quantity of tickets he/she wants to purchase. The validation is also made OTA.

When comparing the initial design (see Figure 14 a) with the final design of the tickets purchasing screen (see Figure 14 b), the button "buy" was introduced in the same screen of the ticket's choice, decreasing the number of swipes to complete the action. The type of ticket can be selected through a combo box, instead of a list. The current balance is also visible to the user during the purchase process.



a) b)

FIGURE 14. MOBIPAG STCP PURCHASE OF TRAVEL TICKETS SCREENS: A) INITIAL DESIGN; B) FINAL DESIGN

Example 12: Anda Project

The Anda solution is based on a check-in/be-out scheme, requiring an intentional user action when entering the vehicle and the alight station is automatically detected by the system, as well as intermediary stations along the trip. To start a journey, the passenger taps the mobile phone against a validator, communicating via NFC. During the journey the mobile phone interact with BLE beacons installed in metro and train stations and inside buses, through Bluetooth connection, to locate the customer along the transport network. When the passenger leaves the vehicle, the mobile phone loses the beacons signal and the application automatically closes the journey.

The ticket validators used in MAP, despite having NFC technology incorporated, were not prepared to communicate with smartphones, it was necessary to install a Security Application Module (SAM). Therefore, almost 2.000 SAMs were installed inside all ticket validators of the MAP network (see Figure 15) to enable the interaction of the validators with smartphones. Validators installed inside buses had an additional communication problem with smartphones, forcing the replacement of 500 antennas. Regarding the beacons technology, the MAP network did not have this technology installed. More than 1.500 BLE beacons were installed inside all ticket validators of metro and train stations and inside buses. In underground stations beacons were also placed on the boarding platform. These installations and replacements took about 5 months to be completed.

FIGURE 15. INSTALLATION OF SAM INSIDE TICKET VALIDATORS

Stage 7: Evaluating the Service Solution in a Real Environment

Designing mobile services for urban passenger transport is a very particular case of service design because of its specificities. The customer is not co-creating the service in a specific place or context, he/she is rather moving (travelling) and therefore the context is dynamic, influencing the service experience. Therefore, evaluating a service solution in context has never played such an important role. It is also important to involve real passengers of the transport system in the evaluation process since they are the experts of their own experiences. Their opinion in relation to the service that is being tested is fundamental to the success of the solution. It is important to keep participants active and interested in sharing their experiences and make the most of their feedback to improve the solution.

One of the main problems of current evaluation tools, such as travel diaries, is the long delay in receiving users' feedback and the high response time of the development team to the reported problems. Other tools, such as observation or following users while travelling, is unfeasible in terms of time and cost required, being the travelling experience influenced by the presence of other people. Therefore, the DMTS method proposes a tool that would allow users to report and share their experience in real-time and also get timely response. This tool was implemented in Mobipag STCP and Anda projects and has proved to be very effective and successful. It takes advantage of social networks, such as Facebook, as a mean of interaction between stakeholders, such as participants, researchers and developers. This allows to get information in context as the experience occurs, to clarify doubts, and ask participants questions or ask them to try different procedures.

For the developers this tool works as a real-time debugging of the solution. They are able to analyse errors, ask participants to repeat the situation that originated the error and identify problems they had not even thought about. When identifying errors and fixing them it is important to launch updates of the mobile application. This prevents participants from being always referring the same errors. Participants feel that their opinion is important and allows to fine tuning the final solution for deployment. Incorporating the customers' feedback in the design and development of the solution is a clear example of value co-creation in design.

This tool presents several advantages:

1) Sense of community: participants share their experience, common problems and concerns to a closed group on a social network. They identify with one another's problems and are able to help each other.
2) Convenience: it takes advantage of something that already exists, that people already use while travelling by public transport and that makes part of their daily habits. It is very convenient for them to use the communication media they already use daily to share their experiences, and avoids having to open and use a new mean, which can be easily forgotten. Besides, it is available on the same device that they are using to test the mobile ticketing application.
3) Available time: while travelling by public transport people have time available to do other things. If they are testing a mobile ticketing service, it is the perfect time for them to share their experience in real-time and in context. This makes the information provided more accurate and complete than if they had to fill out a travel diary at the end of the day.

The interaction with participants through social networks, email or even phone is very useful to identify errors and problems, to collect opinions and to ask brief questions. However, this information has to be complemented with other data gathering techniques, such as interviews or focus group that require face-to-face interaction. Therefore, during or at the end of the tests it is important to meet the participants in person to explore additional issues. Questions related to their travelling habits and needs, security and privacy concerns, adoption factors and potential business models are examples that may be addressed during interviews or focus group sessions.

One of the main objectives of this stage is to evaluate not only the user interface but also the performance and effectiveness of the entire solution (frontend, backend and infrastructure). Often problems arise when components of a functional prototype (communications, software and hardware) are combined. By thoroughly testing the prototype, problems can be early identified before they represent a large sunk cost and fixing them becomes unrealistic. Prototype testing and evaluation provides concrete evidence to back up performance claims and results in a more reliable final solution that can be confidently deployed.

To conduct experiments in real environment several recommendations can be drawn:

1) Restrict the tests to a small area of the transport network. Choose, for instance, a single transport operator, few lines of different transport operators, or transport operators operating in a small geographical area.
2) Select passengers who use the urban transport of selected operators/area more often. The selection may be done using the transport operators' database, by placing ads inside vehicles, stations or social media, and/or by recruiting in universities, business centres and other places located in the target geographical area.
3) Provide presentation and training sessions. Prepare sessions to present the project, the tests and what is expected from participants. After agreeing in participating, training sessions should be provided to help participants to download the mobile application and to explain how it works. These sessions should take place at different days/hours to cope with participants' free time.
4) Gradually introduce participants to tests. During the first weeks of testing, several errors will occur and this gradual introduction of participants in the tests will prevent everyone from reporting the same problem over and over again. Also when entering the tests, newcomers bring dynamics to the discussion and raise new concerns and ideas.
5) Interact with participants and show that their opinion is important. Participants should realize that communication through social networks or email is bilateral and that they always get answers to their comments and questions. Also, fixing problems and introducing new versions of the application shows that their suggestions are taken into account, encouraging them to continue to contribute.
6) Conduct interviews and/or focus group sessions. Face-to-face interaction is always important to explore additional questions and gather further information. Participants can express themselves better and give information that they could not provide during the tests.

Example 13: Anda Project

In the Anda project this stage lasted about 1 year. A first set of tests was done from April 2017 to July 2017. One line of each four different types of transport operators (metro, train, public bus and private bus) was chosen to perform the tests. Beacons were deployed in every metro and train station and inside the buses of the selected lines. The participants were selected from the Transportes Intermodais do Porto (TIP) customer database and from the Faculty of Engineering of University of Porto (FEUP) and Science and Technology Park of University of Porto (UPTEC). The main criteria for selecting users were: i) to have monthly pass; and ii) frequently use (more than 20 monthly validations) at least two of the lines under test. From the selected clients, 90 participated and received the monthly pass for free as a reward for participation.

Another set of tests started in October 2017 and lasted until June 2018. The expansion of the lines used in the tests began in March 2018 and spread to the entire MAP network in June 2018. From the previous group, 15 participants were selected to continue. Ticket store operators, call centre collaborators and inspectors were introduced in the tests as participants. The introduction of frontline employees in the tests is crucial since they are going to interact directly with the customers when the solution is deployed, and they have to be prepared to help them. Also, their point-of-view is key as co-designers of the solution, since they interact with customers every day and know their problems and concerns. From March until June 2018 several other workers of the various transport operators have been introduced in the tests. In total 90 people participated in this test phase.

The introduction of the participants during the tests was gradual: 37 started in April, 40 in May, 11 in June, 2 in July, 25 in October and so on. This gradual process allowed the identification of errors, which were corrected before the entry of new users, and the integration of improvements suggested by them. In this way, it was possible to avoid having all participants mentioning the same error simultaneously and to increase the dynamics of the group with the introduction of new participants each month.

The participants were introduced at the beginning of each month and the tests were preceded by a presentation and training session. At the end of each month the individual participation of each client was analysed (number of total validations and comparison of the validations performed with the mobile app and with the smartcard) and a decision was made about their participation in the tests for the following month. Participants were also asked to fill in an online questionnaire, whose main objective was to characterize the sample in sociodemographic terms and to analyse individual perception about mobile payments before the tests.

The presentation sessions consisted of explaining the project, the objectives of the tests, the requirements to participate (see Figure 16). After the presentation session, clients who were interested in participating attended the training session. The training sessions consisted of downloading the Anda application to the participants' mobile phones, explaining how the beacons work and their interaction with the application (see Figure 17). Since the application was not available in the PlayStore for the general public it was necessary to give individual access to each participant through the email associated with the PlayStore. Participants could then download the application via a web link (https://play.google.com/apps/testing/op.opt.ANDA). After downloading the application and registering the users interacted with the beacons placed in the room, that were made available by the development team (see Figure 18).

Example 13: Anda Project (cont.)

FIGURE 16. PRESENTATION SESSION OF ANDA

FIGURE 17. TRAINING SESSION OF ANDA

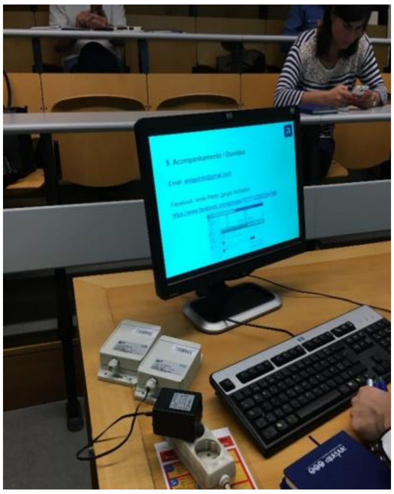


FIGURE 18. TRAINING SESSION OF ANDA (DETAIL OF THE BEACONS)

Example 13: Anda Project (cont.)

The experimental pilot consisted of using the mobile application ANDA, by the selected users, to travel in the 4 public transport lines under test (see Figure 19). The objectives of these field tests were to evaluate the usability and performance of the application, the interaction with the beacons, with the NFC and the post-billing system.

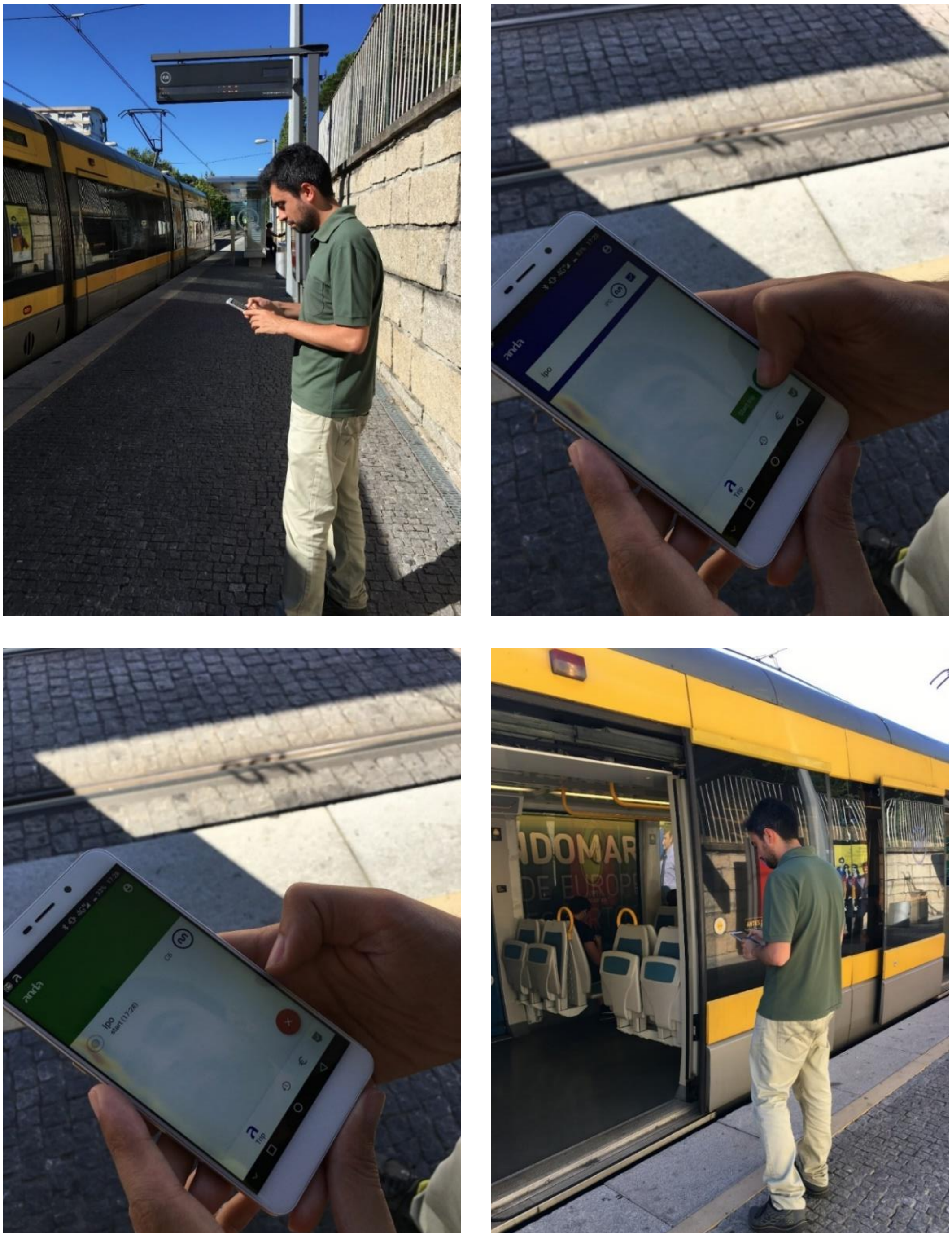


FIGURE 19. USER INTERACTION WITH THE MOBILE APPLICATION IN REAL ENVIRONMENT

Example 13: Anda Project (cont.)

During the tests, the participants contacted the project team daily via email and a closed group in Facebook (see Figure 20) to ask questions, share experiences, difficulties and suggestions for improvement. Some of the comments were also accompanied by screenshots of the application to which they referred (see Figure 21). The logs of the mobile application could also be sent by email, allowing access to more details regarding the mentioned error. These media allowed daily interaction between participants, researchers and the development team, being also possible, through Facebook, interaction between participants. It was also useful for issuing information to participants and to make quick surveys (see Figure 22). All comments placed on the Facebook page and emails were transcribed to a platform, developed internally for that purpose, and categorized. The comments were also analysed and discussed during weekly meetings between TIP, researchers, and technology companies, continuing the process of co-design and improvement of the solution.

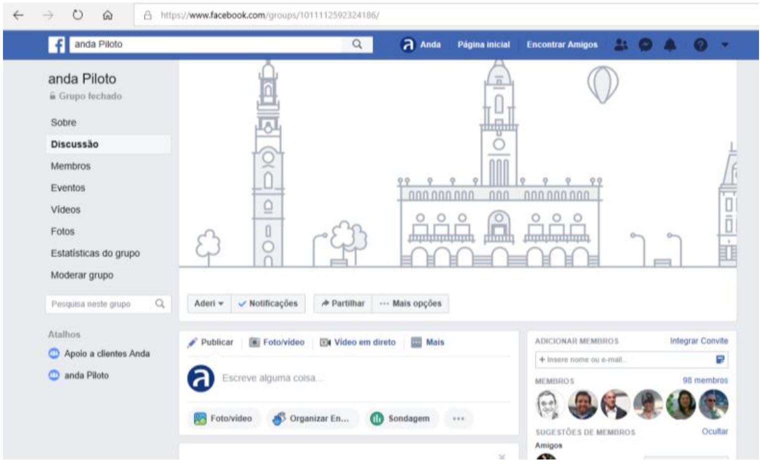


FIGURE 20. FACEBOOK CLOSED GROUP OF ANDA

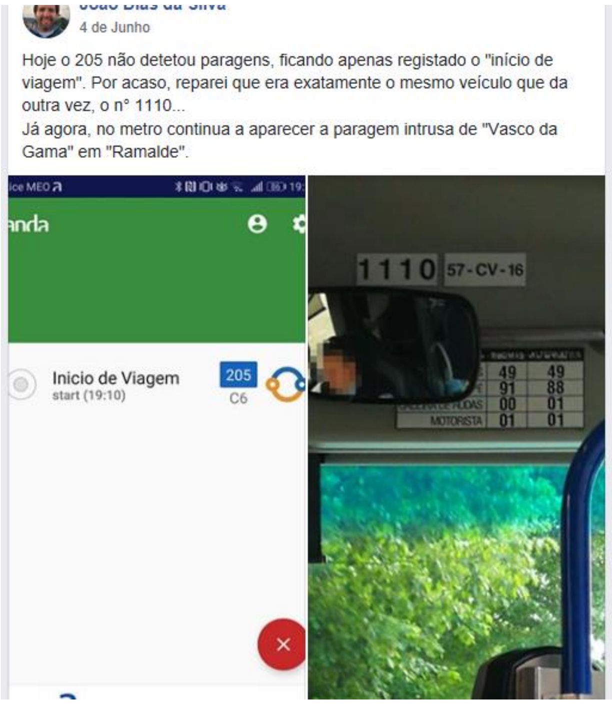


FIGURE 21. COMMENT OF A PARTICIPANT COMPLEMENTED BY PICTURES

Example 13: Anda Project (cont.)

FIGURE 22. SURVEY RELEASED IN THE FACEBOOK GROUP

At the end of the first set of the field tests, 3 focus group sessions were conducted with selected users (see Figure 23). The selection of the participants took into account the individual performance during the tests, namely the total number of validations and the frequency of interaction with the project team. The sessions were moderated by 3 people (1 researcher and 2 people from technology companies) and had 10, 7 and 8 participants each. The objectives of the focus group sessions were to understand the participants' experience with the application (what they liked, perceived confusing and improvement suggestions), security and privacy concerns, travelling habits, and perception of the payment of the public transport service with the mobile phone. The sessions lasted about 1:30h each, were recorded in audio and the content was literally transcribed and later analyzed following qualitative research tenets (Charmaz 2006; Glaser and Strauss 1967). The qualitative analysis results can be found in Appendix F.10.

FIGURE 23. FOCUS GROUP SESSION OF ANDA

Stage 8: Preparation

A successful deployment depends not only on a well-designed and well-functioning service solution but also on a well-prepared deployment. It is very different to pass from tests with some customers, who know the project, are condescending with failures and willing to help, to the market with thousands (or millions) of customers. Therefore, to prepare the deployment several tasks can be outlined:

Task 1 – Preparing a communication plan:

The new mobile ticketing service solution should be advertised to all people served by the transport network through various means of communication. The objective is not only to disseminate the new service, but also to explain how it works. This may involve news in TV channels, newspapers and social networks, placing outdoors and stands at stations, decorating vehicles, distributing flyers and informational leaflets, and having promoters presenting the service and helping customers. Communication pieces need to be carefully designed and produced in a timely manner, as well as communication channels and important dates need to be defined. The strategy to increase market penetration is vital, since more users and transactions could help to negotiate better deals with payment providers.

Task 2 – Preparing a customer support for launch:

During the first days after launch, the customer traffic will increase and customer support need to be prepared for it. Customer support personnel and sales staff should be trained to deal with customers' doubts, questions and concerns. Organizing training sessions and letting support personal to deal with testing participants in the last weeks before launch is a good way to introduce them to the problems that may arise. It may also be necessary strengthen the customer support team, since a new ticketing media will be offered and previous problems with other ticketing media will continue to exist. Contact channels should also be prepared, such as phone number, email, and physical stores.

Training sessions should be provided to operational staff and ticket inspectors as well, for them to be aware of the new ticketing solution. They are the frontline employees and people will ask them for help. It is also important to define their role and responsibility. A grace period may be needed, for customers to get used to the new ticketing service and to deal with eventual technology problems that may emerge.

Providing documentation and information through terms and conditions, Frequently Asked Questions (FAQs), tutorials and service providers' websites and social networks are useful to customers and reduce direct contacts by phone, email or in person. These should carefully explain registration, set-up and use of the system procedures and provide a list of types of handsets and operating systems that are compatible with the solution.

Task 3 – Developing a customer portal:

A customer portal may be useful to provide further and detailed information to customers, not supported by the mobile application. Actually, designers may decide, for example, what activities should be supported on smartphone, or in a website, or both. For instance, customers may check a certain journey details and complain about wrong information (entrance or alight station, fares, and others). The complaint is then analysed by the service provider, which gives reason or not to the customer.

Task 4 – Developing a web platform for customer support:

A web platform is useful for customer support personnel to help customers when contacted by them. It can be used to access customers' information, register interactions with customers and visualize the status and outcome of each interaction. This may trigger a ticket process that is redirected to the stakeholders responsible for its resolution.

Task 5 – Developing a monitoring system:

The introduction of a mobile ticketing media that interacts with other technologies and infrastructures requires monitoring the information produced and conveyed, the ticketing transactions, and the state of the communications and technologies. A monitoring system may trigger alerts to developers, maintenance, customer support and others in charge of solving the problem.

Task 6 – Carrying out stress test for the mobile ticketing system

When launching the mobile ticketing to the market the number of registrations and transactions will massively increase and a new flow of data have to be processed by the back office. This environment is very different from the tests phase, therefore it must be previously tested.

Task 7 – Preparing for needed data storage

The amount of data being stored and accessed by customers and staff everyday will increase. These should be compliant with GDPR regulation.

Task 8 – Developing security plan for the operational phase

Providing a mobile ticketing service introduces new technological devices and over-the-air connections, opening doors to cyber security attacks that did not exist until now. Plans to handle these kind of incidents and emergencies (cyber-attacks, fraud cases, technical breakdowns) should be prepared.

Task 9 – Defining criteria for success

When launching a new service, that usually involves a significant amount of investment, is convenient to define a set of Key Performance Indicators (KPIs) that allows to measure its evolution and impact. The number of customers using the mobile application per number of registered customers, the number of trips using the mobile application, the amount of sales per customer, and retention rate are examples of such indicators. These indicators help to measure the impact of the service demand and to identify potential problems that need to be addressed.

Example 14: Anda Project

All these steps were taken into consideration and followed during the Anda project. Some of them are highlighted below.

Regarding task 1 (prepare a communication plan), the dissemination of the new service started during the early stages of the design through social media news (see Appendix A). The goal was to introduce the solution that was being developed and to prepare the public for the launch. The release of the mobile application was complemented by various material such as leaflets, flyers (see Figure 24), billboards and news in TV channels, newspapers and social networks. Dedicated customer service stations were placed in several metro stations, buses were decorated (see Figure 25), and promotion activities were carried out in schools and universities.

FIGURE 24. ANDA FLYER (IN PORTUGUESE)

FIGURE 25. BUS DECORATION WITH ANDA INFORMATION

Example 14: Anda Project (cont.)

Presentation of the project and training sessions (Task 2) were provided to inspectors and their supervisors in order to explain how the mobile ticketing service and the inspection procedure would work. This first session, illustrated in Figure 26, was also important in terms of the service co-design process. The inspection screen of the mobile app was showed to inspectors (see Figure 27) and they suggested the inclusion of more information such as the customer’s photo, which they find crucial to their work.

FIGURE 26. PRESENTATION AND TRAINING SESSION PROVIDED TO INSPECTORS AND SUPERVISORS

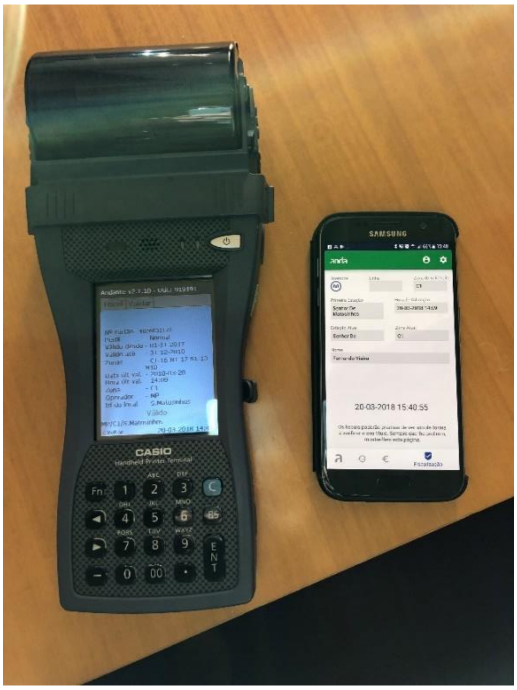


FIGURE 27. INSPECTION SCREENS IN HANDHELD DEVICES AND MOBILE APPLICATION

Example 14: Anda Project (cont.)

Presentation and traning sessions were provided to customer support and sales staff (see Figure 28). These sessions were divided in two parts. During the first part, the Anda application was presented as well as the most frequently asked questions from participants during the pilot phase and the answers they should give to customers in the deployment phase. The second part consisted on presenting the web platform for customer support and training to fill in information with some examples from the participants of the pilot. The session materials were given to the employees, who repeated the presentations with their colleagues.

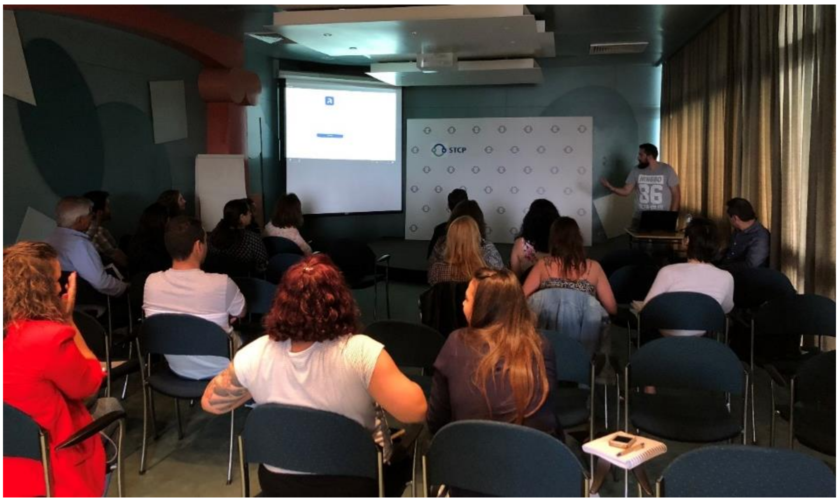


FIGURE 28. PRESENTATION AND TRANING SESSIONS PROVIDED TO CUSTOMER SUPPORT AND SALES STAFF

A video tutorial, available at https://tinyurl.com/y9wad53b, was produced to explain the registration, set-up and use of the application. This tutorial was released on social networks of transport operators, ticket sales stores and metro stations. In 15 days it has had more than 15.000 visualizations on social networks.

Stage 9: Deployment

When the mobile ticketing solution is deployed, and when it was accompanied by a mass communication campaign, lots of customers start to download and register on the application. This is the moment of truth of all the work that has been done. Probably errors may occur, user account registrations would fail, customers would complain. It is important that all stakeholders who were more actively involved in the design and in the development of the solution are available to help, not only customers, but specially trained staff.

Customers may ask questions and ask for help through all means: transport operators websites and social networks, mobile applications store, phone, email and physical stores. There are many touchpoints to manage and resources are scarce, but it is important to answer all customers in a timely manner. It is crucial to identify the main issues and to react quickly.

During the initial phase of deployment it is important to monitor the operation closely and adjust the strategy accordingly. It is important to understand if people are joining the service in the expected way, if they are actively using the application, if they stopped using it and why. Being proactive and directly contacting people, having specific physical locations where clients can go, continuing to publicize the new service, are some strategies that can be followed to attract and retain new customers.

The deployment is just the beginning of a continuous improvement process. Enhancing the usability of the application, improving the monitoring system and the customer support platform, integrating alternative payment providers, and integrating further services and mobility service providers are possible paths to be addressed. The deployment of a mobile ticketing system is just a step of a long-term mobility strategy for a region.

Example 15: Anda Project

The Anda application was launched to the market on June 29th of 2018. A presentation session with all stakeholders involved in the project was organized in the city of Porto. It consisted of a demonstration of the Anda application during a multi-modal trip (see Figure 29), culminating with the discourse of government and MAP entities and transport operators representatives (see Figure 30). The launch was widely reported in the media (see Appendix B).

FIGURE 29. DEMONSTRATION OF THE ANDA APPLICATION DURING A MULTI-MODAL TRIP

Example 15: Anda Project (cont.)

FIGURE 30. SPEECH OF THE MINISTER OF ENVIRONMENT, ENG. JOÃO PEDRO MATOS FERNANDES, DURING THE PRESENTATION OF THE ANDA SOLUTION

During the first week of deployment, stands were placed at the main metro and train stations and promoters were presenting the mobile application to customers, helping them to download and register, and travelling with them to show how the system work (see Figure 30).

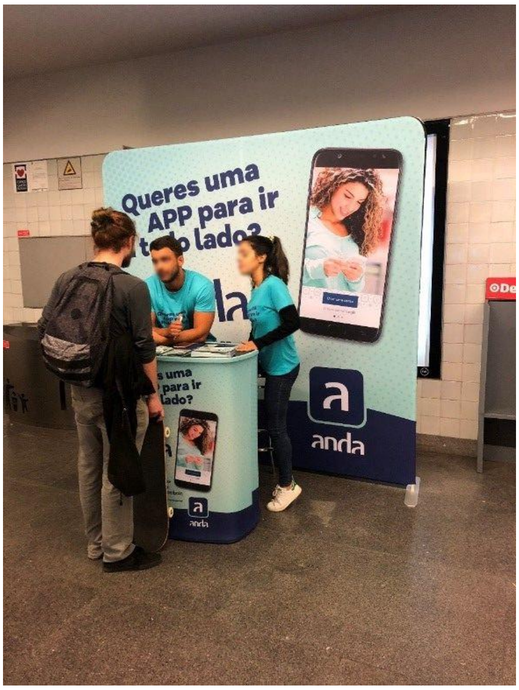


FIGURE 31. ANDA'S CUSTOMER SUPPORT STAND

3.3 DMTS Methodology Contributions

The DMTS methodology enables the design of mobile ticketing services, covering the entire design process: conceptualization, design, development, evaluation and deployment. It combines different perspectives and approaches, from participatory design, user-centric design, interaction design, service design, value-co-creation and software engineering. The integration of various areas of knowledge allows to leverage the best of each and fill the remaining gaps.

Service design principles are used to address complex stakeholder relationships. However, the DMTS methodology tackles this issue by addressing more effectively the design of ticketing services in complex ecosystem environment. It follows a user-centred design approach, using participatory design techniques to actively involve all stakeholders in the value co-creation process. Interaction design is used in the DMTS methodology for creative exploration. Compared to service design it is less structured, more emphatic and has a tradition of pushing new technological systems into the world. Finally, more structured models from software engineering are used in the DMTS methodology to fill the gap in specification and development of the mobile ticketing solution that other perspectives are not capable of.

It is a customer focused methodology, in which the customer actively participates throughout the design process, since early stages. However, what distinguishes this methodology from others is the ability to actively involve all the stakeholders of the complex mobile payment ecosystem. All stakeholders interact with each other and add value during the service design process. Several methods can be used to foster this participation and co-creation of value, which have been presented throughout this chapter.

One of the innovative ways of interaction developed and tested during the projects was the use of social networks. It takes advantage of the ubiquity, convenience and widespread use of social networks to form a community of sharing, common interests, and value creation. It is clear that there are a set of rules that must be followed to get the most out of this technique, in particular to encourage the discussion and contributions of the participants.

In addition to the involvement of the obvious stakeholders of the mobile payments ecosystem, such as transport operators, technology companies, banks, MNOs and customers, the university and researchers play a key role in the design of mobile ticketing service solutions. This role was even singled out as one of the success factors of the Anda application by the UITP experts group (UITP 2018). In fact, researchers contribute with knowledge, experience and know-how and make sure that a methodology is followed, avoiding important phases of the process to be overcome. It is known that companies have a very short time-to-market, wanting to deploy the solution in the market as soon as possible. Universities restrain this hurry a little bit and ensure that the necessary tests are carried out before the solution is released. Researchers also play a facilitator role by bringing together different perspectives into a new service solution. They represent an agnostic entity with no commercial interests allowing to establish a consensus among stakeholders.

Finally, the DMTS methodology is presented as a methodology for the design and development of mobile ticketing services, but it is a sufficiently comprehensive and abstract methodology that can be implemented in the design of other technology-based services. This elasticity was demonstrated, for example in the MobiPag project, where value added services such as coupons, simple payments and peer-to-peer transactions were designed and developed.

3.4 Chapter Summary

This chapter presents the DMTS methodology. It starts by describing the theoretical concepts and components on which the DMTS methodology is based: value-co-creation, participatory design, user-centric design, interaction design, service design, and software engineering. The DMTS methodology combines contributions from the different perspectives, leveraging the best of each and filling the remaining gaps. Service design principles are used to address complex stakeholder relationships, overcoming the inability of interaction design approaches to take on this challenge. However, despite its superiority to interaction design in this subject it still relies on a rather simplistic framing of customer and service provider. Therefore, the DMTS methodology tackles this issue by addressing more effectively the design of ticketing services in complex ecosystem environment. It follows a user-centred design approach, using participatory design techniques to actively involve all stakeholders in the value co-creation process.

Interaction design is used in the DMTS methodology for creative exploration. Compared to service design it is less structured, more emphatic and has a tradition of pushing new technological systems into the world. Mobile ticketing is about disruptive solutions and cannot rely on the adoption of well-know and well-understood technologies, as does service design. Finally, more structured models from software engineering are used in the DMTS methodology to fill the gap in specification and development of the mobile ticketing solution that other perspectives are not capable of.

The DMTS methodology consists of 4 main phases: 1) conceptualization, 2) exploration, 3) convergence and 4) launch. These are composed by 9 stages: 1) Identifying the problem and defining the objectives; 2) Mapping the stakeholders ecosystem; 3) Identifying the needs and establishing the requirements; 4) Co-designing the service; 5) Evaluating the artifacts; 6) Redesigning and developing the service solution; 7) Evaluating the service solution in a real environment; 8) Preparation; and 9) Deployment.

The DMTS methodology fosters the development of inter-organizational relationships, which is key for the success of a mobile ticketing solution. It was applied, and refined, during the design of four mobile ticketing service solutions, that are detailed in the next section. The last one, Anda, was launched in the market in June 2018 and is being used by thousands of people every day, validating the proposed methodology.

4. Application of the DMTS Methodology to Design Four Mobile Ticketing Services

The DMTS methodology was conceptualized, developed and improved as part of four mobile payments and ticketing service design research projects. These projects have already been introduced throughout the thesis and are described in more detail in this chapter. They provided rich settings for the DMTS methodology development and validation, as they involved several stakeholders, including researchers, since the initial identification of needs to functional prototyping, and deployment in the case of Anda, of new mobile ticketing services.

The first project – MobiPag – was a National Initiative for Mobile Payments, developed over two and a half years (December 2010 – April 2013), whose main goals were to promote the dematerialization of money and leverage new features and uses of personal mobile devices. It has been a very comprehensive project, encompassing mobile payments in general, and resulted from the effort of a consortium of several companies and universities and the involvement of the main national banking institutions and mobile network operators. The final solution comprised a universal mobile payments and services platform that was demonstrated through the development and test of two mobile payment applications (customer and merchant) based on NFC.

Within this project another project, called MobiPag STCP, was carried out during 6-month (December 2012 – June 2013). Its main objective was to apply the acquired knowledge on mobile payments to the public transport sector. This project has the peculiarity of having been executed at a time when the country was experiencing a severe financial crisis, being one of the impositions of the transport operators to not make any investment in new equipment or infrastructures. The challenge consisted on designing a mobile ticketing solution only based on customers' mobile devices, with no interaction with transport operators' infrastructures.

These two projects were followed by another one, called Seamless Mobility, developed over 18-months (January 2014 – June 2015). The main objective was to add complementary services to the payment in the public transport field. It was designed, developed and tested a mobile service solution, based on QR Codes, that allows not only to purchase travel tickets, but also to access transport information in real time, leveraged by the concept of social network.

The evolution and maturity of technologies and the increasing openness of customers and transport operators to mobile payments led to the development of another project, called Anda. It was developed over 22 months (September 2016 – June 2018), and the objective was to design a mobile ticketing solution to be launched in the market. The final solution is based on NFC and BLE technologies and was deployed in all transport network of the MAP in June 2018.

Since three of the four projects were carried out taking into account the reality of the MAP, the public transport network of MAP is described below. The application of the DMTS methodology to each of the four projects is described in sections 4.2, 4.3, 4.4 and 4.5.

Public Transport Network of the Metropolitan Area of Porto (MAP)

The public transport network of the Metropolitan Area of Porto covers an area of 1,575 km2 and serves 1.75 million of inhabitants. The network is composed of 11 operators: 150 bus lines (72 public and 78 private) and more than 550 bus stops, 81 metro stations and 19 train stations. A total of 137.79 million journeys were recorded in the year of 2016, resulting in a 90 million euros revenue (Transportes Intermodais do Porto 2016). The electronic ticketing system is an open (ungated) system, composed by ticket readers (1.846 in 2016) along the platforms at each metro/train station and at each bus vehicle, and handheld devices for inspectors. The fare media are contactless travel cards, called Andante, which are accepted by all 11 operators. Transportes Intermodais do Porto (TIP) is the entity responsible for managing the ticketing system, collecting the fares and distributing by the transport operators. The revenue distribution is based on what the passengers travelled on each operator.

Andante is an entry-only Automated Fare Collection (AFC) system and the fares are defined by a zonal structure. The network is divided into 46 geographic travel zones (see Figure 32) and the journey fare depends on the number of zones travelled between its origin and destination. Complexity is built in this system by lack of familiarity with zones' borders locations and lack of understanding on how the zone crossing system works. For example, according to Figure 32, passengers are lead to believe that if they want to go from some point in zone C6 to zone N10, they need a Z3 travel ticket in whatever situation. However, if a passenger chooses to use metro from C6 to N10, the required travel ticket is Z4 because it is necessary to first travel to C1 in order to change lines before going to N10, and from C1 to N10 the number of zones is larger.

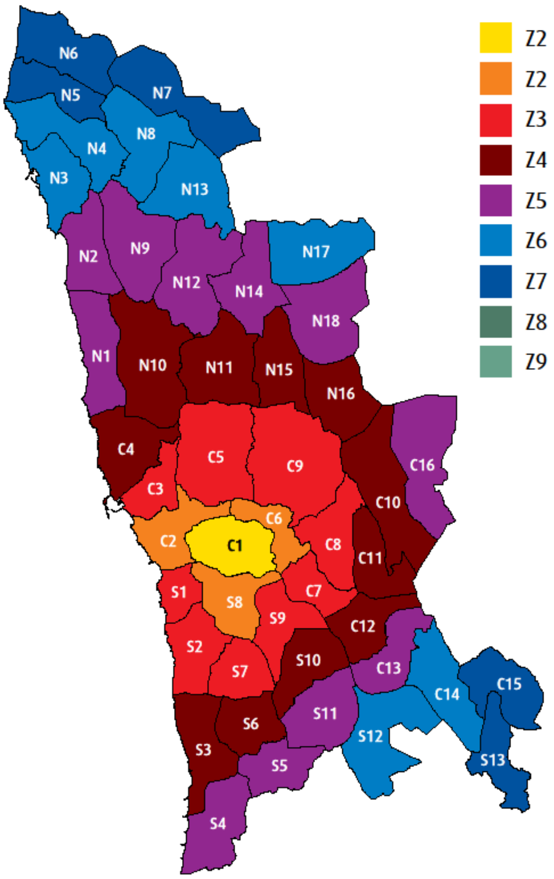


FIGURE 32. MAP TRAVEL ZONES AND CORRESPONDING TRAVEL TICKETS FOR A JOURNEY STARTING IN C1

There are two types of Andante travel cards: occasional and monthly subscription. Passengers charge the occasional tickets with the numbers of zones they want to cross during a certain journey. In the case of monthly subscriptions they are valid for a set of adjacent zones previously chosen by the passenger. Andante is a time-based system, allowing pay-per-use passengers to make unlimited transfers in a given time period, which increases according to the number of zones that are included in the respective fare. To start a journey, passengers tap the travel card on a reader. This validation must happen at the beginning of the journey and whenever changing vehicles during the journey.

4.1 MobiPag: Integrated Mobile Payment, Ticketing and Couponing Solution Based on NFC

The MobiPag project was a National Initiative for Mobile Payments, whose main goals were to promote the dematerialization of money and leverage new features and uses of personal mobile devices. The solution comes from the effort of a consortium of companies (CardMobili, PT Inovação, Multicert, Creative Systems, and Wintouch) and universities (FEUP, Instituto Superior Técnico and Universidade do Minho) with the coordination of CEDT. The advisory board composed of the main national banking institutions (Gaixa Geral de Depósitos, Millenium BCP, BES and BPI), mobile operators (TMN, Vodafone and Optimus) and other financial institutions (SIBS, Visa, Mastercard and CTT), supported the initiative and contributed with their know-how and expertise. It consisted on designing, developing and testing an integrated mobile service solution (payment, ticketing and couponing) based on NFC.

The most distinctive characteristic of Mobipag is its open architectural model that allows multiple partners to become part of the payment value-chain and create integrated solutions that complement payments in many new and unexpected ways. This openness is an important step towards payment solutions that support flexible business models. In particular, it does not impose any particular collaboration pattern to many different stakeholders that are normally involved in payment solutions, allowing them to adjust their role according to the specificities of particular markets. It also enables many value-added services to be created by combing services from third-party providers into the payment process. An Application Programming Interface (API) enables this integration and also leads to the possibility of creating many different applications that provide very diverse views of payment transactions.

The Mobipag solution was tested in a controlled real-world environment at the University of Minho Campus, for a period of one month. The prototype was carefully designed to be a compromise between the simplification needed to run a technology that was still being prototyped at the moment and the need to create an evaluation environment that was realistic enough to provide a valuable assessment of the respective user experience. The evaluation was focused on the technical feasibility of the system, including the connection to quality accounts at the participating bank, and also on the identification of multiple adoption barriers associated with realistic user experience of mobile payments. To support usage studies six mobile payments scenarios were designed, corresponding to common day-to-day transactions. These scenarios considered transactions with a broad range of properties, including simple payments, tickets and discount coupons.

Next subsection details the MobiPag architecture, followed by the description of the uses cases in sub-section 4.1.2. Sub-section 4.1.3 presents the prototype that was developed and sub-section 4.1.4 detail the evaluation procedure. Sub-section 4.1.5 presents a critical analysis of the application of the DMTS methodology to the design of the MobiPag solution. Finally, sub-section 4.1.6 discusses the MobiPag results and conclusions.

4.1.1 MobiPag Mobile Payments and Services Platform Architecture

The MobiPag platform aims at dematerialising payments with the use of personal mobile devices as an automatic payment terminal that will be interoperable between different financial and national mobile communications agents and able to be universally adopted by users, merchants, shopkeepers and service providers. In addition to payments, it also integrates all the needed logic for merchants and service providers to define their loyalty strategies, including the offer, sale, emission and validation of vouchers, tickets and other value-added services associated with the payment operations.

The system architecture comprises six entities as depicted in Figure 33. The customer's mobile device is a phone, a tablet, or any other mobile device running the Android operating system, which is capable of communicating via NFC with other devices and contains a Secure Element, either a secure microSD Card (micro Secure Digital card) or a UICC (Universal Integrated Circuit Card) device, which is able to run java applets in a secure and safe way (Rodrigues et al. 2014).

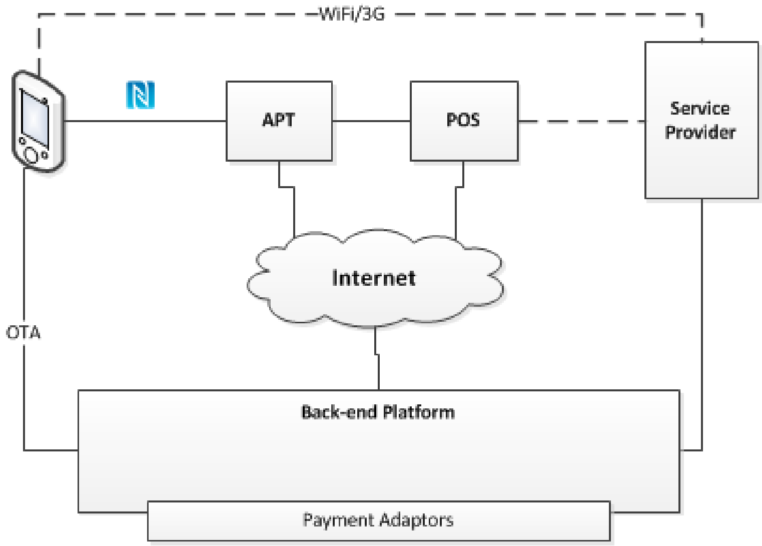


FIGURE 33. GENERAL VIEW OF THE MOBIPAG ARCHITECTURE

On the merchant's side, the payment infrastructure is usually comprised of an Automated Payment Terminal (APT) and a Point of Sale (POS) application. The POS application may be integrated in the APT but its function is well differentiated. The POS interacts with the customer through the APT and with the merchant Service Provider to agree on the payment amount due in each transaction.

The merchant's APT may be a specific device built for that purpose, similar to current APTs, but with NFC capabilities, or another mobile device, similar to the one carried by the customer, in which case the transactions between customer and merchant can be framed as person-to-person payments. Similarly, the POS may also be a common merchant's POS or specific POS software running on the merchant's mobile device. This solution targets payments to small merchants, where the actual business logic of the merchant (e.g. stock, price list, etc.) can be inside its mobile device.

Financial institutions own financial account services, which are outside of MobiPag scope but interconnected with the system. Financial institutions manage the accounts for both merchants and customers, which are identified by virtual cards (vCards), i.e. each customer or merchant possesses one or several of these vCards representing accounts on financial institutions.

Each merchant or group of merchants may deploy additional service providers containing the business logic for other value-added services such as ticketing or loyalty management, making the architecture fully extensible.

At the heart of the MobiPag payment system is the MobiPag payment backend platform. The backend platform acts as a broker interlinking every service and merchant device, providing facilities to manage all aspects of the associated business model and ensuring compliance with regulation requirements. It contains several payment adapters that connect with each financial account service. Both the merchant's POS and APT can contact the backend platform to make a payment and redeem loyalty and/or service tokens (vouchers, tickets, discounts, etc.) provided by the associated external service providers. MobiPag is able to handle several different types of tokens within an opaque construction dubbed vToken.

All payment and redemption supported scenarios rely on the MobiPag NFC protocol. This generic messaging protocol between the customer and the merchant may be described in three steps, separated by two tapping moments, in which both peers explicitly communicate with each other. According to this protocol the payment process is done in two taps and the validation processes are completed in a single tap. Further information regarding the MobiPag NFC protocol and payment terminal's architecture may be reviewed in (Rodrigues et al. 2014).

4.1.2 MobiPag Main Use Cases

In stage 4 of the DMTS methodology – co-designing the service – six mobile payment scenarios corresponding to common day-to-day transactions were designed: a) basic payment; b) buying a bus ticket, c) buying a meal ticket and receiving a coupon; d) bus ticket validation; e) meal ticket validation and f) redeeming a coupon. These scenarios were designed to include distinct transaction properties, including simple payments, tickets and discount coupons. The respective transaction of use cases d) and e) only involves one protocol tap. Next, the interactions performed on each of the six payment scenarios (see Figure 34) are described.

a) Basic payment

At the bar (Figure 34 a), the merchant registers the requested goods into the merchant's application. The user approaches the merchant's payment terminal with his/her mobile phone. He/she receives the payment amount in the mobile phone, confirms and enters the security PIN (if applicable). He/she approaches the payment terminal with his/her mobile phone again and receives a payment confirmation message. The transaction is then completed.

b) Buy bus ticket

At the bus ticket counter (Figure 34 b), users may purchase bus tickets. The transactions are the same, but this time, an electronic ticket is received in the second tap and stored in the mobile phone for subsequent validation in the bus.

c) Buy meal ticket and receiving a coupon

At the meal ticket counter (Figure 34 c), the merchant registers the number of tickets into his terminal. The transactions are equal to those described in the previous scenarios. The user receives the meal tickets on his/her mobile phone. In this particular situation, the user also receives a discount coupon.

FIGURE 34. THE SIX PAYMENT SITUATIONS IN THE MOBIPAG PILOT: A) BASIC PAYMENT; B) BUYING A BUS TICKET; C) BUYING A MEAL TICKET AND RECEIVING A COUPON; D) BUS TICKET VALIDATION; E) MEAL TICKET VALIDATION; F) REDEEMING A COUPON

d) Validate bus ticket

On the bus (Figure 34 d), the user validates the bus tickets stored on the mobile phone. The merchant enters the number of tickets to validate into his terminal. The user selects the corresponding tickets on his/her mobile phone and approaches the driver's terminal with the mobile device. When the transaction is completed, the user receives a confirmation message.

e) Validate meal ticket

At the meal ticket validation counter (Figure 34 e), users pay for their meals with a meal ticket previously acquired and stored on their mobile phone. The merchant enters into his terminal the number of required meal tickets. The user selects the corresponding meal tickets on his/her mobile phone and approaches the terminal with the mobile device. The transaction is then processed as above.

f) Redeem coupon

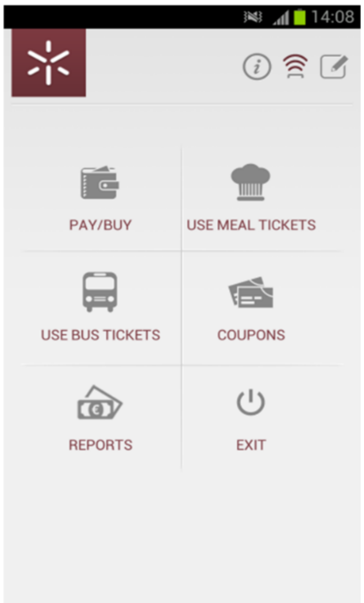
At the bar (Figure 34 f), the user selects in his/her application stored discount coupons before paying. The new total amount is then calculated, and the transaction proceeds as above.

4.1.3 MobiPag Prototype

The above mentioned payment situations were materialized in two mobile payment applications: User App and Merchant App, targeted at the community of the University of Minho Campus where it was evaluated. The prototype presented in this section corresponds to the final version, being the result of applying the stage 6 of the DMTS methodology – redesigning and developing the service solution. It allows customers to make payments at the University canteens, cafeterias and students' support office. Customers can also receive and redeem bus and meal tickets, and discount coupons.

The main menu interfaces of the User MobiPag UM and Merchant MobiPag UM applications are represented in Figure 35. The user app (Figure 35 a) allows customers to pay for goods and services selecting the Direct Payment menu. In this menu, they can choose a vCard and the coupons to redeem. It also allows customers to validate meal and bus tickets, by selecting the Meal Tickets and Bus Tickets menus, respectively. Moreover, customers may check the discount coupons that they have stored in their virtual wallet (the Check Coupons menu) and the transactions they have performed (the Reports menu).

The merchant app interface is represented in Figure 35 b). The option "Sell Products" is used in the University cafeterias. The merchant selects the goods he/she wants to sell (type and quantity), and the application calculates the total price. This option will accept money and discount coupons from customers' devices. Further discount coupons can be sent to customers during the second tap. With the "Meal Tickets" option, merchants can sell and validate meal tickets. They just have to specify which tickets they are going to sell/validate and the respective quantity. A similar service is performed with the Bus Tickets menu. The Reports menu shows the performed transactions. A video was produced to illustrate the use of the two mobile applications during the six payment scenarios and is available at https://tinyurl.com/ya2vmud7.



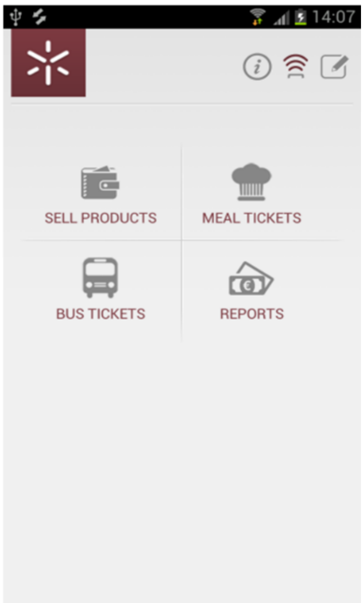


FIGURE 35. MOBIPAG MAIN MENU APPLICATION INTERFACES: A) CUSTOMER INTERFACE; B) MERCHANT INTERFACE

4.1.4 MobiPag Evaluation Procedure

The methodological approach regarding the evaluation of the Mobipag solution is summarized in Table 6. Technologies evaluation occur during stage 5 of the DMTS methodology – evaluating the artifacts. NFC was a relatively recent technology at the time of the MobiPag project, little was known about it and the availability of NFC-enabled smartphones in the market was scarce. Compatible mobile phones were then acquired for the project to carry out performance and reading tests. These devices were also used to conduct tests with participants during the pilots. Another challenge was related to the choice of the secure element, having fallen on the SIM card. This was not a straightforward process since the Android system has limited or no access to the SIM card, so it was necessary to analyse how the SIM card could be used as a secure element and make developments for it to work.

The evaluation of the MobiPag final solution, was divided into two phases. The first phase (laboratory pilot) corresponds to stage 5 of the DMTS methodology – evaluating the artifacts. It occurred in March 2013, involved 9 participants and consisted on asking them to perform a set of tasks with the mobile application in a laboratory environment. The main goal of this phase was to test the usability of the application interface and to identify any related problems, particularly with the sequence of taps from the protocol (Ferreira and Cunha 2014). After the results of the first test, the application was improved, according to the stage 6 of the DMTS methodology – redesigning and developing the service solution –, and the second evaluation phase was initiated, corresponding to the stage 7 of the DMTS methodology – evaluating the service solution in a real environment. This second phase (experimental pilot) occurred in April 2013 and involved 17 customers and 8 merchants. During the experiment, users and merchants were asked to execute all of the payment situations in real-world context.

The selection of the participants was based on a pre-pilot survey (using the Google Docs platform) open to the University of Minho academic community (see Appendix C.1). The main purpose of the pre-pilot survey was to present the MobiPag project, to assess respondents' perception about mobile payments and to recruit volunteers to participate in the pilot. A total of 317 responses were collected, from which 112 expressed interest in participating in the pilot. A diverse sample of participants in terms of gender, age and occupation (students, professors and non-teaching employees) was recruited, consisting of 9 people for the laboratory pilot and 17 for the experimental pilot. For the experimental pilot, 8 merchants were also recruited for the different payment scenarios: student support office, cafeteria, canteen and bus.

In this experimental pilot, the users' and merchants' devices were all Android Samsung Galaxy SIII smart phones with NFC. The objective was to simulate in real environment the six payment scenarios presented in Figure 34. All prices, products and services were real, but the users did not pay for them with their own money. A major bank acted as the financial clearing institution, supplying quality accounts for the merchants and customers.

The user app and the merchant app were installed on Samsung smartphones and provided to the participants. For both types of users, the testing was comprised of 4 moments:

1. Pilot initial training: including a brief explanation of the MobiPag project, of the experiment itself and of the payment and coupon semantics.
2. Survey for sample characterization of customers (see Appendix C.2) and of merchants (see Appendix C.3);
3. User test and observations (see Appendix C.4). The main goals were to directly analyse how the users interacted with the mobile payments system, to understand which payment or validation tasks were more intuitive to execute with the mobile phone, to encounter the main participants' difficulties, and to find out if there were substantial differences between participants.

4. Interview (see Appendix C.5). The objective was to understand the overall customer perception regarding the use of the mobile payment application, the things customers most liked or perceived as confusing or difficult and suggestions to improve the application. All involved merchants were also interviewed. In this situation, the main goal was to understand if merchants perceived the new technology as an added value to the payment process.

From the observations and analysis of the user tests and interviews, five relevant topics emerged allowing to identify a set of design lessons: a) usability in the payment system, b) perceived value, c) embodiment of payment system, d) guidelines for the design of NFC infrastructure, e) being in control, and f) security perception. These are explained in detail in Appendix A - Discussion of MobiPag qualitative results. Further details regarding the experiments can also be reviewed in (Ferreira, Cunha, et al. 2014), (José et al. 2013) and (Rodrigues et al. 2014).

TABLE 6. METHODOLOGICAL APPROACH OF EACH EVALUATION PHASE OF THE MOBIPAG SOLUTION

Evaluated Component	Evaluation Approach	Sample	Procedure
NFC technology and SIM card	Laboratory Tests	Researchers and development team	- Measure the reading process of the NFC technology in the following metrics: detection time, distance range and battery consumption. - Explore and develop access to the SIM card, through the UICC, to be used as the secure element.
Mobile payment solution	Laboratory pilot	N=9 (3 female and 6 male) Age: 22 - 50 years	- Pilot initial training; - Answer to a questionnaire to characterize the sample. - Explore the functional prototype of the application based on a script with specific tasks, and rate the perceived difficulty in performing each task (Likert scale ranging from 1 to 5); - Answer to an interview with focused questions and open answers to extract participants' overall opinions and ideas regarding the application usability.
	Experimental pilot	N=17 customers (6 female and 11 male) and 8 merchants (8 male) Age: 22 - 50 years	- Pilot initial training; - Answer to a questionnaire to characterize the sample. - Explore the functional prototype of the application based on a script with specific tasks undertaken in real environment, and rate the perceived difficulty in performing each task (Likert scale ranging from 1 to 5); - Answer to an interview with focused questions and open answers to extract participants' overall opinions and ideas regarding the application usability.

4.1.5 Analysis of the Application of the DMTS Methodology to the MobiPag Project

From a methodological point-of-view, the MobiPag project was very well succeeded in involving all stakeholders of the mobile payments ecosystem (technology companies, banks, MNOs and universities). The actors of the companies and universities consortium were very well identified, as well as their individual role and contribution to the project. The communication between all flowed very well and regular meetings were held to discuss ideas, work and make decisions.

Meetings and workshops with members of the Advisory Board were also carried out to present the ongoing work, collect their opinions and encourage their participation in the project. In fact, Caixa Geral de Depósitos bank actively contributed to the experiments by creating quality bank accounts to test the monetary transactions between merchants and customers. All MNOs

(Vodafone, Optimus and TMN) also actively contributed by providing SIM cards that served as secure element of all transactions and information that was being kept.

Potential customers had a less active role during the design process. The first interaction with customers was through an online questionnaire, whose main objective was to collect their opinion about mobile payments and recruit volunteers to test the solution. Then, customers were only asked to contribute when the final solution was already designed and ready to test. This has been improved in the following projects, where customers were involved during early design stages by applying more inclusive participatory design techniques.

Regarding the application of stage 4 of the DMTS methodology – co-designing the service – several reports and presentations were produced, and all decisions and requirements have been documented in great detail. A team of designers was hired to design the UI of the mobile applications and several prototypes were produced until the final solution was developed.

Taking into account the high complexity and the ambitious objectives of the project, the experiments fell short of expectations, regarding the application of stage 7 – evaluating the service solution in a real environment. The initial idea was to have about 100 people testing the mobile payment solution with their own mobile phones in the University of Minho Campus. However, due to mainly technological constraints (only the Samsung Galaxy SIII – new and very expensive equipment at the time – supported the solution developed), the experimental pilot had to be reduced to 26 customers and 8 merchants. The selected users tested the mobile payment solution, in a controlled environment and with the smartphones bought for that purpose. Users were accompanied by a team of researchers that asked them to perform a set of tasks with the mobile phone and were taking notes. After the experiments, interviews were conducted to collect additional information. This was key to realize the importance of choosing a more inclusive technology that would allow more people to participate in the experiments, and the following projects took this into account. One of the positive aspects was that merchants also participated in the pilot, being possible to analyse both demand and supply points-of-view.

4.1.6 Discussion on the MobiPag Results and Conclusions

Concerning the technical validation, it was possible to demonstrate how the various components that compose the MobiPag open architecture can be instantiated into a specific and complete solution for mobile payments based on NFC technology. In addition to the inevitable integration issues, the major technical challenge was the lack of reliability of NFC. This technology was not yet stable and mature enough at that time (2013), leading to occasional communication failures. Even though most of the transactions have been successfully completed, those occasional ones in which an error occurred were highly frustrating for users and had a very negative influence on the overall perception of the system.

Regarding the user experience, the results demonstrate the broad range of elements that may have a strong influence on the overall experience and, consequently, on the value proposition of mobile payments. In this research, participants undergo a set of realistic payment situations to assess this type of element, and a number of critical design elements were identified.

In general, the six use cases payment scenarios were successfully supported in the field trial. However, the scenario of validating a meal ticket has revealed to be by far the most problematic. On average, all of the procedures involved in a transaction of this type were completed in 30 s.

From the merchants' perspective, this was not efficient enough, as the current approach of delivering a paper ticket takes, on average, only 3 s. Moreover, the social pressure by the people standing behind in the queue was paramount. The simple prospect that something could go wrong at the moment of paying was reported by multiple users as being the only really stressful moment of the trial.

The results in relation to the perceived value of mobile payments have confirmed the importance of doing more than just enabling payment transactions through technology. The ability to integrate tickets and discount coupons directly into the payment process were highly appreciated and clearly seen as a differentiating element that could lead to people's adoption of these systems. However, it was possible to observe that this flexibility comes with a cost in the complexity of the procedures and cognitive overload for users in payment situations. The added flexibility leading to a myriad of added services integrated with payments is simultaneously one of the strongest points and one of the biggest challenges in interaction design. What could be a simple payment procedure may become very complex for users when multiple types of coupons, discounts and loyalty schemes become part of the payment process.

Like other digital artifacts, mobile payment services should not be designed on the assumption that the frame of reference from previous payment systems can be applied directly to a new technological approach. One should acknowledge their disruptive effect on many of the practices and respective safeguards people normally resort to when making payments with currently existing methods. For example, from a technology perspective, credit cards are known to have multiple risks, but their use is based on a trust model that has evolved over the years to deal with the perception of risk by users and the management of risk by issuers. These practices have evolved and matured over the years and are now something that people trust and understand. As a new service, mobile payments need to face the lack of knowledge about the service itself, the lack of practices surrounding technology-based payments and the lack of well-known reference scenarios that provide confidence and trust.

Another finding from this work is how important real-world usage of the service can be in overcoming this practice vacuum and many of the potential adoption barriers. This was particularly evident in regard to security perception, during the trial. While security is clearly the number one concern in any acceptance survey on mobile payments, in this deployment, this concern was strongly mitigated by the sense that the system was actually working. Being asked for a PIN in some transactions and receiving proper feedback seems to have been enough to generate a general sense of trust in the system. Thus, other payment systems should thus focus on how to achieve a positive initial user experience and how to leverage upon real-world contact with the technology to create a solid path for gradual acceptance through the development of new practices and the perception of value.

The last general observation is the very positive attitude that participants, both customers and merchants, have shown in regard to the use of the service. While it is not possible to extrapolate this into acceptance of the technology in real-world daily usage, it was proved that people are open to the new possibilities offered by mobile payments and are willing to experiment with how they can use them in realistic payment situations. The initial enthusiasm that people can demonstrate in regard to the service means that managing expectations is crucial. First impressions should be strongly focused on quickly creating a sense of confidence, familiarity and added value with the service that provides the foundation for sustained use and subsequent exploration of more advanced features. Designing for emerging practices and not letting people down can mean focusing at the beginning on simple procedures that, albeit limited in regards to the range of technological possibilities, are much safer and less likely to disappoint and drive users away.

4.2 MobiPag STCP: Mobile Ticketing Solution based on Wireless Technologies

The MobiPag STCP was developed under the MobiPag project and resulted from a partnership between FEUP, STCP and OPT. The objective was to apply the knowledge about mobile payments, acquired during the MobiPag project, to the public transport field. When FEUP challenged the public bus operator STCP, they were very receptive to the idea. However, they set a restriction: not investing in new equipment or infrastructures. The challenge was to design a mobile ticketing service based on passengers' mobile devices that does not require interaction with the transport operators' infrastructure.

The final solution consisted of an account-based mobile ticketing service that allowed to purchase and validate travel tickets OTA, using wireless technologies (3G/4G and Wi-Fi), as well as to access to the tickets balance, travel history and account movements. All customers' information – tickets, validations, account – is stored in the back office system, conferring additional independence from the device that is being used to travel.

The solution was tested by 26 real passengers of the public transport bus operator of the city of Porto during 2 weeks. They interacted daily with the researchers and development team through a closed group on Facebook and email. This evaluation technique was extremely successful as it allowed participants to share, in real time, their opinions, worries and suggestions for improvements. Individual in-depth interviews were conducted after the tests in order to explore additional questions regarding the user experience, such as travelling behaviours, perception of security and potential business models.

The next subsection details the MobiPag STCP architecture, followed by the description of the uses cases in sub-section 4.2.2. Sub-section 4.2.3 presents the prototype that was developed and sub-section 4.2.4 detail the evaluation procedure. Sub-section 4.2.5 presents a critical analysis of the application of the DMTS methodology to the design of the MobiPag STCP solution. Finally, sub-section 4.2.6 discusses the MobiPag STCP results and conclusions.

4.2.1 MobiPag STCP Architecture

Advances in communication technologies allow for the introduction of account-based ticketing systems. Most traditional transport ticketing systems are "card centric" or cash based systems. This means that the travelling information and the right to travel on public transport is stored on the ticket and only secondarily in the readers and then in the centralized back office system. Therefore, the card reader and fare payment media make the decision to approve or deny the payment transaction, as well as, determining the fare (Smart Card Alliance 2011). Account-based ticketing systems use the back office to apply business rules, decide the fare, and complete the transaction. Hence, the back office maintains the logic of the system and decides whether the card is valid or not.

The proposed solution follows an account-based ticketing architecture. The user interacts with the mobile application, which sends the information to the back office OTA. The back office determines whether the information is valid and returns an "approve or deny" signal to the passenger and the bus operator on whether to allow passage. The system architecture comprises three main components: user, inspector and server.

The user component allows the passengers to interact with the system. They may interact using a mobile device, such as a mobile phone or a tablet, running the Android operating system. The user component allows to purchase, store and validate travel tickets, as well as access the tickets balance and prices, movements of the account, validation history, and to get information about routes, stations and schedules.

The inspector component allows the inspectors (in some situations, the inspector can be the bus driver) to confirm if a passenger is travelling with a valid ticket for that particular journey. The user and inspector components are incorporated in the same mobile application, uploaded to the passengers' mobile device. So, the inspectors do not need to carry an additional device with them.

These two components, user and inspector, receive, remotely, from the server component the services they need. The latter is divided in three subcomponents (see Figure 36):

a) Webpage: functions as a control panel that allows the platform manager to administer all parts of the system and to access to the passengers' travelling information.
b) Web services: processes the utmost logic of the system, by intermediating the customer/inspector components and the central database.
c) Database: stores all the information of the system, whose business logic is done server-side.

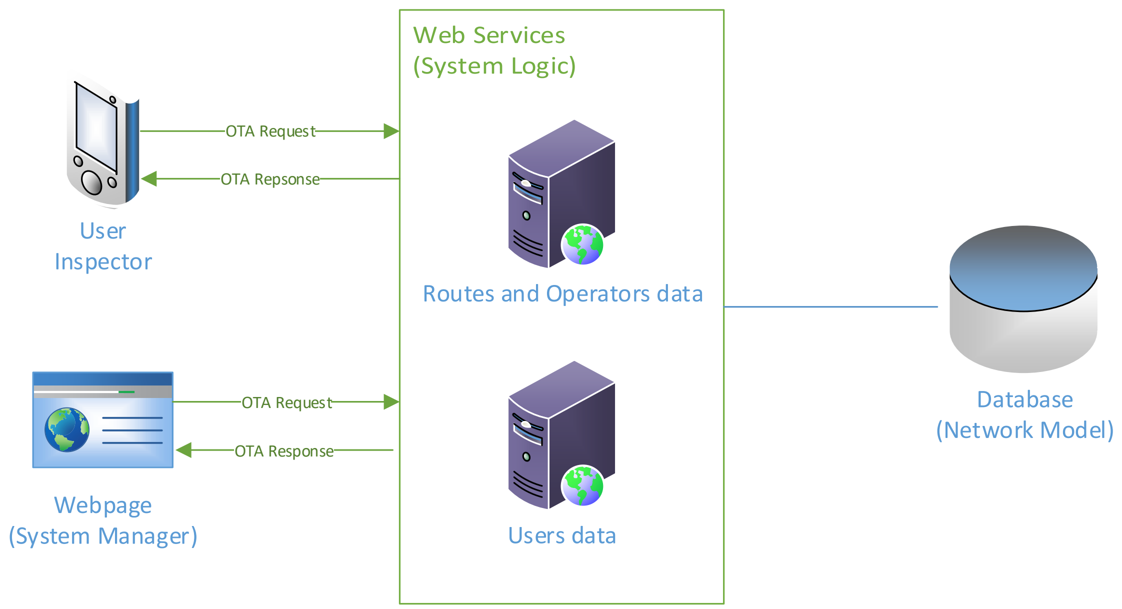


FIGURE 36. MOBIPAG STCP ARCHITECTURE

The application is based on a traditional client-server architecture, using a local database support, which only helps to accelerate some processes, since it is always necessary to inform the server of any changes that are made. The application and the webpage communicate with the server via an Internet connection using its own API through web services. Furthermore, the services related with the routes and operators such as information about lines, stops, operators, and near stops use the same web services as the mobile application MOVE-ME[16]. The other services, related with the user, such as registration, payment, validation, prices, account movements and user profile use an API developed exclusively for MobiPag STCP solution.

A mobile application, developed for Android devices, integrates the user and inspector components. The local database, used by the mobile application, uses SQLite technology since it runs in low memory environments. The next section describes the main use cases of the mobile application that were tested in real environment.

4.2.2 Mobipag STCP Main Use Cases

During stage 4 of the DMTS methodology – co-designing the service – four main use cases were designed: a) purchase ticket; b) validate ticket; c) inspect ticket; and d) check information.

a) Purchase ticket

The system allows the users to purchase travel tickets anywhere, anytime. The purchase process is made OTA, using 3G, 4G or Wi-Fi technologies. Before starting a journey the user must purchase the corresponding travel ticket. The system may store various types of tickets simultaneously, so the user can check the tickets he/she has available. The payment of the tickets is done through a pre-paid account for travelling purposes. The loading of the balance may be done in several ways, such as credit or debit card, Paypal and MB Phone.

b) Validate ticket

The validation of travel tickets is also made OTA. Since this system is suited for ungated ticketing systems, the user informs the system about the route he/she will make. Location providers (GPS and network triangulation) are used to identify user's location, helping the user to identify the boarding station. The mobile application also allows to select manually the boarding station, in case of the GPS is not working properly. The validation is made before the user enters the vehicle. Once the validation process is completed, the system creates a notification on the mobile phone about the journey that is taking place. Furthermore, this notification provides access to the inspection menu, if requested by the inspector.

c) Inspect ticket

The system allows inspectors to verify the validity of travel tickets. The user only needs to show the inspection menu generated on the mobile phone after validating a ticket. This menu has information about the journey that is taking place: boarding station and line, type of ticket, date and hour, sequential number and security symbol. This inspection process is mainly visual.

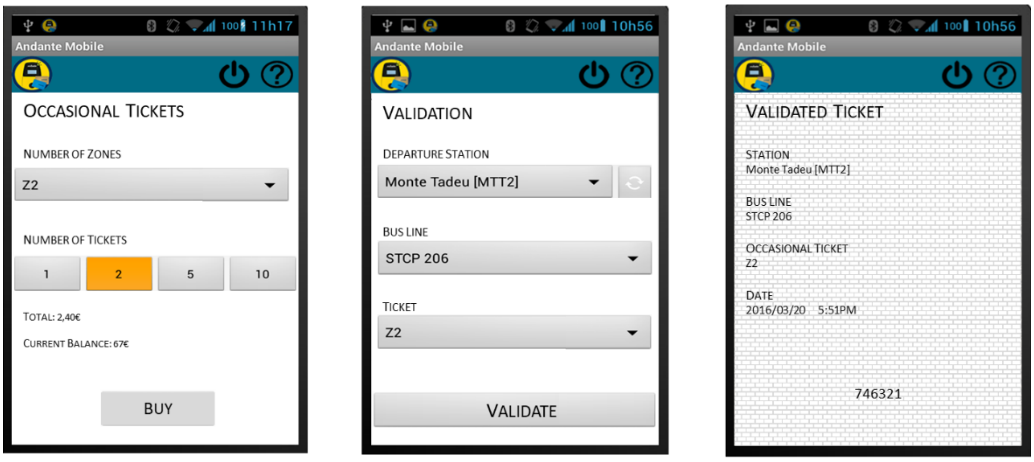
d) Check information

The system allows users to check tickets balance, balance and movements of the pre-paid account, check maps and prices, validation history, and search for nearby stations.

[16] MOVE-ME (http://www.move-me.mobi/) is a Portuguese mobile application that allows passengers to calculate public transport routes based on real-time information.

4.2.3 MobiPag STCP Prototype

The development of the mobile ticketing solution moved from low to high fidelity prototypes, as recommended in stage 4 of the DMTS methodology. Every stage of this iterative approach was discussed with transport operators, software companies and users. A functional version of the prototype was developed for Android devices and the main screens are shown in Figure 37.



a) b) c)

FIGURE 37. INTERFACES OF THE MOBIPAG STCP MOBILE APPLICATION: A) PURCHASE TICKET BY CHOOSING THE TYPE (NUMBER OF ZONES); B) VALIDATE TICKET; C) VALIDATED TICKET

The purchase and validation of travel tickets is made through wireless communication technologies and the validation process is simplified with the use of location providers. Regarding the purchase of travel tickets, the system shows the user the list of tickets he has stored in his wallet, before choosing which ticket he wants to purchase. The user has then two options: he/she chooses the type and number of tickets he/she wants to purchase (see Figure 37 a), or alternatively, he chooses the boarding and the alight station and the system automatically transforms this information into the corresponding type of ticket. This option represents a major improvement in the actual solution implemented in the city of Porto, since it is very confusing for passengers to know what type of ticket they need to buy. There are about 800 routes where the outward and back corresponds to different types of tickets. Another improvement of the proposed system is related to the fact that the system can store more than one type of ticket at the same time. Currently, the passengers must carry as many travel cards as the number of different zone tickets they want to have.

Regarding the ticket validation process, it was a major concern from transport operators to know exactly the bus stop and line where passengers are boarding in. So, location technologies, such as GPS and network triangulation, are used to locate passengers and identify the nearest stops. From those, the passenger selects the boarding stop and bus line, and the ticket he/she wants to redeem to perform that journey (see Figure 37 b). After validating the ticket, the passenger may travel in as many zones as the ticket gives access to, during a certain period of time (which increases as the number of zones included in the ticket increase). The passenger may check on the display the remaining time he/she has to travel, being also notified when the time to travel ends.

During the journey, the passenger may be approached by an inspector to ensure he/she is traveling with a valid ticket. In this case, the passenger shows the validated ticket screen on his/her mobile device (see Figure 37 c). This screen has information about the validation, such as boarding stop and line, date and hour of the validation and the type of ticket that was validated. To prevent fraud, this information is complemented with a security symbol and a sequence number. The security symbol (represented by the watermark image in Figure 37 c), changes every day, preventing passengers to create false ticket images. The inspector knows every day what symbol he/she expects to see on passengers' mobile phones. Additionally, each validation is assigned an incremental sequence number (represented by the number 746321 in Figure 37 c). This means, for instance, that during a certain day and journey the sequence number of the passengers inside the vehicle should be close to each other. If this does not happen, it acts as a warning signal for the inspector to check the validity of the ticket more carefully.

4.2.4 MobiPag STCP Evaluation Procedure

The solution was evaluated by experts and potential customers at two different design stages (stage 5 and stage 7 of the DMTS methodology), and are summarized in Table 7. Stage 5 corresponds to the evaluation by experts, through heuristic evaluation, and by potential customers, through usability testing, of a mockup of the mobile application. The application of stage 7 corresponds to the evaluation in a real environment by potential customers of a functional prototype running on Android devices.

During the early design stages of the project (stage 4 of the DMTS methodology), a mobile application mockup was developed using a web prototyping tool. As mentioned before the evaluation of the mockup, which occurred during stage 5, was done using two different but complementary methods. The first usability inspection method used was the heuristic evaluation. The heuristic evaluation was performed by three experts and was useful to identify usability issues, such as inconsistency of words, complexity of information, and lack of undo and feedback buttons in certain screens. These usability issues were solved in order to prepare the next evaluation phase.

The second evaluation method used was the usability testing. During this procedure the user interface design was evaluated by potential users who performed a list of tasks using the application mockup. The main objectives were to evaluate the user interaction with the mockup and how the information presented to the users was understood by them. A post-test questionnaire was administered to each user, to gather additional information regarding the usefulness of the solution and the acceptance of the idea of paying with the mobile phone. The sample involved 14 participants and the tests were performed in a test environment. Participants were sampled in the campus of the University of Porto. Each test took about thirty minutes to be completed. Data was gathered by videotaping the participants and recording their voice and the screen. Observers also took notes and recorded the execution time of each task. The test was divided into three parts:

1. Pre-test questionnaire to characterize the sample (see Appendix D.1).
2. User test (see Appendix D.2). Users had to perform a set of actions (tasks) on the mockup. Observers recorded the time each user took to complete tasks, as well as the type and number of errors. Each task was also rated by users according to the difficulty

they experienced in performing the task. It was used a five-point Likert scale (Matell and Jacoby 1972), where 1 was considered “Very Difficult” and 5 “Very Easy”. Participants were also encouraged to speak and think aloud during the test.

3. Post-test questionnaire (see Appendix D.3). These questioned users about their perception of the usefulness of the application and about the concept of paying with the mobile phone.

Further details regarding the mockup evaluation may be reviewed in (Ferreira, Nóvoa, and Dias 2013).

The analysis of the results of the mockup evaluation and an extensive discussion with all stakeholders prompted to the development of a functional prototype of the mobile application, triggering the start of stage 6 of the DMTS methodology. The prototype was developed for Android devices, representing a high fidelity version of the application. The functional prototype was tested in real environment, in the city of Porto, during two weeks, by real passengers (application of the stage 7). The main objectives were to understand the perception of participants about the concept of purchasing and validating travel tickets with the mobile phone, and to identify a holistic set of experience factors.

STCP announced the initiative through their website and with information inside their buses, in order to recruit volunteers to participate in the experiments. Of the customers who signed up for the initiative, 37 were selected, taking into account the greatest possible socio-demographic heterogeneity. From those, 26 participated in the tests (some gave up or did not meet the requirements listed hereinafter). In order to participate in the experiments, the participants had to meet some requirements, namely they must own a mobile phone with the Android operating system, make at least five validations per week in the public transport network, and have internet access through the mobile phone. The tests comprised three different phases:

1. Pre-test phase: The evaluation process was explained to the participants by email and in person. They had also to fill in a questionnaire for sample characterization purposes (see Appendix D.4).
2. Test phase: The participants tested the functional prototype, during two weeks, in real environment. Throughout the experiments, the participants could interact with the researchers and development team through a closed Facebook group, created for this purpose, and by email. This allowed real-time interaction between all and an exchange of very rich and detailed information.
3. Post-test phase: After the experiments, the participants were interviewed individually and in person, to gather further information regarding the tests (see Appendix D.5). Questions related to their travelling habits and needs, security perceptions and potential business models were also addressed in the interviews. Each interview was recorded and lasted about 50 minutes.

The content of the Facebook group and the transcription of the interviews were analysed with the Nvivo program following qualitative research tenets (Charmaz 2006; Strauss and Corbin 1998). Each comment on the Facebook group and each relevant excerpt from the transcribed interviews were analysed and assigned provisional conceptual codes. Considering the relationships between the codes, they were then aggregated into categories. These were continuously compared with ideas and concepts emerged from the literature review. The objective was to systematically improve and relate categories. At the end, the categories were integrated and refined. This qualitative study enabled a deep understanding of the customer experience with mobile services, with the identification of a rich set of customer experience factors. By aggregating and renaming the similar concepts, 32 initial categories were first identified. These were then aggregated into ten dimensions of experience factors, which are explained in detail in Appendix D.6. Further details regarding these experiments can be reviewed in (Ferreira, Dias, and Cunha 2014).

TABLE 7. METHODOLOGICAL APPROACH OF EACH EVALUATION PHASE OF THE MOBIPAG STCP SOLUTION

Evaluated Component	Evaluation Approach	Sample	Procedure
Mobile application UI	Analytical Evaluation	3 experts	- Examine the user interface design guided by a checklist of usability principles (heuristics) to assess if the user interface elements are in compliance with those principles.
	Usability testing in laboratory environment	N=14 (3 female and 11 male) Age: 17 - 60 years Public Transport: 9 are frequent users	- Answer to a questionnaire to characterize the sample. - Explore the functional prototype of the application based on a script with specific tasks, and rate the perceived difficulty in performing each task (Likert scale ranging from 1 to 5); - Answer to an interview with focused questions and open answers to extract participants' overall opinions and ideas regarding the application usability.
Mobile ticketing solution	Pilot Trial	N=26 (10 female and 16 male) Age: 21 - 68 years Public Transport: All frequent users	- Attend presentation and training session (optional); - Answer to a questionnaire to characterize the sample; - Test the mobile ticketing solution (front-end and back-end) while traveling in all lines of the STCP network; - Share opinions, report problems and suggest improvements through Facebook and email; - Individual interviews to explore further information regarding the tests.

4.2.5 Analysis of the Application of the DMTS Methodology to the MobiPag STCP project

The MobiPag STCP project was a small project, compared to the others, with few stakeholders directly involved. All stakeholders were very cooperative and communication between them flowed very well. Several meetings were held to define and design the mobile ticketing solution. Users were involved since the early stages of the design, when evaluating the mockup, by identifying errors, suggesting improvements and additional features.

The application of stage 7 – evaluating the service solution in a real environment – revealed to be a success. It was tested by real passengers, during their daily commute, and the interaction with them was almost in real time. Through the Facebook group they could express their opinions, worries and questions. The development team was able to reply to the problems reported by participants almost instantly. A new version of the mobile application was launched after a week of tests, taking into account the suggestions made by participants. This feedback encourage the participation of the users, making them to participate more and more, as they see that their opinion is taken into account.

Although small, it was a good test for the implementation of the DMTS methodology, allowing to fine tune the methodology for larger future projects. It also played an important role in raising the interest of transport operators in mobile ticketing solutions as the next step in the future of ticketing.

4.2.6 Discussion on the MobiPag STCP Results and Conclusions

An overall analysis of evaluation results allows to conclude that the value and usefulness of the proposed ticketing solution was consensual among all participants. The users enjoyed the concept of using mobile phones to buy and validate travel tickets and considered the application very intuitive and easy to use. One of the main advantages of mobile ticketing solutions stressed by the participants was the ability to purchase travel tickets ubiquitously. The ease and speed of the purchase process, the avoidance of long queues and not having to carry coins are decisive factors for users. Aesthetical pleasure, satisfaction and functionality may also explain why people prefer some mobile payment systems over other.

The mobile phone characteristics (screen, memory, sound) allow to provide additional and complementary functionality which is not possible through a contactless card. Participants appreciated the fact of having access to information related to their journey and their account. They suggested the inclusion of further services such as journey planner, interactive maps, and real time bus arrival information.

Complexity is often mentioned as a barrier to the adoption of mobile payments. Among the most complex issues, the ticket validation process was the one that received most criticism. This procedure was considered laborious and heavy when compared to the traditional system. Therefore, ticket validation process using mobile phones need to be simple and fast in order to be able to compete with physical cards. Reliability and availability of the technologies and mobile devices were also considered crucial to the delivery of a valuable mobile ticketing experience.

Mobile ticketing systems usually involve personal and sensitive information. During the tests, participants felt secure to pay with the mobile phone, comparing it with the security they feel when using mobile banking applications. Perceived risks of mobile payments mentioned by participants include risk of theft and errors in payment transactions. The inspection process may also raise some fraud and security concerns from the service providers' perspective. Further prevention mechanisms and automatic processes may help to prevent, or at least decrease, fraud.

Regarding the business model, when asked about how they would prefer to pay for the tickets, most of the participants answered they would prefer to have a pre-paid account for travelling purposes rather than having the bank account or mobile operator bill linked to the system. This field trial allowed corroborating the great potential of mobile ticketing systems over traditional ones. Designing and integrating additional and complementary services to the travelling experience are also crucial to a wider adoption of mobile ticketing services. Additionally, it is important to explore the potential to this privileged channel – mobile phone – of interaction between passengers and transport operators, with regard to the delivery of customized services to each customer.

4.3 Seamless Mobility: an Integrated Route Planner, Mobile Payment and Social Network Solution based on QR Codes

The Seamless Mobility project aimed to leverage personal mobile devices and ubiquitous communication networks for the dematerialisation of tickets and the offering of timely information to passengers, according to their travel patterns. The solution comes from the joint collaboration between FEUP and Octal, company of the Novabase group. Other stakeholders, such as Metro do Porto, STCP, Transdev, and TIP also collaborated in the project.

This project distinguishes from the others because it incorporates additional mobility related services in the mobile ticket solution. The final solution comprises three main components: (i) mobile payments, (ii) route planner, and (iii) social network. The payment component is based on the pay-as-you-go concept with check-in and check-out requiring the reading of the corresponding QR Code station. The route planner combines information from published schedules with real-time information to identify the nearest stops, the next departures, or the best route for a scheduled trip. The social network component allows real time sharing among travellers of public transport information, related to several aspects of the service (e.g. noise, cleanness, skilfulness of drivers).

To test the concept, a mobile application, called OneRide, was developed. This application was tested by potential users and experts in both laboratory and real environment. The testing procedures took place in the transport network of the Metropolitan Area of Porto, Portugal.

Next subsection details the Seamless Mobility architecture, followed by the description of the uses cases in sub-section 4.3.2. Sub-section 4.3.3 presents the prototype that was developed and sub-section 4.3.4 detail the evaluation procedure. Sub-section 4.3.5 presents a critical analysis of the application of the DMTS methodology to the design of the Seamless Mobility solution. Finally, sub-section 4.3.6 discusses the Seamless Mobility results and conclusions.

4.3.1 Seamless Mobility Architecture

The Seamless Mobility solution has a modular architecture, in order to facilitate the inclusion of new services or geographical areas (see Figure 38). It has three main components: broker manager, user manager and operator manager. The broker manager mediates the communication with all external entities: use of mobility services provided by operators, planning services, and social networking. The user manager deals with users and their accounts. It may communicate with external systems to manage users not directly registered on the platform. The operator manager is responsible for managing the delivery the operators' services. It may communicate with external systems for the use of the services allowed for each operator.

All components are supported by a centralized platform that combines information from several operators, to offer services related to both the transport network as well as timely route updates. This platform manages the transactions through pricing workflows, billing (customers' invoice emission) and clearing (distribution of the revenue for the service providers). It also allows the configuration of the system (service providers, products, tariffs) and customer management (customer service, customer complaints). The modular structure allows to adapt the system to other operational models. It also allows to adapt other specific parameters such as currency and payment methods.

The architecture of the centralized management platform is based on a cloud environment, in this specific case under the Microsoft Windows Azure technology. This allows to adequate its resources according to the level of use at each moment (scalability). This also means almost zero-investment from operators, since the platform is available through public cloud, according to a "software-as-a-service" model. The integration mechanisms with the systems of the transport operators is based on import and export data. The operator shall provide all the necessary data in order to make it possible to implement the business rules of the products that will be available on the platform.

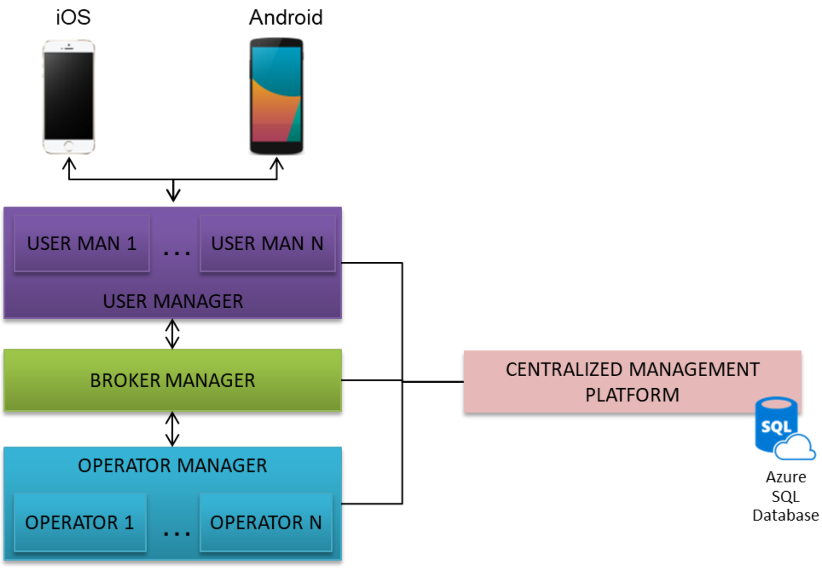


FIGURE 38. SEAMLESS MOBILITY SOLUTION ARCHITECTURE

4.3.2 Seamless Mobility Main Use Cases

During stage 4 of the DMTS methodology – co-designing the service – three main use cases were designed: a) plan a journey, b) pay the journey, and c) share information.

a) Plan a journey

The customer may plan a journey by identifying the nearest stops; the next departures based on real-time information if available; and available routes between an origin and destination, for a scheduled trip defined by the user.

b) Pay the journey

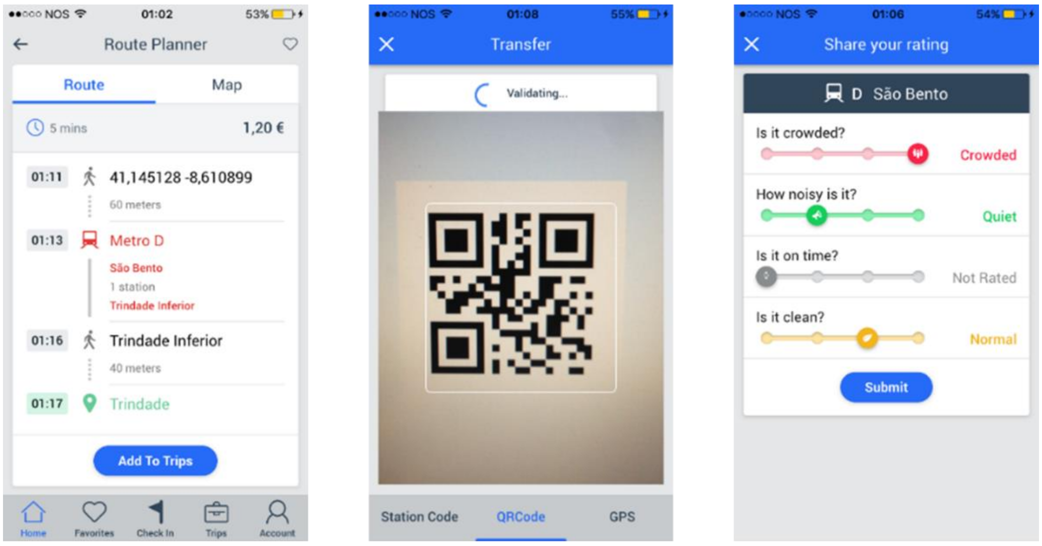
The proposed solution is based on the pay-as-you-go approach. The passenger only need to indicate the entry points in each means of transport of a given trip (check-in) and the completion of the same (check-out). The technologies chosen for the check-in/check-out process with the mobile phone were the QR Codes combined with location providers (GPS) and wireless communication technologies (3G, 4G or Wi-Fi)..

c) Share information

The solution enables collaborative exchanges of information between passengers. Such information may include information about a particular vehicle (crowding levels, temperature, and noise); incidents or other events that affect a specific service; or even about the skilfulness and courtesy of public transport drivers and other staff. Similarly, transport providers may have operational information that is difficult to distribute in real-time, and which only affects a set of passengers. Examples include service delays, incidents and changes of schedules or travel destinations.

4.3.3 Seamless Mobility Prototype

Following the application of the stage 4 of the DMTS methodology, the above mentioned use cases were materialized in a mobile payment application, called OneRide, which was developed both for Android and iOS devices during stage 6. The main menu interfaces are represented in Figure 39.



a) b) c)

FIGURE 39. INTERFACES OF THE ONERIDE MOBILE APPLICATION: A) PLANNING A JOURNEY; B) CHECKING IN; AND C) SHARING INFORMATION

Regarding the journey planner feature (see Figure 39 a), the Seamless Mobility solution combines information from several transport operators to offer services related to the transport network as well as timely route updates. The mobile application relies on this information to provide features such as identification of the nearest stops, the next departures based on real-time information if available, and available routes between an origin and destination, for a scheduled trip defined by the user. The current multi-modal journey planning system is based on real-time information for a 60-minute time window. When real-time data is not available or when the time window is greater than 60 minutes, journey planning is done based on published schedules.

The solution allows passengers to board more than one transport vehicle to complete their journey, without purchasing a ticket or having fare knowledge. The proposed mobile ticketing system is based on the pay-as-you-go approach. The passenger only need to indicate the entry points in each means of transport of a given trip (see checking in screen in Figure 39 b) and the completion of the same (check-out). In an even higher level of simplification and attractiveness, the Seamless Mobility solution supports regressive rates, where the cost decreases as the utilization rate increases, benefiting the most frequent passengers (it should be noted that this feature is only conceptual and has not been developed or implemented).

The technologies chosen for the check-in/check-out process with the mobile phone were the QR Codes combined with location providers (GPS) and wireless communication technologies (3G, 4G or Wi-Fi). These technologies are widely available, are easy to deploy and are cheaper than other technologies, such as NFC or BLEs (Couto et al. 2015). Also the combination of more than one technology allows for a double confirmation of the information that is being processed, avoiding fraud situations. Nevertheless, the Seamless Mobility solution may be implemented using any other technology.

The solution enables collaborative exchanges of information between passengers (see Figure 39 c). It leverages data generated by the mobile payments component. Analysis of these travel patterns allows for the dynamic creation of circumstantial social networks in real-time to aggregate passengers whose travel patterns are geographically and temporally relevant (Costa et al. 2016). Therefore, each user of the OneRide application may receive information personalised according to their unique travel profile in order to ease their journeys and improve travel experience (Nunes et al. 2016). Such information may include information about a particular vehicle (crowding levels, temperature, and noise); incidents or other events that affect a specific service; or even about the skilfulness and courtesy of public transport drivers and other staff.

Similarly, transport providers may have operational information that is difficult to distribute in real-time, and which only affects a set of passengers. Examples include service delays, incidents and changes of schedules or travel destinations. This social component includes validation mechanisms to encourage active participation from users and safeguard the reliability of information. It consists of a rating feature (e.g.: upvoting and downvoting) that gives passengers the possibility to evaluate information provided by others.

4.3.4 Seamless Mobility Evaluation Procedure

The OneRide application consists of different components and technologies that were first assessed independently before making an integrated evaluation. Thus, the evaluation was conducted in three distinct phases, summarized in Table 8. The first two phases corresponds to the application of the stage 5 of the DMTS methodology, and the third evaluation phase corresponds to the application of the stage 7. In the first phase the journey planner and social network components were evaluated through a field test and cognitive walkthroughs. The second phase consisted on the evaluation of the mobile payments component and the QR Codes technology performance, through laboratory tests and a field study. Finally, the third phase consisted on the evaluation of all the components integrated through a pilot trial. Following Nielsen and Budiu (2012) recommendation for qualitative user research – 5 participants – the number of participants of the field studies and pilot trial were 6 and 5, respectively. Regarding the analytical evaluation, it was carried out by 5. The evaluation procedures conducted in a real environment (field tests and pilot trial) took place in the transport network of the Metropolitan Area of Porto, Portugal. Further details regarding the evaluation of the solution may be found in (Ferreira, Fontes, et al. 2017)

4.3.5 Analysis of the Application of the DMTS Methodology to the Seamless Mobility Project

From a methodological point of view this was the least successful project, since it failed on applying the DMTS methodology correctly, and this was reflected in the results achieved. The project was very ambitious, with a solution that would integrate several means of transport, provide several mobility services and culminate in a single mobility bill, having fallen short of expectations.

TABLE 8. METHODOLOGICAL APPROACH OF EACH EVALUATION PHASE OF THE SEAMLESS MOBILITY SOLUTION

Phase -Evaluated Component	Evaluation Approach	Sample	Procedure
First Phase - Journey planner and social network	Field Study	N=6 (2 female and 4 male) Age: 18 - 25 years Public Transport: Frequent users	- Explore the functional prototype of the application based on a script with specific tasks, and rate the perceived difficulty in performing each task (Likert scale ranging from 1 to 5); - Answer to a questionnaire to characterize the sample and collect feedback.
	Analytical Evaluation	5 experts	- Freely explore the functional prototype of the application; - Observed by a moderator, in order to register the problems encountered, the suggestions and to discuss possible improvements.
Second Phase - Mobile payments and QR Codes technology	Laboratory Testing	Development team	- Measure the reading process of the QR Codes under different circumstances: i) Use of two QR codes to perform the tests, printed on white paper, one with 5.82 cm x 5.82 cm and another with twice the size. These dimensions were used to fit existing infrastructures, such as buses or stops; ii) Placement of QR codes under different lighting conditions (high (~ 80 lx), medium (~ 20 lx) and low (~ 5 lx)); iii) Reading of the QR codes at different distances (1m, 0.75m, 0.50m and 0.25m).
	Field Study	N=6 (1 female and 5 male) Aged: 19 - 26 years Public Transport: 4 are frequent users	- Tests were performed in a bus line between two predefined stops. Perform the check-in by reading the QR Code placed inside the bus and the check-out by reading the QR Code placed at the arrival stop; - Answer to a questionnaire to characterize the sample, identify mobility patterns and collect feedback.
Third Phase - Journey planner, social network, mobile payments and QR Codes technology	Pilot Trial	N=5 (2 female and 3 male) Age: 29 - 43 years Public Transport: 3 are frequent users	- Travel in the three transport operators that are part of the consortium of the project, boarding at pre-defined stops. Test all the components of the application: unplanned journey, planned journey, manage favourites list, share information about the journey; - Answer to a questionnaire to characterize the sample and collect feedback.

The project was structured in two components, one operational and the other relational. Octal (Novabase) was responsible for the operational component, which includes pre-trip information, the design and development of the mobile application and the central management platform. FEUP was responsible for the relational component, which includes the design and validation of a social network adapted to the mobility requirements and the evaluation of the technology and the solution. The collaboration and communication between stakeholders did not flow very well. Both promoters worked separately in their components and at the end they came up to a final solution.

The DMTS methodology in built on a mind-set of close collaboration among stakeholders, and this was the main point of failure of the project. The stakeholders and their responsibilities were identified, but it failed on applying participatory design techniques to co-create the service. Stakeholders worked separately on their components and did not share ideas, knowledge and expertise much often.

Also, what distinguishes the DMTS methodology from others is the focus on customers, involving them actively in the co-design of the service. In this project, potential customers were involved during the design of the social network component, but were not involved during the design of the other two (journey planner and mobile payments). Customers' perspective is vital to design a mobile ticketing solution.

The application of the stage 6 – redesigning and developing the service solution was a failure. Most of the features defined in previous stages were not implemented in the functional prototype (e.g. the mobile application did not calculate the price to be paid for the journey) and those implemented did not work correctly (e.g. the mobile application failed in identifying the stop while reading the QR Codes). Because of this, the implementation of the stage 7 – evaluating the service solution in a real environment – was a failure. At the end of the project it was expected to place QR Codes in selected lines of the transport operators and test the solution with real passengers, but the mobile application was never prepared for these tests. They were summed up to tests carried out by 5 project collaborators in real environment.

In short, several aspects can be pointed out that led to a poor application of the methodology:

- Lack of communication and collaboration between stakeholders;
- Little exchange of knowledge and know-how between partners;
- Little interaction with the users during the design of the solution;
- High team turnover which delayed responses and development;
- Lack of a significant field trial with real passengers.

The project had a great concept and idea behind, of integrating several mobility services in one mobile application, but failed to evolve from the initial conceptualization phase to the others. It showed how a project can be less successful if it fails to apply key points of the DMTS methodology.

4.3.6 Discussion on the Seamless Mobility Results and Conclusions

The results of the usability evaluation of the first phase component, conducted through field studies, indicates that the majority of participants classified the activities easy to implement and of simple interaction (average rate of 4.7 out of 5). However, despite the generally positive perception, the survey indicates that there were also some difficulties in understanding the meaning of the social network concept. Nevertheless, after understanding the concept, the users appreciated the simplicity of how the tasks are performed. Some users showed difficulties in understanding the need to classify the comments of other users, especially when they do not receive any reward for it. Both the favourite journeys and schedule features were perceived as very useful and of simple interaction. The option for setting a scheduled journey for certain days of a week, for example, was seen as very useful, easy and intuitive.

Regarding the analytical evaluation results, the general consensus among the experts was that the application is very easy to use, with a 'linear' navigation in most cases. The development process of the application was also validated, highlighting the importance of the inclusion of users and experts during the design phase and the use of low-level prototypes and usability tests before an implementation phase. Several contributions were given by the experts, which were useful to enhance the application, such as the dimension of certain buttons, consistency of interaction regarding the selection of items, implementation of timeout when writing a comment and introduction of new buttons.

Laboratory tests of the second phase component revealed that the reading speed of the QR Codes in different light levels was quite regular, not varying much when different illumination levels were available (Min.: 5 lx; Max.: 80 lx). Nevertheless, it was possible to determine a minimum level needed to perform the readings successfully: 4 lx. This may be a challenge in bus stops at night, with low lighting conditions, requiring an extra light source, such as the flash. In addition, the two codes that were used were read at different distances. It was determined that the smaller one (5.82cm x 5.82cm) could be read at the maximum distance of approximately 0.5m (M=589.5ms SD=232.6ms), while the bigger one at approximately 1m (M=502ms SD=18.4ms). In this case, the consequence of doubling the size of the code, resulted in doubling the maximum distance at which the code can be read. Also, when the code is read too close, the reading process may be inconclusive, therefore the minimum distance for successful reading is dependent on the code size.

Concerning the results of the field study, most of the participants expressed interest in the proposed ticketing system, being preferable when compared with the existing system (contactless card based on RFID technology). They mentioned several problems regarding the current system, such as forgetting whether the ticket was validated or not, difficulty of knowing which type of ticket to buy for a certain trip, and the need to carry coins. After the tests, the participants considered the system easy to use (average rate of 3.5 out of 5). They found the application useful and appealing. Nonetheless, there were some problems while reading the QR Codes, since the correct position and distance to the code had to be found. This was one of the major problems identified in the solution, which influenced the evaluation of the ease of use of the application. The participants also suggested the introduction of additional features such as schedule information and trip planning (these are part of the final solution, but were not tested by these users).

Regarding the pilot trial of the third phase component, the participants considered the mobile application functional and easy-to-use. The concept of check-in and check-out was easy to understand, as well as the search for routes and next stops. Regarding the performance of the application, sometimes the check-in proved to be a little slow as the QR Code information is always crossed with the GPS signal. The participants were also able to identify some usability problems, such as lack of feedback in some screens, words inconsistency and complex information presented to the users.

4.4 Anda: a Mobile Ticketing Solution based on NFC and BLE Technologies

The Anda project aimed to promote the dematerialization of travel tickets through the use of personal mobile devices. The solution comes from the joint collaboration between TIP (promoter), FEUP (scientific partner) and OPT, Card4B, BIT, AMI and Dynasys as technological partners.

The project consisted on designing, developing, testing and deploying a mobile ticketing service solution based on BLE and NFC technologies. It is based on a check-in/be-out scheme, requiring an intentional user action when entering the vehicle, and the alight station is automatically detected by the system, as well as intermediary stations along the trip. The price to be paid by the customer is calculated through a fare optimization algorithm, which minimizes the cost for the passenger. This feature allows passengers to travel throughout the transport network without requiring knowledge of fares and tickets.

Before the solution was deployed, it was tested by real passengers of the public transport services of the city of Porto, Portugal, during 1 year. They interacted daily with the researchers and development team through a closed group on Facebook and email. Focus group sessions were also conducted, to explore additional questions regarding the user experience, perception of security and willingness to use. It was also necessary to install beacons on every stations and buses that part of the Andante system and reconfigure all validators so that they can read the NFC-enabled mobile phones. This project represents the culmination of several projects and years of research with the actual implementation of a mobile ticketing solution. This solution was deployed (go-live) in the city of Porto, in June 29th 2018.

Next subsection details the Anda architecture, followed by the description of the uses cases in sub-section 4.4.2. Sub-section 4.4.3 presents the prototype that was developed and sub-section 4.4.4 detail the evaluation procedure. Sub-section 4.4.5 discusses the deployment of the solution and sub-section 4.4.6 presents a critical analysis of the application of the DMTS methodology to the design of the Anda solution. Finally, sub-section 4.4.7 discusses the Anda results and conclusions.

4.4.1 Anda Architecture

The global architecture of the solution is represented in Figure 40 and consists of six main components: mobile application, back-end, CCB (Central Ticketing Computing), MESS (Merchant Secure Server), SAM (Security Application Module) Farm and HCE (Host Card Emulation).

The mobile application, called Anda, is the front-end of the solution. It was developed for Android devices, equipped with NFC technology, and is responsible by:

- The interface with the customer;
- The validation at the boarding station/stop (check-in), by emulating an Andante Card according to the Calypso HCE (Host Card Emulation) specification. In the emulated virtual card (midlet / HCE module) a ticket is instantiated with spatial validity extended to the entire SIA network (Intermodal Andante System) and temporal validity according to the contracted mode of use. The validation of the emulated virtual card is done in the same on-board validators (road mode) or station (rail mode) where the validation of the physical tickets are carried out, through the NFC communication mechanism.
- The tracking algorithm of the stages and journeys made by the customer (be-out), supported in micro-location through a network of BLE Beacons.

The back-end is the subsystem supporting the operation of the mobile application, being responsible for:

- Configure and parameterize its operation through information obtained from the CCB;
- Collecting data and maintaining the context and usage history;
- Optimization algorithm (spot-price);
- Invoicing and electronic payments;
- Prepare the information needed to feed the CCB's revenue sharing mechanism.

The CCB (Central Ticketing Computing) is the central system for the entire ticketing system of the SIA, and stores all the information necessary for the commercial operation of Anda, namely, network topology, types of tickets available, tariff architecture and respective tariffs.

The MESS (Merchant Secure Server) is the orchestrator of external channels to the SIA ticketing system. It allows remote applications (POS, smartphones, web portals, others) to carry out personalization and loading operations of “Portable Objects” (Andante card and HCE midlet), by keeping all data model logic, business rules, and security architecture on its side. Remote applications should therefore be able to be completely agnostic in relation to all aspects of implementation of the SIA ticketing system. MESS is responsible for handling all implementation details (types of tickets, business rules, data models, security, "Portable Objects" access commands), with the exception of the UI (User Interface) of the remote applications with the users. In this context, the Back-End and HCE Server are considered, to a large extent, external components, which must also be orchestrated by MESS.

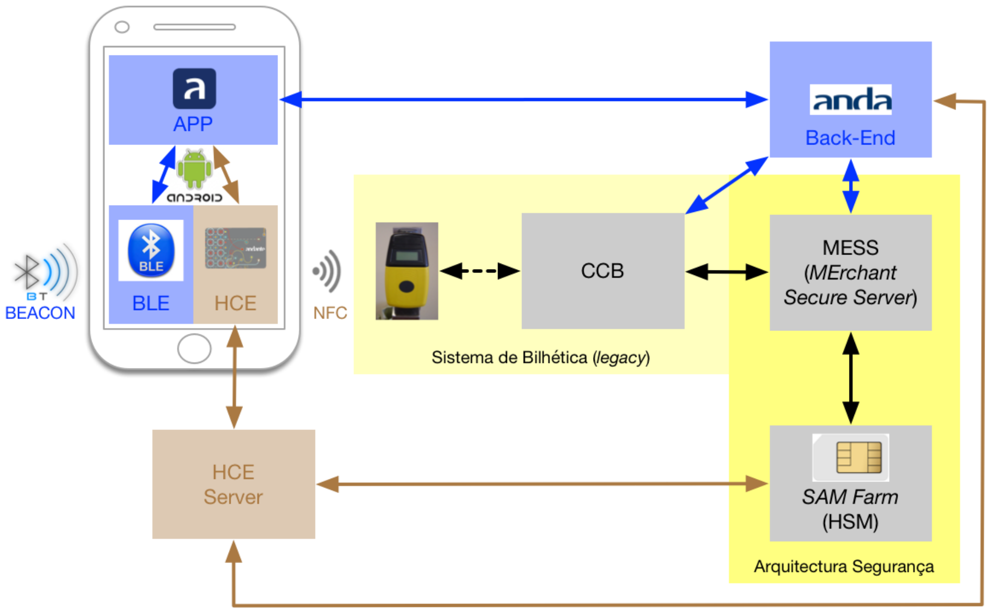


FIGURE 40. ANDA SOLUTION ARCHITECTURE

The SAM (Security Application Module) Farm, remote SAM server based on HSM (Hardware Security Module), is the central component of SIA's Calypso security architecture, in particular with respect to external channels.

The HCE (Host Card Emulation) is the component responsible for securing the required security and fraud prevention / detection mechanisms of the HCE-based dematerialized solution.

4.4.2 Anda Main Use Cases

During stage 4 of the DMTS methodology – co-designing the service – four main use cases were designed: a) ticket purchase, b) ticket validation, c) ticket inspection, d) check journey history, and e) check fares.

a) Start a journey

To start a journey the user only has to tap his/her mobile phone on a validator and the validation is made via NFC. At the beginning of the project the validation was done through Bluetooth (Ferreira, Dias, and Cunha 2018). The user would arrive at the station, open the application and it would start searching for beacons. Then the user only had to select the station/vehicle in which he/she was going to enter. However, when presented to transport operators, especially buses representatives, they stated they wanted a system similar to the physical card, where customers touch on the validator and it emits a sound and light when it is ok. This became a requirement and the design of the solution was changed in order to support validation through NFC.

b) Check ongoing journey information

During the journey the user can see the stations/stops he/she is passing through and at the end of the journey the mobile application automatically closes the ongoing trip. This is possible through the constant communication of the Bluetooth of the mobile phone with the BLE beacons placed in stations and inside buses.

c) Journey inspection

The solution allows inspectors to verify the validity of the journey. The inspection is done in two steps. First the user opens the inspection menu generated on the mobile phone after starting a journey and shows it to the inspector. This menu has information about the journey that is taking place: boarding station, operator, line, zone, date and hour, current station, zone, date and hour, and name and photo of the user. This menu only has information available when a journey is active. The second step consists on approaching the mobile phone to the inspectors' handheld device and automatically check the journey validity.

d) Check journey history

The application allows users to check their travel history at any time.

e) Check fares

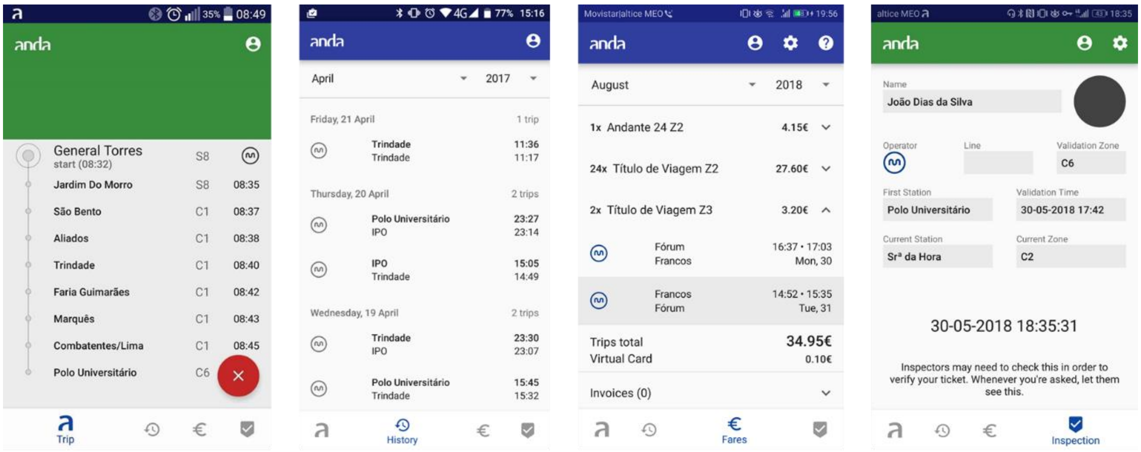
The application allows users to check the total amount due at any time. The fare optimization algorithm is always grouping the journeys made by customers in travel tickets, according to SIA's tariff structure, ensuring that the customer pays the least possible. The grouping of the trips in tickets can be consulted by the user in real time.

4.4.3 Anda Prototype

The development of the mobile ticketing solution moved from low to high fidelity prototypes as recommended in stage 4 of the DMTS methodology. The design of the prototypes followed a participatory mindset, where all stakeholders co-created the service. Further details on this codesign process may be reviewed in (Ferreira, Dias, and Cunha 2018). A functional version of the prototype was developed for Android devices and the main screens are shown in Figure 41. These screens are the final solution that was launched to the market, after endless iterations between customers, researchers, technology companies, transport operators representatives and staff, and represent the outcome of applying the stage 6 of the DMTS methodology.

In the final solution, the passenger downloads de mobile application and registers by introducing personal information: name, email, phone number and password. Then the passenger access to the email and confirms the registration. The passenger opens the mobile application and logs in by entering the email and password. Before using the application to travel, the passenger must introduce his/her bank account details in the user profile settings.

To start a journey the user has to turn-on, on his/her mobile device, the NFC, Bluetooth and location services. Then the passenger taps the mobile phone on the validator. The system allows to start a journey offline, if in the last 12 hours there was an internet connection.



a) b) c) d)

FIGURE 41. INTERFACES OF THE ANDA MOBILE APPLICATION: A) ONGOING JOURNEY; B) JOURNEYS' HISTORY; C) JOURNEYS' FARES; D) JOURNEY INSPECTION

During the journey, the passenger can check the stations he/she is going through (Figure 41 a) and at the end of the journey the mobile application closes the ongoing trip. This is possible through the constant communication of the Bluetooth of the mobile phone with the beacons. BLE beacons installed in metro and train stations and inside buses are constantly sending information regarding the station or bus stop from where they are placed. These messages are captured by the customers' smartphones through Bluetooth connection, allowing to identify the stop/station where the customer is located.

Regarding the way of how the journey ends, two options were discussed: be-out or check-out. The main aim of the proposed solution was to require the least possible interaction from the customer. Since the beginning of the journey was difficult to implement without any user interaction, transport operators decided to follow a be-out scheme, with no objection from the technological point-of-view. Therefore, when the passenger leaves the vehicle, the mobile phone loses the signal of the beacon. This information, combined with the mobile phone accelerometer, allows to understand the passenger left the vehicle and the mobile application closes the journey automatically.

During the journey the user may be approached by an inspector to check the validity of the trip. Therefore, the user opens the inspection screen and shows it to the inspector (Figure 41 d). This screen has information about the journey that is taking place: boarding station, operator, line, zone, date and hour, current station, zone, date and hour, and name and photo of the user. The current date and hour on the screen allow for a quick visual inspection as the second timer is constantly running, indicating it is not a screenshot of another journey. The inspection process also consists of an automatic step, by approaching the mobile device to the handheld device of the inspector.

The customer may check at any time the history of his/her trips (Figure 41 b). These are grouped by days and are sorted from the most recent to the oldest. The amount due may also be checked (Figure 41 c). The fare to be paid is calculated by the system and not by the customer. Since the system knows the exact origin and destination, it was developed a fare optimization algorithm in order to optimize the fare to be paid by the customers. The algorithm groups the journeys in the cheapest combination of tickets for the customer. For instance, if the customer has made enough trips to reach a monthly subscription, only the monthly subscription is charged. This is one of the biggest advantages of the proposed mobile ticketing service when compared with the traditional ticketing system. Customers only pay what they travel and do not need to have any knowledge about routes and fares.

4.4.4 Anda Evaluation Procedure

The solution was extensively evaluated over the various stages of design and development, and are summarized in Table 9. One of the components to be evaluated during stage 4 is the technology. The initial idea of the project was to develop a mobile ticketing solution based only on BLE technologies. The use of this technology for mobile ticketing purposes is very recent and examples of implementation are very scarce. Therefore the main concern was to study how the technology behaved and what specifications it should have to be used in the urban passenger transport field. Several tests were performed either in laboratory environments, either in context, to evaluate radiation patterns, parameters influence, detection times, coverage and loss of signal. These tests were useful to define the requirements the beacons should fulfil to be used in this specific context and to decide the location and number of beacons that should be installed.

During the application of stage 4 of the DMTS methodology, the mobile application interface should be tested with the users. A first version of the functional prototype was tested with users through usability testing technique in laboratory environment. During this procedure the user interface design was evaluated by potential users who performed a list of tasks using the application prototype (see Appendix E.3). The main objectives were to evaluate the user interaction with the prototype and how the information presented to the users was understood by them. The sample involved 5 participants who were sampled in the campus of the University of Porto. Each test took about thirty minutes to be completed. Observers took notes and recorded the execution time of each task.

At a later stage of the mobile application development and before being released to the general public, a new set of tests to the UI was performed. The main objective was to find further issues that should be improved before the deployment, which have not been identified or pointed out by participants during the pilot. These set of tests consisted on two different approaches. The first was the heuristic evaluation, performed by four experts (Nielsen (1992) recommends between three and five). Experts were asked to provide their feedback on Anda app answering a list of 13 heuristics (see Appendix E.4) and a checklist of subheuristics (156 in total), also commenting on each of them while using the mobile ticketing solution in context, that is, the experts answered to the checklist while travelling by public transport and using the app. In the checklist, there were 156 Yes, No or Not Applicable questions elaborated based on previous checklists and usability manuals. The average time for performing the heuristic evaluation was 71 minutes.

The second approach consisted on usability testing performed in real environment. The purpose of the usability testing was to assess if the Anda application is easy to use and navigate for users. The sample involved 8 participants. From these four were customers participating in the pilot, having already experience in using the mobile application (two of them had more than a year of experience, while the other two had between 3 and 12 months). The remaining four had never used the Anda application. The tests were done individually and participants were accompanied by a researcher, who explained the tests, read the questions and took notes from participants' answers and observations on their behaviour. The test was divided into two parts:

1. Pre-test questionnaire to characterize the sample (see Appendix E.5).
2. User test (see Appendix E.6). Users had to perform a set of actions (tasks) on the app. The researcher recorded the time each user took to complete tasks, as well as the type and number of errors. After a finishing task, participants were asked to assess the function used to perform it in terms of comprehensibility and utility and they also were encouraged to make comments about it, positive or negative. Comprehensibility and utility were assessed in a scale from 1 to 4. Participants were also encouraged to speak and think aloud during the test.
3. Post-test questionnaire (see Appendix E.7). These questioned users about their perception of the usefulness of the application, what they found confusing and suggestions for improving it.

Finally, the last evaluation procedure consisted on testing the mobile application and the other components during a pilot trial, and was carried out during the application of the stage 7 of the DMTS methodology. The tests consisted in real passengers using the mobile application during their daily trips. In the beginning of the tests they had to fill in a questionnaire for sample characterization (see Appendix E.8). During the tests, participants interacted daily with researchers and development team to share their experience. This stage lasted about 1 year, from April 2017 to June 2018. First, participants could only use the Anda app in four pre-selected lines (where the beacons were installed). Then, in March 2018, the test lines started to expand, spreading to the entire MAP network in June 2018. The pilot trial was divided in two different moments:

1. Test the mobile ticketing solution based only on BLE, from April 2017 until December 2017 and;
2. Test the mobile ticketing solution based on NFC and BLE, from January 2018 until June 2018.

Regarding the first moment, a first set of tests was done from April 2017 to July 2017. Participants were selected through the Transportes Intermodais do Porto (TIP) customers database and disseminated in the Faculty of Engineering of University of Porto (FEUP) and Science and Technology Park of University of Porto (UPTEC). Of the selected clients, 90 participated and received the monthly pass for free to participate. After this set of tests, 3 focus group sessions were conducted with selected participants, to understand the participants' experience with the application (what they liked, perceived confusing and improvement suggestions), security and privacy concerns, travelling habits, and perception of the payment of the public transport service with the mobile phone (see Appendix E.9). Each session lasted about 1:30h, the audio was recorded and then completely transcribed and analysed. Analysis of the post-pilot focus group sessions may be reviewed in (see Appendix E.10).

In October 2017 the tests of the solution based on BLE continued. From the previous group 15 participants were selected to continue and ticket store operators, call centre collaborators and inspectors also participated in the tests. The introduction of frontline employees in tests is crucial since they are going to interact directly with the customers when the solution is deployed, and have to be prepared to help them. Also their point-of-view is key as co-designers of the solution. In January 2018 the tests of the solution based on NFC and BLE started with the same participants. From March until June 2018 several other workers of the various transport operators have been introduced in the tests. In total 90 people participated in this test phase.

TABLE 9. METHODOLOGICAL APPROACH OF EACH EVALUATION PHASE OF THE ANDA SOLUTION

Evaluated Component	Evaluation Approach	Sample	Procedure
BLE technology	Laboratory Tests	Researchers	- Tests performed inside an anechoic chamber to measure the radiation pattern of the beacon by placing it in different positions. - Analyse beacons to understand the influence of different API parameters in the following metrics: detection time, intercallback time and battery consumption.
	Field Tests	Researchers and development team	- Place beacons on potential locations (bus, train stations, surface and underground metro stations) to measure the detection time and coverage inside and outside buses and in metro and train stations. These experiments allowed to decide the location and number of beacons to be placed inside buses and in stations. - After installing beacons in final locations another set of tests were performed. These tests consisted in: 1) recording the RSSI (Received Signal Strength Indicator) of the beacons, on selected stations and buses, to measure their performance; and 2) analyse the loss of signal by measuring the number of beacons detected in a certain interval of time (3 seconds) during 24 hours, on a selected train station.
Mobile application UI	Usability testing in laboratory environment	N=5 (2 female and 3 male) Age: 20 - 24 years Public Transport: 3 are frequent users	- Explore the functional prototype of the application based on a script with specific tasks, and rate the perceived difficulty in performing each task (Likert scale ranging from 1 to 5);
	Analytical Evaluation in context	4 experts	- Answer to a checklist of 156 heuristics (yes, no or n/a) and comment each one, while using the mobile application in context, that is, the experts answered to the checklist travelling by public transport and using the app.
	Usability testing in context	N=8 (4 female and 4 male) Age: 20 - 66 years Anda mobile app knowledge: 4 have already used the app	- The tests were performed in context, during a metro trip, the audio was recorded and the researcher wrote down the participants' answers and observations on their behaviour. The tests consisted on: - Answer to a questionnaire to characterize the sample and collect feedback; - Explore the functional prototype of the application based on a script with specific tasks, and rate the perceived difficulty in performing each task (Likert scale ranging from 1 to 4); - Answer to an interview with focused questions and open answers to extract participants' overall opinions and ideas regarding the application usability.
Mobile ticketing solution	Pilot Trial – Phase 1 (BLE)	N=100 (50 female and 50 male) Age: 20 - 67 years Public Transport: All frequent users	- Attend presentation and training sessions; - Answer to a questionnaire to characterize the sample; - Travel in the four lines that are part of the tests. Test the mobile ticketing solution (front-end and back-end) as well as the beacons; - Share opinions, report problems and suggest improvements through Facebook and email; - Participate in focus group sessions to explore additional questions.
	Pilot Trial – Phase 2 (BLE+NFC)	N=90	- Attend presentation and training sessions; - Travel in the MAP network and test the mobile ticketing solution based on NFC and BLE; - Share opinions, report problems and suggest improvements through Facebook and email.

During the test year, participants were introduced at the beginning of each month and the tests were preceded by a presentation and training session, as detailed in Section 3.2, stage 7 of the DMTS methodology. During the tests participants contacted the project team daily via email and Facebook to ask questions, share experiences, difficulties and suggestions for improvement. Basic logs of their mobile application were also collected by the development team and more detailed logs could be sent by the participants through email. All comments posted on the Facebook page and email contents were transcribed to a platform, developed internally for that purpose, and categorized. This categorization analysis may be reviewed in (see Appendix E.11). The comments were also analysed and discussed during weekly meetings between TIP, researchers, and technology companies, continuing the process of co-design and improvement of the solution.

4.4.5 Deployment of the Anda Solution

The deployment is the moment of truth of all the work done by the stakeholders involved in the co-design of the solution. It is the moment when the solution is released to the market and everything has to work. A successful deployment depends not only on the solution itself, but also on good preparation for deployment.

The tasks listed on Stage 8 were all followed to prepare the deployment of the Anda solution. The communication plan defined the strategy to convey the information of the new payment method to customers. Diverse graphic material (outdoors, flyers, posters, and others) were produced to be placed at stations, stops, ticket offices, and streets in general. Buses were decorated, promoters and dedicated service stations were placed at certain metro stations and many news were broadcast through television news, newspapers and social networks. Promote awareness, communicate the advantages and encourage the use were the main objectives of the campaign.

Frontline employees and staff have been trained to know how to respond to customers with any questions or issues related to the new payment solution. Despite training efforts, some technical questions made by customers could not be answered by the operational staff of the transport operators. They needed help from more technical personnel involved in the design and development of the solution. In addition of being available by phone, two days a week were scheduled so that technical staff would be physically available in one of the physical stores to personally assist customers.

In order to solve problems, to answer questions and track customer interactions history, a web tool was developed to support staff. The web tool gives access to the customers' history, making it possible for the staff to clarify doubts and see the status of the problems reported by customers (e.g., solved, pending). Also, a monitoring system was developed to monitor the technologies status and communication events (Botelho, Ferreira, and Dias 2018). This was useful to identify possible hardware or configuration issues and forward them to the responsible management and maintenance teams.

To assess the evolution and impact of the operation a set of KPIs were defined as well as management analysis. It is important to monitor the operation daily and adjust the strategy accordingly and timely. For instance, after 2 months of the application launch it was found that there were about 1800 people with everything ready to start using the system but they had never used it. A sample was then selected to be contacted by phone and after several calls it was noticed that people had doubts and fear of using the application. A dedicated permanent service station was created at the busiest metro station to which customers could personally address and interact. Regular service stations and ticket offices usually have many queues, which hinder people from moving there to ask questions of a new payment method, when they already have the old one. Therefore, it was necessary to look for ways to streamline processes of adhesion, help and clarification of doubts. Moreover, the phone contact was very important to approach the service provider of the customer. Customers felt that their opinion was important and that the service provider was really concerned about them.

Currently, a total of 11 transport operators, consisting of metro, train, one public bus operator and 9 private bus operators, accept the Anda as a mean of payment for the trips of their passengers. Three months after its launch, the Anda mobile application has more than 5.000 customers completely registered (with bank account associated) and more than 2.000 validations per day. From July to September the average weekly growth rate was 8%, and this rate rises to 12% if only the month of September is considered.

4.4.6 Analysis of the Application of the DMTS Methodology to the Anda Project

From the results achieved point-of-view, this was the project that went further and with greater impact on the lives of citizens. A mobile ticketing solution was designed, developed and actually deployed in the Metropolitan Area of Porto, Portugal. The idea and objectives set in stage 1 were clearly identified: design a mobile ticketing service solution that simplifies the use of public transport services. Relevant actors to the design process were then identified and involved, as proposed in stage 2. The design of the solution resulted from a process of constant interaction between the various stakeholders, contributing to a very active and participative process of service co-creation. Potential clients were involved from the initial design stages through focus group sessions to more advanced phases involving real environment tests.

From the pilot trial carried out during the application of the stage 7, it is worth to highlight the daily interaction with customers through the social network Facebook. At first, transport operators representatives were somewhat sceptical about the idea, but in the end they agreed that it was a successful approach. The information flowed fairly quickly and almost in real time. However, this approach is only successful if customers actively contribute with their opinion. During the project it was possible to developed and test ways for this to happen. Introducing participants gradually in the tests allowed to bring dynamics to the discussion and raise new concerns and ideas. Participants also want to get a response from the research and development team, otherwise fail to contribute because they feel that their effort is in vain and is not taken into account. And answers such as: "We will validate the reported occurrence" or "Thank you for the information sent" are not enough to keep the interest and participation of customers. One should try to deepen the topic raised, ask questions and above all explain why certain behaviour of the application or technology is happening. Furthermore, by fixing problems and introducing new versions of the application shows that their suggestions are taken into account, encouraging them to continue to contribute.

This daily interaction generates a lot of precious information, which needs to be addressed. Several approaches have been tested during the project and the one that seems to work better is to delegate the interaction with the customers in one person, who distributes work to the various development teams and monitors the work done. Weekly meetings should be held in order to discuss the issues reported by customers and the status of their respective resolution. The great challenges are to know, at every moment, what is solved and what is not, and not let the problems drag for a long time.

The launch phase is the most complex and most challenging. In spite of trying to anticipate a number of situations during the preparation stage, it is difficult to be truly prepared. The number of customers increases exponentially, as does the diversity of mobile devices. Customers invade all possible touchpoints and a huge effort has to be made to respond to everyone on time. Clearly, in the Anda project, the support team was not expecting the huge initial flow of customers, which was triggered by the news on the various channels. The responses tended to be delayed and were regularized in the following weeks. Despite the training given to the staff and customer support, it was noticed that they were not able to help customers with more technical issues, also due to the appearance of new mobile phone models not tested before. Thus, the technical team went twice a week to a pre-defined station to help customers with difficult problems to solve.

The deployment stage was characterized by analysis, reaction and adaptation of the strategy. For instance, after two months of deployment it was found that there were about 1.800 people who had everything ready to use the application but had never used it. It was necessary to get in touch directly with the people to try to understand what was happening. It was noticed that people had doubts, fears, anguish and that it was necessary to reinforce customer support. It was then set up a service station dedicated to the mobile payment solution, at a pre-defined station, to help customers effectively. There was also the possibility to meet the customer at a different station and test the payment solution while travelling together.

It should be noted that the project promoter hired a Peer Review of the Anda project to UITP experts, which took place in April 2018. During three days the experts evaluated the technological transition, back-office administration, roll-out and user experience. Experts considered the solution innovative, with an innovative and effective use of beacons. The re-use of existing technology system was considered a strength of the solution, being, however, necessary to follow the technological evolution. Automatic fare calculation functionalities allow easy use of public transport, enabling to increase market share due to attractive and easy-to-use ticketing system. The solution also allows to collect precise travel data, which can be used to improve service offer and efficiency. Experts also foresaw a potential lack of resources for after sales support, which eventually happened. Moreover, experts mentioned that the "cooperation with external experts, including the university ensures to bring in experience and know-how" (UITP 2018). Finally, experts emphasized the high customer focus and close involvement of customers in Anda development, which "seems an excellent basis to build a successful app" (UITP 2018).

4.4.7 Discussion of the Anda Results and Conclusions

BLE technology tests revealed that beacons should be placed in relatively high locations, away from physical or infrastructure barriers, thus reducing interference and increasing coverage. However, due to ease of installation and access to power supply reasons, the beacons were installed inside ticket validators. Field coverage tests revealed that one beacon per metro/train station platform and one per bus should be enough. Therefore, beacons were installed inside pre-selected validators in metro/train stations and inside buses.

These assumptions were assessed during the pilot trial, which revealed a different reality. In fact, the major problems during the first months of tests with passengers were related to the beacons. Often, the passengers' mobile phones did not catch the beacons signal, which prevented the stations from being correctly identified. Clearly, the installation of the beacons inside the validators reduced their coverage and was greatly affected by body and infrastructure barriers that were at the same level of the validators. The final solution was to install more beacons in the train/metro stations, one per validator, and also in underground platforms, where there are no validators. One beacon per bus proved to be enough, being the reported problems related with configuration issues.

Another problem that occurred, which was not possible to anticipate, was how to deal with the high number of Android mobile devices so different from each other. Depending on the manufacturer and version of Android, mobile devices have very different behaviours when reading the beacons, and it is sometimes necessary to develop an individual programming for each model. For instance, some models stop searching for beacons, after a few minutes of intensive searching, to reduce battery consumption, and some changes had to be made to prevent this from happening.

NFC technology also proved to be a challenge. Although the validators already have NFC technology, it was necessary to install a SAM card inside all validators to allow the communication with mobile devices and to fine tune the power of the antennas. It was also necessary to make software changes and to replace the NFC antennas of the validators of the buses that did not read the mobile phones correctly.

In addition to technological problems that hinder a fast and successful validation process, problems with the passengers' behaviour were also identified during the check-in. The way to validate with the physical card is different from the mobile phone and it is difficult for customer to adapt to the new way of validating. The mobile phone must be standing, at 2 or 3 cm from the validator and it takes a few seconds longer than with the card. A video tutorial[17] was recorded to explain the validation procedure to future customers. However, like any new procedure or technology, it takes time for people to adapt and get used to it. As happened in the MobiPag STCP project, the validation procedure was criticized by the passengers. Passengers want simple and fast validation procedures, while transport operators want to make sure that the validation is correctly made and is visible to drivers and other passengers, sometimes sacrificing the speed of the process.

Regarding the UI of the mobile application, it has evolved over time, based on usability testing, experts' evaluation and feedback from participants. From the last UI usability evaluation a set of 34 usability problems were identified (Amorim, Dias, and Ferreira 2019). From these 2 were considered critical (having no "Help" function and not requiring the previous password when changing password), 15 worrisome and 17 trivial. Those considered critical and worrisome were fixed before the mobile application launch and the others will be considered for next updates.

As far as concerns the user experience, participants enjoyed to use the mobile phone to travel on public transport and considered the solution convenient and innovative. They consider the optimization of the tariff to be the differentiating factor of the application, because it promotes savings in the payment of travel. It is undoubtedly a determining factor for the adoption of the mobile phone as a mean of payment, and operators should invest in effective communication

[17] Availabe at https://tinyurl.com/y9wad53b

of this added value to their customers. The fact that they can travel without having to buy tickets or monthly passes, neither to think about whether they have the right ticket for a given trip is another determining factor in the adoption of such a system. Paying just what you travel, avoiding queues, machines that do not work and going to the physical stores are additional advantages referred.

Regarding privacy and security issues, participants do not feel at all "followed" by the transport operators because they use the mobile phone to travel. They even consider it useful to be able to follow the route of their journey. Participants feel secure using the application to pay for travel. However, they suggest introducing an optional PIN to the application entry and somehow hiding the profile's personal information. The confidence conveyed by the application is also critical for security awareness. The fact that the application crashes or gives error raises doubts as to the effectiveness of the actions performed, such as validation being registered or not, and traveling legally or not.

Participants consider that such a system tends to reduce fraud, since it is always available, does not depend on notes and coins and conveys the image of being a more controlled system. Finally, participants consider it useful to integrate a payment application in public transport with information related to mobility, such as maps, schedules and prices.

4.5 Chapter summary

This chapter presented the application of the DMTS methodology to the design of four mobile payment and ticketing services under four research projects. These projects provided rich settings for DMTS development and validation.

Each project is described and the main artifacts and outcomes resulting from the implementation of the methodology are presented. Functional mobile ticketing prototypes were developed and tested in the context of use. The Anda mobile ticketing solution went further and was released on the market.

The application of the DMTS methodology to the projects showed the importance of identifying all stakeholders and promoting constant communication among all, using participatory design techniques to co-create value in the design. The Seamless Mobility project failed to create this collaboration environment and this was reflected in the poor implementation of the following stages. Also, the introduction of customers since early design stages is key to design successful mobile ticketing services. They are the “experts of the experience” and their perspective is fundamental to the design. In the first project, MobiPag, customers had little participation during design phases. This was corrected in the following projects, MobiPag STCP and Anda, with the active participation of customers.

Regarding the results and conclusions of the projects, an overall analysis allows to highlight the positive attitude of all actors towards mobile ticketing services. Service providers want to deliver better services and enhance customer experience and customers are open to the new possibilities offered by mobile payments and are willing to experiment and test. This makes expectation management crucial in order to take advantage of everyone's enthusiasm. First impressions should be strongly focused on quickly creating a sense of confidence, familiarity and added value with the service, providing the foundation for a sustained use and subsequent exploration of additional services. Designing for emerging practices and not letting people down can mean focusing at the beginning on simple procedures that, albeit limited in regards to the range of technological possibilities, are much safer and less likely to disappoint and drive users away.

It was also clear that offering a different payment method to customers is not enough. Exploring the unique characteristics of mobile phones to offer additional and complementary services to the payment is crucial to contribute to a wider adoption. Customers are expecting to do more tasks with the mobile phone than just paying. They want, for instance, to be able to check the balance and the transactions history, to search for information about the service and service provider and even to interact with other customers.

The perception of security, a major concern in every acceptance survey of mobile payments, was clearly mitigated during the real-world experiments. Providing proper feedback about the transactions and ask for a PIN seems to have a positive impact on customers' confidence in the mobile payment service (Ferreira, Dias, and Cunha 2017). Thus, other payment systems should focus on how to achieve a positive initial user experience and how to leverage upon real-world contact with the technology to create a solid path for gradual acceptance through the development of new practices and the perception of value. The technologies used in the mobile ticketing solutions also proved to be a challenge. These were emerging technologies that were not mature at the time, compromising sometimes the overall user experience.

A critical analysis of the implementation of the methodology to the design of each mobile service solution is also provided in this chapter. While in some projects the customers actively participated in the co-design of the service from early stages, in others customers' participation was more limited. Value co-creation among various actors within the service network was also not equal in all projects. It was very clear that the success of the design of a service is highly dependent on a close interaction between all stakeholders involved.

5. Conclusions

Complex transport networks and lack of seamless options have proven to be barriers to the adoption public transport services (Puhe, Edelmann, and Reichenbach 2014). The attractiveness of public transport therefore increases as it becomes easier to use. Modern mobile ticketing service solutions are able to free customers from difficult purchase decisions, allowing easier access to services. This thesis is concerned with developing a methodology to design mobile ticketing solutions in complex ecosystem context, leveraging the ubiquity of personal mobile devices and allowing easy access to mobility services. The main aim is to stimulate behavioural shifts towards more sustainable transport by increasing urban passenger transport attractiveness.

Firstly, this thesis introduced the theoretical framing of this research. Secondly, it presented the DMTS methodology, which stands out from other methodologies by joining contributions of several design methodologies and by promoting a close collaboration between all stakeholders of the mobile ticketing ecosystem. Lastly, this thesis provided empirical validation of the DMTS methodology through the design of four mobile ticketing services. The deployment of the Anda solution in the market emphasizes the relevance and value of the DMTS methodology since it was launched in the market and is being used by thousands of customers daily. Next sections present the research contributions and future work.

5.1 Discussion and Research Contributions

To address the fundamental goal of this thesis, three main research objectives were defined. The first objective was concerned with understanding the mobile ticketing ecosystem. This objective was accomplished with a comprehensive literature review about mobile payments, which represents the first main contribution of this thesis. It provided an updated and complete literature review about mobile ticketing, complemented by empirical work. Mobile ticketing can be defined as "the use of a mobile device to purchase and/or validate a travel ticket or to initiate a journey" and there are several technologies available in mobile devices that can be used to implement mobile ticketing solutions, such as SMS and phone calls, Wi-Fi and 3G/4G, RFID, NFC, BLE, and QR Codes.

When comparing mobile ticketing with traditional ticketing systems several advantages can be outlined such as remote and ubiquitous access to payments, queue avoidance and lack of need to carry cash around. It also reduces operational and maintenance costs, as it will decrease the need of tickets production, storage and distribution, ticket sellers and collectors and cash handling. Operational and productivity gains may also be achieved, by increased throughput in closed gate systems and improved bus boarding times. Despite its clear advantages, several factors are hindering the expansion of mobile ticketing services worldwide, from which the main factor is related to the complexity of the mobile ticketing ecosystem and the difficulty in solving conflicting interests. Therefore, the first necessary step for a successful mobile ticketing implementation is to develop inter-organizational relationships. This fact frames the contribution and innovative features of the next research objective.

The second objective comprised the development of a methodology to design mobile ticketing services in complex ecosystem context – DMTS methodology. The DMTS methodology joins contributions from several design methodologies and was validated and refined through empirical work. It consists of 4 main phases: 1) conceptualization, 2) exploration, 3) convergence and 4) launch. These are composed by 9 stages: 1) Identifying the problem and defining the objectives; 2) Mapping the stakeholders ecosystem; 3) Identifying the needs and establishing the requirements; 4) Co-designing the service; 5) Evaluating the artifacts; 6) Redesigning and developing the service solution; 7) Evaluating the service solution in a real environment; 8) Preparation; and 9) Deployment.

It is a customer focused methodology, in which the customer actively participates throughout the design process, since early stages. However, what distinguishes this methodology from others is the ability to actively involve all the stakeholders of the complex mobile payment ecosystem, including universities. All stakeholders interact with each other and add value during the service design process. One of the innovative ways of interaction developed and tested during the projects was the use of social networks. It takes advantage of the ubiquity, convenience and widespread use of social networks to form a community of sharing, common interests, and value creation. Incorporating the customers' feedback in the design and development of the solution is a clear example of value co-creation in design.

Mapping the stakeholders ecosystem is also an important contribution of this thesis, since it proposes models that allow to identify stakeholders and their roles, to organize collaboration between them and to capture the value each stakeholder is able to extract from the participation to a mobile ticketing ecosystem. This answers to the concerns raised by Dahlberg, Guo, and Ondrus (2015) and Patrício, Gustafsson, and Fisk (2018).

In addition to the involvement of the obvious stakeholders of the mobile payments ecosystem, such as transport operators, technology companies, banks, MNOs and customers, the university and researchers play a key role in the design of mobile ticketing service solutions. In fact, researchers contribute with knowledge, experience and know-how and make sure that a methodology is followed, avoiding important phases of the process to be overcome. Researchers also play a facilitator role by bringing together different perspectives into a new service solution.

Moreover, despite being concerned with the design of mobile ticketing services, the elasticity of the DMTS methodology was empirically demonstrated. It can be applied to design other mobile value-added services and to other domains not related to urban passenger transport, such as basic mobile payments, peer-to-peer transactions and loyalty schemes.

The third objective was concerned with the design of four mobile ticketing services developed under four research projects: MobiPag, MobiPag STCP, Seamless Mobility and Anda. These projects provided rich settings for the DMTS methodology development and validation, as they involved several stakeholders, from initial identification of needs to functional prototyping, or deployment, of new mobile ticketing services. The last one, Anda, was deployed in the city of Porto, Portugal, in June 2018 and is being used by thousands of passengers every day. This thesis details the entire solutions and identifies a number of challenges and guidelines that may help to shape future versions of mobile ticketing services. The results were also widely disseminated through conferences and publications, which are detailed in the next subsection.

5.2 Main publications and presentations

The following papers were published in the course of the research described in this thesis:

Daniel Meireles de Amorim, Teresa Galvão Dias, Marta Campos Ferreira. 2019. "Usability Evaluation of a Public Transport Mobile Ticketing Solution." In: Ahram T., Karwowski W., Taiar R. (eds) Human Systems Engineering and Design. IHSED 2018. *Advances in Intelligent Systems and Computing*, vol 876, Springer, Cham, pp. 345-351

Marta Campos Ferreira, Teresa Galvão Dias, João Falcão e Cunha. 2018. "Codesign of a Mobile Ticketing Service Solution Based on BLE." *Journal of Traffic and Logistics Engineering* (accepted for publication)

Marta Campos Ferreira, Teresa Galvão Dias, João Falcão e Cunha. 2018. "With Whom Transport Operators Should Partner? An Urban Mobility and Services Geolocation Data Analysis." *INTSYS Conference 2018* (accepted for publication)

Miguel Botelho, Marta Campos Ferreira, Teresa Galvão Dias. 2018 "Real-time monitoring of a mobile ticketing solution." *MATEC Web of Conferences* (accepted for publication)

Marta Campos Ferreira, Teresa Galvão Dias, João Falcão e Cunha. 2017. "Understanding commercial synergies between public transport and services located around public transport stations." *Transportation Research Procedia*, Volume 2, pp. 125-132, https://doi.org/10.1016/j.trpro.2017.12.052

Marta Campos Ferreira, Tânia Fontes, Vera Costa, Teresa Galvão Dias, José Luís Borges, João Falcão e Cunha. 2017. "Evaluation of an integrated mobile payment, route planner and social network solution for public transport." *Transportation Research Procedia*, Elsevier, Volume 24, pp. 189–196, https://doi.org/10.1016/j.trpro.2017.05.107

Tânia Fontes, Vera Costa, Marta Campos Ferreira, Li Shengxiao, Pengjun Zhao, Teresa Galvão Dias. 2017. "Mobile payments adoption in public transport." *Transportation Research Procedia*, Elsevier, Volume 24, pp. 410–417, https://doi.org/10.1016/j.trpro.2017.05.093

Costa, P.M., Fontes, T., Nunes, A.N., Ferreira, M.C., Costa, V., Dias, T.G., Borges, J.L., Falcão e Cunha J. 2016. "Application of collaborative exchange concepts to urban public transport networks: the Seamless Mobility solution." Transport Research Arena Tra2016, Volume 14, *Transportation Research Procedia*, ISSN 2352-1465, DOI 10.1016/j.trpro.2016.05.191, pp. 1201-1210

Marta Campos Ferreira, Teresa Galvão Dias. 2015. "How to Encourage the Use of Public Transport? A Multiservice Approach Based on Mobile Technologies." *Lecture Notes in Business Information Processing*, LNBP 201, Springer, 2015, ISSN 1865-1348, ISBN 978-3-319-14980-6, DOI: 10.1007/978-3-319-14980-6_25, pp. 314-325.

Helena Rodrigues, Rui José, André Coelho, Ana Melro, Marta Campos Ferreira, João Falcão e Cunha, Miguel Pimenta Monteiro, Carlos Ribeiro. 2014. "MobiPag: Integrated Mobile Payment, Ticketing and Couponing Solution Based on NFC." *Sensors*, 2014, 14(8): 13389-13415; doi:10.3390/s140813389.

Marta Campos Ferreira, Teresa Galvão Dias, João Falcão e Cunha. 2014. "Design and Evaluation of a Mobile Payment System for Public Transport: the MobiPag STCP Prototype." in *Proceedings* *of MOBILITY 2014: The Fourth International Conference on Mobile Services, Resources, and Users*, Iaria, 2014, ISSN: 2308-3468, ISBN: 978-1-61208-366-7, pp. 71-77.

Marta Campos Ferreira, João Falcão e Cunha, Rui José, Helena Rodrigues, Miguel Pimenta Monteiro, Carlos Ribeiro. 2014. "Evaluation of an Integrated Mobile Payment, Ticketing and Couponing Solution Based on NFC." *Advances in Intelligent Systems and Computing*, Volume 276, Springer, 2014, ISSN: 2194-5357, ISBN: 978-3-319-05948-8, pp 165-174.

Marta Campos Ferreira, Henriqueta Nóvoa, Teresa Galvão, João Falcão e Cunha. 2014. "A Proposal for a Public Transport Ticketing Solution based on Customers' Mobile Devices" *Procedia - Social and Behavioural Sciences*, Volume 111, Elsevier, 2014, ISSN: 1877-0428, DOI: 10.1016/j.sbspro.2014.01.056, pp. 232–241.

Rui José, Helena Rodrigues, Ana Melro, André Coelho, Marta Campos Ferreira. 2013. "Design Lessons from Deploying NFC Mobile Payments." in *Lecture Notes in Computer Science*, LNCS 8276, Springer, 2013, ISSN: 0302-9743, ISBN: 978-3-319-03175-0, pp.86-93.

Marta Campos Ferreira, Maria Henriqueta Nóvoa, Teresa Galvão Dias. 2013. "A proposal for a mobile ticketing solution for metropolitan area of Oporto public transport." *Lecture Notes in Business Information Processing*, LNBP 143, Springer, 2013, ISSN: 1865-1348, ISBN: 978-3-642-36355-9, pp.263-278

The following papers were presented in conferences in the course of the research described in this thesis:

Marta Campos Ferreira, Teresa Galvão Dias, João Falcão e Cunha. "Exploring urban mobility and points-of-interest data to discover potential commercial partnerships." presented at EWGT 2018, *21st Meeting of the Euro Working Group on Transportation*, Braunschweig, Germany, 2018.09.17-19

Luís Miguel Azevedo Duarte, Teresa Galvão Dias, Marta Campos Ferreira. 2018. "START - Sustainable Transport Awareness Recommendation Tool." presented at EWGT 2018, *21st Meeting of the Euro Working Group on Transportation*, Braunschweig, Germany, 2018.09.17-19

Marta Campos Ferreira, Teresa Galvão Dias, João Falcão e Cunha. 2017. "Guidelines for designing customer centred mobile payment services." presented at *QUIS*, Porto, Portugal, 2017.06.12-15

Pedro Costa, Fontes, T., António Nunes, Ferreira, M.C., Costa, V., Dias, T.G., Borges, J.L., Falcão e Cunha J. 2015. "Seamless Mobility: a disruptive solution for public urban transport." presented at *22nd ITS World Congress*, Bordeaux, France, 2015.10.5-9.

Marta Campos Ferreira, João Falcão e Cunha. 2014. "Experiences from evaluating an integrated mobile payment, ticketing, and couponing service solution based on NFC." presented at *23rd Frontiers in Service Conference*, Miami, USA, 2014.06.26-29.

Marta Ferreira, André Cunha, Henriqueta Nóvoa, Teresa Galvão, Manuel Moniz da Cunha, João Falcão e Cunha. 2012. "A Survey of Current Trends in Smartphone Based Payment and Validation Services for Public Transport Users." presented at *Art & Science of Service Conference*, Maastricht, The Netherlands, 2012.06.27-29.

5.3 Future Work

Future work identified was divided into four main research directions. The first is related with a holistic vision of public transport services, leveraging mobile ticketing to deliver personalized offers from city service partners. The second concerns the application of the DMTS methodology to integrate other mobility providers in the design of mobility-as-a-service solutions. The third is related with the use of O-D matrix generated by Anda to validate O-D matrix estimation algorithms. The fourth is related with mobile ticketing services post-deployment studies.

The first research direction is related to the main motivation of this thesis which is to promote the use of cleaner and more efficient means of transport such as the public transport. Most mobile-based solutions are focused on services related with the journey itself (mobile ticketing, real-time traffic information and trip planners). By adopting a holistic point of view, and considering every trip has a purpose (work, school, shopping and entertainment), a new service approach is proposed by Ferreira and Dias (2015). This multiservice approach consists in linking city services and public transport through partnerships that may include discounts, combined packages, reduced prices, deals and marketing campaigns, targeted to each specific audience. New technologies are essential to make these initiatives more effective and targeted. For example, services made available through personal mobile devices allow companies to interact directly with their customers and customize the offer. Service providers acquire knowledge about their customers, through their mobility profiles and spending habits, and are able to target their offerings to a specific audience.

In order to develop these partnerships it is important to analyse the services located around the stations and the public transport usage. Urban mobility and services geolocation data were analysed to discover the type of services that tend to concentrate around public transport stations (Ferreira, Dias, and Falcão 2018). A case of service exposure to different demographic segments was explored to demonstrate the value of transport usage data to service providers (Ferreira, Costa, et al. 2017). A personalized recommender system based on public transport passengers' mobility profiles and daily activities was developed (Duarte, Dias, and Ferreira 2018). From this ongoing research work, an empirical validation is missing. Testing the concept and the recommendation tool is important to assess the value of the multiservice approach proposal and represents a first step towards its implementation. These are the proposals for future work regarding the first research direction.

The second research direction consists in evolving the concept of mobile ticketing into a mobility-as-a-service solution. This adds complexity to the model since other mobility providers, usually competitors, are introduced. It is believed that the DMTS methodology serves this purpose very well, since it is characterized as being a methodology that actively involves all the stakeholders in the value co-creation process.

The third research direction is related with the Anda mobile ticketing solution. This solution was deployed in Porto, Portugal, in June 2018 and opens doors to further research. It produces a lot of data and the micro-location of passengers based on beacons allows to know the exact origin-destination matrix. First it is important to measure the accuracy of the information recorded. Then it may be useful to validate O-D matrix estimation algorithms that are consecutively being proposed by researchers.

The fourth research direction is related with mobile ticketing services post-deployment studies. Now that there are already mobile ticketing solutions in place, two types of studies may be conducted. One is related with the natural evolution of technology adoption studies into studies about customer churn factors. Why do people have everything ready to use a mobile ticketing solution and never use it? Or why do people stop using mobile ticketing solutions and prefer to go back to traditional systems? Answering these questions will be useful to understand customers' behaviour in post-deployment environments.

The second study is related with a deeper exploration of mobile ticketing solutions impacts. There are already studies on expected impacts, now it is important to measure the actual impacts. Are stakeholders' expectations fulfilled? What is the level of customer satisfaction with public transport services? Are mobile ticketing services contributing to people make the switch from private to public transport? Answering these research questions is key to assess the actual impacts of mobile ticketing services.

Appendix

Appendix A – News about Anda development

Several news on the development of Anda were published in the various media channels. Figure 42, Figure 43 and Figure 44 are to examples.

Andante deve estar disponível no telemóvel já em Abril | Transportes |... https://www.publico.pt/2018/01/15/local/noticia/andante-deve-estar-d

TRANSPORTES

Andante deve estar disponível no telemóvel já em Abril

Transportes intermodais do Porto estão satisfeitos com a evolução dos testes na aplicação. Telemóveis da Apple ficam de fora, para já, por questões tecnológicas.

ABEL COENTRÃO · 15 de Janeiro de 2018, 17:33

O Anda já está em testes desde Abril do ano passado JOANA GONÇALVES

À primeira vista funciona tudo bem. Aberta a aplicação, basta encostar o telemóvel ao validador e iniciar viagem no metro do Porto, num comboio urbano da CP ou num autocarro com tarifário Andante. No ecrã, o percurso vai sendo registado, estação a estação, ou paragem a paragem, e não é preciso fazer nada ao sair, pois ao nosso afastamento do veículo a viagem é dada como terminada. A partir de Abril, quem tiver um telemóvel Android vai poder deixar de usar cartões para viajar nos transportes do Porto, e paga no fim do mês. O *Anda* até pode tornar a nossa mobilidade mais barata, promete a empresa

Leia sem limites ASSINE JÁ Desde 0,99€ ×

FIGURE 42. NEWS ABOUT THE ANDA DEVELOPMENT IN PÚBLICO JOURNAL[18]

[18] Available at https://www.publico.pt/2018/01/15/local/noticia/Andante-deve-estar-disponivel-no-telemovel-ja-em-abril-1799401

to: bilhete Andante vai estar nos telemóveis em abril | TVI24 https://tvi24.iol.pt/sociedade/metro/porto-bilhete-andante-vai-estar-nos-...

tvi24

https://tvi24.iol.pt/sociedade/metro/porto-bilhete-andante-vai-estar-nos-telemoveis-em-abril

Porto: bilhete Andante vai estar nos telemóveis em abril

Aplicação "Anda" poderá ser usada no Metro, STCP, CP e e em operadores privados da Área Metropolitana do Porto. Metro será prolongado a partir do próximo ano, com estações desenhadas por Souto Moura e Siza Vieira

2018-01-15 14:43

Porto (arquivo). Reuters

O sistema de bilhética Andante, adotado em operadores como o Metro do Porto, pode ser usado no telemóvel a partir de abril, dispensando cartões, dinheiro e "otimizando o tarifário" pago pelo cliente.

Criado pela Transportes Intermodais do Porto (TIP), a aplicação "Anda" é um título "Andante" desmaterializado, que evita preocupações com o tipo de viagens a comprar, no início do mês ou a cada deslocação, porque o sistema "atribui a cada passageiro o tarifário mais favorável", enviando-lhe a fatura para casa, explicou aos jornalistas esta segunda-feira, José Mendes, secretário de Estado Adjunto e do Ambiente.

Apenas disponível para smartphone [sistema Android], o "Anda" pode ser usado no Metro do Porto, nos autocarros da Sociedade de Transportes Coletivos do Porto (STCP), na CP e em operadores privados da Área Metropolitana do Porto.

> ***Nas Áreas Metropolitanas há tantos tarifários que é difícil às pessoas conseguirem perceber qual o que lhe é mais favorável, até porque muitas não conseguem, no início do mês, antecipar as necessidades que vão ter. Com este sistema de bilhética desmaterializado, o próprio sistema aplica ao cliente o tarifário que lhe é mais favorável"***, esclareceu o secretário de Estado Adjunto e do Ambiente.

Para o governante, "isto significa trazer mais pessoas para o transporte público".

> ***As pessoas não precisam de se preocupar em definir, no início do mês, qual o cartão que vão comprar. E isto pode mesmo significar poupança, porque o preço apresentado é sempre o preço mínimo para cobrir as deslocações que a pessoa efetuou"***, esclareceu João Marrana, administrador delegado da TIP (entidade formada pelo Metro, STCP e CP e

FIGURE 43. NEWS ABOUT THE ANDA DEVELOPMENT IN TVI24[19]

[19] Available at https://tvi24.iol.pt/sociedade/metro/porto-bilhete-Andante-vai-estar-nos-telemoveis-em-abril

FIGURE 44. VIDEO ABOUT THE ANDA DEVELOPMENT IN SIC NOTICIAS[20]

[20] Available at https://sicnoticias.sapo.pt/economia/2018-01-15-Bilhete-Andante-do-Metro-do-Porto-pode-ser-usado-no-telemovel-a-partir-de-abril

Appendix B – News about the Anda deployment

Several news were broadcasted in the various media channels (see Figure 45, Figure 46 and Figure 47 and Figure 47).


TRANSPORTES (HTTPS://WWW.DINHEIROVIVO.PT/TOPICO/TRANSPORTES/)

Anda. Passe Andante disponível no telemóvel a partir de sexta-feira

(Pedro Granadeiro/Global Imagens)

FIGURE 45. NEWS ABOUT ANDA THE DEPLOYMENT IN DINHEIRO VIVO[21]

FIGURE 46. VIDEO ABOUT THE ANDA DEPLOYMENT IN ANTENA 1[22]

[21] Available at https://www.dinheirovivo.pt/empresas/Anda-passe-Andante-disponivel-no-telemovel-a-partir-de-sexta-feira/

[22] Available at https://www.facebook.com/antena1/videos/10156248071690659/

FIGURE 47. VIDEO ABOUT THE ANDA DEPLOYMENT IN PORTO CANAL[23]

[23] Available at http://portocanal.sapo.pt/noticia/159418/

Appendix C – MobiPag Project

Appendix C.1 – MobiPag pre-pilot survey

1. What is your opinion about the possibility of making all payments through the mobile phone? (Select all options that apply)

a) I would love to try, since it would make payments easier.
b) I do not know if I trust / I think it is dangerous, but I would like to have information about how it is processed.
c) I would like to try, if it does not require a lot of work (training, changing mobile phone, changing phone number).
d) I do not think it is interesting / I do not need an additional payment system.
e) I do not know how it works, so I cannot give an opinion.
f) Another. Which?

2. What disadvantages or concerns do you associate with a payment situation through the mobile phone? (Select all options that apply)

a) What if my cell phone is stolen or lost?
b) What if the mobile application does not work?
c) What if the cell phone battery runs out?
d) What if I do not have enough balance?
e) Is the transaction between my mobile phone and the payment device secure?
f) Is my data on my phone secure?
g) How is the payment confirmed?
h) Another. Which?

3. What advantages do you associate with a payment situation through the mobile phone? (Select all options that apply)

a) I do not need to have money in my wallet.
b) Payment is faster
c) I may have access to value added services such as access to discounts or validation of tickets
d) I can maintain and access my payment history electronically
e) Can I have personalized services with some providers
f) I'm more likely to forget my wallet at home than my cell phone.
g) Fewer cards in the wallet (loyalty and banking for low value transactions).
h) Another. Which?

4. From the following scenarios, indicate the advantages and disadvantages you encounter in the situation where payment is made through the mobile phone.

Go to a bar or restaurant of the University and make the payment through the mobile phone. What advantages and disadvantages do you find?

____

You will take a trip on the University buses. You purchase the ticket in the Student Support Office and receive an electronic ticket on the mobile phone. On the bus, you validate the ticket using the mobile phone. What advantages and disadvantages do you find?

____

You use the university canteen. You purchase the meal ticket at the usual places and receive the electronic meal ticket in the mobile phone. The meal ticket is validated later using the mobile phone. What advantages and disadvantages do you find?

____

You lend 10 euros to a friend or colleague. Later, your friend or colleague pays you the debt through direct communication between your mobile phone and his. What advantages and disadvantages do you find?

____

6. In addition to these scenarios, where would you like to use mobile payments at the University of Minho?

____

7. Which mobile phone carrier do you currently use?

a) Vodafone
b) Optimus
c) TMN

8. Gender?

a) Female
b) Male

9. Age?

____

10. If you are interested in collaborating with the implementation of the mobile payments prototype, please give your email.

____

Appendix C.2 – MobiPag pilot customers' sample characterization questionnaire

1. Age?

a) 22-26 years
b) 27-31 years
c) 32-36 years
d) 37-41 years
e) 42-46 years

2. Gender?

a) Female
b) Male

3. Educational qualifications?

c) 12nd year
d) Bachelor, Graduate, Post-graduate
e) Master, PhD, Post-doctorate

4. Status at University of Minho

a) Student
b) Nonteaching employees

5. To which School/Institute of the University of Minho do you belong to?

a) Engineering School
b) Educational Institute

6. Do you have a smartphone?

a) Yes
b) No

(If you answer b) please move to Question 9).

7. What is the operating system of your smartphone?

a) Android
b) IOS
c) Symbian
d) Windows Mobile

e) RIM
f) Other

8. Select (up to 5 types) the applications you use most often.

a) Books
b) Business/Finance
c) Education
d) Transport
e) Games
f) Health/Fitness
g) Lifestyle
h) Music
i) Navigation
j) Newspapers/Magazines
k) Photos/Video
l) Social networks
m) Sport
n) Utilities
o) Meteorology

9. How often do you use the University of Minho canteen?

a) Everyday
b) More than 10 times per month
c) Less than 5 times per month
d) Never

10. How often do you use the University of Minho bars?

a) Everyday
b) More than 10 times per month
c) Less than 5 times per month
d) Never

11. How often do you use the University of Minho transport?

a) Everyday
b) More than 10 times per month
c) Less than 5 times per month
d) Never

12. Which payment method do you use most often?

a) Credit card
b) Coins and bills

13. How interested would you be in making payments with the mobile phone?

a) Very interested
b) Interested
c) Not very interested
d) Not interested

(If you answer a) or b) please move to Question 15).

14. Why are you “not interested” or “not very interested” in making payments with the mobile phone? (Select all options that apply)

a) I do not consider it safe
b) I lose my privacy
c) It requires training
d) Connection, network or battery problems may occur
e) I lose control over my expenses
f) It takes more time to pay
g) I need to buy a compatible mobile phone
h) I am afraid of losing my mobile phone

15. Would you prefer to have a different mobile payment application per merchant or a single mobile payment application for all merchants?

a) Use different mobile payment applications
b) Use the same mobile payment application

Appendix C.3 – MobiPag pilot merchants' sample characterization questionnaire

1. Age?

a) 22-26 years
b) 27-31 years
c) 32-36 years
d) 37-41 years
e) 42-46 years

2. Gender?

a) Female
b) Male

3. Educational qualifications?

a) 12nd year
b) Bachelor, Graduate, Postgraduate
c) Master, Doctorate, Post-doctorate

4. What university service do you belong to?

a) Bar
b) Student Support Office
c) Canteen
d) Academic Association

5. How do you consider your smartphone knowledge?

a) Very good knowledge
b) Satisfactory knowledge
c) Reasonable knowledge
d) I do not have any knowledge

6. Which payment method is most used by your customers?

a) Credit card
b) Coins and notes

7. Are you interested in receiving payments via mobile phone?

a) Very interested

b) Interested
c) Indifferent
d) Not very interested
e) No interest

8. Why are you “very interested” or “interested” in receiving payments via mobile phone? (Select all options that apply)

a) It will allow to increase sales
b) Students with no physical money can pay
c) The payment will be faster
d) Receipts and invoices will be easier to control

9. Why are you “not interested” or “not very interested” in receiving payments via mobile phone? (Select all options that apply)

a) It is not a safe payment mode
b) Customers will lose their privacy
c) It requires training
d) Connection, network or battery problems may occur
e) I lose control over my income
f) It takes more time to pay
g) I need to buy a compatible POS

10. Would you prefer to have a different mobile payment application per merchant or a single mobile payment application for all merchants?

a) Use different mobile payment applications
b) Use the same mobile payment application

Appendix C.4 – MobiPag usability testing script

Participants information:

Name: ____

Email: ____

Mobile phone number: ____

Mobile phone IMEI: ____

Tasks:

You should read the tasks aloud and think aloud while you work them out.
At the end of each task you should assign a rating of 1 to 5 regarding the difficulty you had in resolving the task in question, where 1: Very difficult, 2: Difficult, 3: More / less difficult, 4: Easy, 5: Very Easy.

1. Open the Mobipag application

Time (seconds)	
Rating (1 to 5)	
Comments (verbal user comments, menu selection errors, difficulties, ...)	

2. Make a purchase of a fruit, taking into account the following parameters:
    a. Multibank account to use: CGD;
    b. Simple payment without resorting to coupons or discounts.

Time (seconds)	
Rating (1 to 5)	
Comments (verbal user comments, menu selection errors, difficulties, ...)	

3. Go to the Student Support Office and make a purchase of 1 bus ticket.
    a. Multibank account to use: CGD;
    b. Simple payment without resorting to coupons or discounts.

You will receive the ticket you purchased + an offer of a travel ticket.

Time (seconds)	
Rating (1 a 5)	
Comments (verbal user comments, menu selection errors, difficulties, ...)	

4. Check the bus tickets that have been stored on your mobile phone. How many?

Time (seconds)	
Rating (1 to 5)	
Comments (verbal user comments, menu selection errors, difficulties, ...)	(the participant must indicate 1 ticket)

5. Go to the canteen ticket sales office and buy 1 student meal ticket and 4 tickets in the amount of 0.05 € / each.
   a. Multibank account to use: CGD;
   b. Simple payment without resorting to coupons or discounts.

You will receive:

- The meal tickets purchased (1 meal ticket + 4 tickets of 0.05 €);
- 1 coffee coupon valid for use in the School of Engineering bar;
- 1 discount voucher in the amount of 0,2 € to use in the bar of the School of Engineering.

Time (seconds)	
Rating (1 to 5)	
Comments (verbal user comments, menu selection errors, difficulties, ...)	

6. Check how many meal passwords are stored on your phone. How many?

Time (seconds)	
Rating (1 to 5)	
Comments (verbal user comments, menu selection errors, difficulties, ...)	(the participant must indicate 1 meal ticket + 4 tickets of 0.05 €)

7. Verify what coupons have been stored on your phone. How many are and what kind?

Time (seconds)	
Rating (1 to 5)	
Comments (verbal user comments, menu selection errors, difficulties, ...)	(the participant must indicate 1 travel offer coupon + 1 coupon coffee offer + 1 coupon 0.20 €)

8. Go to the canteen and:
    a. Select 1 meal ticket and 4 tickets of 0.05 €;
    b. Put the phone on the tray;
    c. Choose the meal + an extra juice;
    d. Go to the employee and validate the pre-selected tickets.

Time (seconds)	
Rating (1 to 5)	
Comments (verbal user comments, menu selection errors, difficulties, ...)	

9. Go to the School of Engineering Bar and buy a coffee and a chocolate, taking into account the following:
    a. Select the "Direct Payment" option;
    b. Multibank account to use: CGD;
    c. Pay the coffee with the coffee offer coupon and discount the voucher of € 0.20 to the € 0.80 of the chocolate.

Time (seconds)	
Rating (1 to 5)	
Comments (verbal user comments, menu selection errors, difficulties, ...)	

10. Go to the bus stop and validate the bus ticket with the driver.

Time (seconds)	
Rating (1 to 5)	
Comments (verbal user comments, menu selection errors, difficulties, ...)	

Appendix C.5 – MobiPag interview script

1. What do you think of the Mobipag mobile application? Useful or not? Why?

2. What did you like most about the application?

3. What did you did not like about the application?

4. What did you find confusing or difficult about using the application?

5. What do you suggest to improve the application?

6. What options would you like to have available that the application does not have?

7. What do you think about the safety of the application?

8. Suppose you have a smart phone equipped with NFC, would you use this application to make payments? Would you feel safe?

____

If you answered "No" move to Question 10.

9. If yes, would you be willing to pay extra for the service?

   a) Not
   b) Only the value of the application (up to € 2)
   c) 5 Cents per ticket
   d) 10 Cents per ticket
   e) 20 Cents per ticket

Your questionnaire ends here.

10. If no, would you change your mind if tickets purchased through the app were cheaper?

Appendix C.6 – Discussion of MobiPag qualitative results

This appendix is largely based on Rodrigues, Helena, Rui José, André Coelho, Ana Melro, Marta Campos Ferreira, João Falcão e Cunha, Miguel Pimenta Monteiro, and Carlos Ribeiro. 2014. "MobiPag: Integrated Mobile Payment, Ticketing and Couponing Solution Based on NFC." Sensors 14 (8): 13389–415. doi:10.3390/s140813389.

From the analysis of the empirical results, five relevant topics emerged allowing to identify a set of design lessons: a) usability in the payment system, b) perceived value, c) embodiment of payment system, d) guidelines for the design of NFC infrastructure, e) being in control, and f) security perception.

All of the interview excerpts were codified. The codes used for laboratory pilot interviews have "Lab" followed by the participant's code: "Cust + number". The codes used for the experimental interviews have "Ex" followed by the customer's code "Cust + number" and the merchant's code "Mrch + number". We will use this notation in the following sub-sections when we are presenting some interview excerpts that are relevant for our analysis.

A. *Usability in the payment system*

Usability testing allowed gathering important information concerning the design of mobile payments applications. Several guidelines and conclusions can be outlined in order to achieve a user-friendly and easy-to-use mobile payment interface.

- Terminology: the choice of words and phrases is very important to prevent from error and misleading actions. We noticed a great improvement when we changed some words in the application screens. Users understood better what they could expect from each menu, preventing them from failing when performing a task.
- Buttons or symbols that don't work should be identified and eliminated. Their existence may cause frustration to users.
- Buttons must be designed so to appear as buttons. Sometimes designers tend to give more importance to the aesthetic aspect rather than the functional. During the testing, users had difficulty in understanding that certain text boxes were actually buttons that could be touched to perform an action. For instance, the buttons "escolha os cupões" and "próximo" from the first screenshot of Figure 48 seemed to users "a banner or a footnote". Users take longer to identify those as buttons, increasing the time they took to complete the tasks. Other buttons like "carregue voltar para cancelar" from the second screenshot of Figure 48 were not identified by users as buttons. When users were performing the payment tasks, they frequently touched the button accidently, cancelling the payment. Users did not understand what had happened and why the payment had been cancelled.

FIGURE 48. MOBIPAG MOBILE APPLICATION SCREENSHOTS

- The system must provide users feedback. This feedback includes giving information about what is going on (e.g. the payment transaction is being processed), and the new status of the system resulting from the user's choices (e.g. show the user he has selected 2 coupons).
- The choice of the technology in which the system will rely on is very important. In this case, our system was based on NFC technology, which is relatively new and is not stable. During the testing several NFC connection problems occurred, making the users take longer to complete the tasks. This lead to users' frustration and influenced their perception of the system in a bad sense. We had also some troubles with wireless network connectivity, which contributed to a poor experience.

B. Perceived value

Participants have perceived the value of our payment solution in very diverse ways. A first group has mainly focused on the payment itself, highlighting the importance of performance, its value as a cash replacement and the advantages of not having to carry the wallet, cash and credit cards.

I usually never carry cash and it was interesting to have the mobile phone for payments, since I already save a lot of information on the mobile phone. [Lab_Cust2]

I find it very useful, I think it's a way of not having to carry the credit card or cash in your wallet. [Lab_Cust9]

It's a way of saving time to people, because it is very fast. It is environmentally friendly, which is very important, it does not use paper. [Lab_Cust9]

Useful, I don't like to carry money, I usually pay everything with credit card. If it is fast enough. [Ex_Cust2]

At the canteen maybe it took more time, but in other places, at the bar, takes up more time [to pay with money or credit card] than what it took [with the mobile phone]. [Ex_Cust6]

The facility of being using something that is already in our hands every day, we can buy daily things. Furthermore, it is easy to use and fast learning. [Ex_Cust7]

On the contrary, another set of participants have referred that they would prefer to pay with cash and that, despite being helpful, they would not see the mobile payments app as necessary.

It is helpful, but not necessary, because there are other payment methods that are satisfactory to me now. And besides, you need to have specific devices that not everyone has or is willing to have. [Lab_Cust1]

I found it interesting. But I prefer to pay with cash." [Lab_Cust8]

While some users seem to associated some value with the possibility to replace cash, problems with battery duration and with the non-ubiquitous nature of NFC payments at points of sale, will create a situation where this type of value of proposition is not enough because, even if deployed in a larger scale, mobile payments will have to share the payment space with other forms of payment and, at least for a long time, with cash. Therefore, more than knowing how many people would prefer mobile payments to cash, our main concern was to find what type of unique value propositions participants associated with mobile payments. Identifying those value propositions could significantly help to frame the design of mobile payments towards early adoption scenarios rather than generic scenarios where they would be competing with cash. In our case, this additional value proposition was mainly centred on the ability to integrate tickets and discount coupons directly in the payment process. These features were largely appreciated by participants, particularly the possibility to buying tickets, carrying them on the mobile phone and validated them for gaining access to services.

[...] More than to not have to carry coins is to facilitate the whole process, because while riding the bus, it was quite boring having to buy the ticket. [Lab_Cust3]

I liked the part about having multiple services, like transports, canteen. [Lab_Cust7]

The improvement suggestions made by participants have also focused very much on this particular point. The integration with online services were the main suggestions received, buy the tickets online and then validate them with the mobile phone would save time and the environment. And another suggestion made was the possibility of having access to all information about payments and validations made, daily, weekly or monthly.

However, we have clearly observed that this flexibility comes with a cost in complexity of the procedures and cognitive overload for users in payment situations. While the overall procedures we considered simple by participants, coupon redemption and to a lesser extent the use of tickets, were clearly the activities in which participants have experienced more difficulties. While some of the problems could be connected with specific usability problems that could easily be overcome, it was also clear that there was also a problem with the overall mental model associated with these complimentary services. The lack of an obvious references and established practices means that people do not have an understanding about how the system is supposed to work:

Some tasks that I have been requested, the use of coupons and iconic concepts, the images are misleading. [Lab_Acq1]

Payments tasks, coupons, the fact that we could not see the coupons and use them directly. [Lab_Acq3]

Coupons associate a free voucher to a bank, it does not feel correct. [Lab_Acq7]

C. *Embodiment of payment system*

A key property of NFC-based payments is the need to approach the mobile device from the reading device, which in our prototype was always another mobile phone. As a consequence, there was not formally a POS optimized for intensive usage, something that seemed to be part of the expectations and frame of reference of the merchants in our study:

The payment receiving system, if it was a reading system, like on supermarkets, it would be more advantageous and faster. [Ex_Mrch1].

While we anticipate that future instantiations of the technology can have a whole different level of integration with Points of Sale (see section D), one of the strong points of this payment system based on mobile phones is also the ability to very quickly establish a payment system using only mobile phones. While not a relevant scenario for major stores, it may constitute a relevant value proposition for many small businesses that due to reduced number of sales or the inherently mobile nature of the their businesses do not justify a full POS system. In our prototype, we considered two approaches, both of which closer to more ad-hoc payment situations: the first was a simple and direct use of two mobile phones that were touched without any particular support for the interaction (Figure 49a); the second was a simple stand for the merchants' mobile phone (Figure 49b, Figure 49c).

a) b) c)

FIGURE 49. MOBIE PHONE INTERACTION WITH POS: A) CONTACT WITHOUT SUPPORT; B) MERCHANT SUPPORT; C) CONTACT WITH A MERCHANT SUPPORT

In the first design, both parts of the transaction had to hold their mobile phones and approach them. The main observation is that it clearly forced participants to break the boundaries of social distance and interact at a level of proximity that was more on the range of personal or even intimate distance. The need to approach hands, aligned them to achieve communication and wait in that position for the communication to occur further, contributed to this feeling. While the extent to which this is a problem may vary considerably between people, it is still an issue that will always be relevant when considering this form of payment for more than occasional transactions.

In the second design, a very simple physical support was used to hold the merchants' mobile phone and make it stand in a vertical position. This would then allow the customers' mobile phone to touch back-to-back with the merchants' mobile phone, while they can both check the information on their display. Our main observation was a clear trade-off in the stand design between having the merchant's mobile phone facing up to facilitate interaction by the merchant or having it facing down, to make it easier for the customer to perform the NFC communication by touching its back. The vertical position offered by our physical stand was an obvious compromise, but it still was not very practical for merchants to interact with the mobile phone while standing at a lower position. For this reason, merchants quickly developed the practice of holding the stand in their hand while inserting the details of a transaction and then placing it next to the customer so that he could perform the NFC transaction. The fact that the stand was mobile gave this flexibility to the merchant, but was not so positive for customers. When approaching the stand to make the NFC transaction, many people have shown some fear of pushing it away. This has negatively impacted on the performance of NFC operations, as it made the correct alignment a bit harder. With time, many customers developed the practice of holding the stand while the person was approaching the mobile phone.

D. Guidelines for the design of NFC infrastructure

Despite the pertinence of the observations described in previous sections, the MobiPag team had, naturally, a clear understanding about the limitations of this purpose-build support. It was, however, a prime tool used for defining what a commercial solution should provide in terms of industrial design for mobile devices holders.

First of all, the support should provide for a stable surface where the mobile phone could be placed without forcing the customer to hold the device until the operation is completed.

With the vertical support used for the pilot, there was a tendency for the customer to remove the device before the operation was completed. With the vertical layout, the customer had to hold the device until the completion of the operation. With duration of some of the operations beyond 15 or event 20 seconds, holding the device completely still could be quite hard on the customers arm.

A horizontal surface, where the phone would be placed, with the screen of the mobile phone facing the customer and giving him the feedback of the pending operations, would certainly offer the best choice for the layout.

The surface should provide a clear indication of the location where to place the phone, possibly with a diagram representing the device, and some instructions on how/where to place the phone. More sophisticated designs could be considered, with displays (LED or a small screen with instructions, similar to those found on current PTA devices) on the surface giving clues/instructions to the customer at each of the payment stages.

One could argue that it would be difficult for certain locations to have the necessary free space on the stores for this "payment surface". Nonetheless, using remote NFC antennas connected to the POS, could solve some of the difficulties arising from this horizontal layout.

From the merchant's point of view (or as in this case, the POS operators) having the system linked to the Point of Sale, could provide for and integrated approach that would avoid redundant operations (the amount to pay, for instance, would be provided by the POS software at the beginning of the payment operation). So, for an operator, the only thing needed would the feedback of the operations being giving directly on the POPS screen, thus making a support unnecessary or, at least, viewing the mobile device screen avoidable.

E. Being in control

Fundamental to any payment process is that users and merchants can always feel that they are in full control of what is happening. When using NFC, the semantics and implications of the taps, in which the mobile devices are touched, is the core part of this control process.

Even though we had a very high success rate in the transactions made by participants, there were also some error situations. These failed transactions were due to a broad range of issues, the most common being some failure in the contact between mobile phones or network failure on the merchants' device. While we could expect this error rate to become even smaller, what was most striking from our evaluation situations was how people felt lost when it happened. With other payment technologies, both customers and merchants have a more developed model of how the system works and what can be tried to circumvent the problem. Faced with a new technology about which they lacked the knowledge that results from previous experience, participants were clearly lost in error situations and unable to initiate any problem solving procedures, other than re-initiating the whole payment process from the beginning and hope it could then work.

One of the strongest points in our solution was the flexibility provided by integrating payments with complimentary services such as tickets and discount coupons. However, we have clearly observed that this flexibility comes with a cost in complexity of the procedures and cognitive overload for users in payment situations. What could be a simple procedure may become very complex from a cognitive perspective when multiple types of coupons, discounts, promotions and fidelity schemes become part of the payment transaction. While the overall procedures were considered simple by participants, coupon redemption and to a lesser extent the use of tickets, were clearly the activities in which participants have experienced more difficulties. While some of the problems could be connected with specific usability problems that could easily be overcome, it was also clear that there was also a problem with the overall mental model associated with these complimentary services.

Payments tasks, coupons, the fact that we could not see the coupons and use them directly. [Lab_Cust3]

There are multiple sequences of procedures that could be followed to achieve essentially the same goals and people do not have established practices for understanding how the system is supposed to work. The fact that certain operations, such as using tickets, required only one tap instead of two was also confusing:

There are situations that it only asks for one tap, and others that asks for two and that is a bit confusing. [Ex_Cust9].

F. Security Perception

Participants expressed the opinion that the system is secure and that the information given by the application provides confidence and security. They indicated that asking for a PIN code in some of the transactions, receiving feedback messages, such as the message "operation successfully concluded", receiving confirmation beeps, feeling the NFC connection vibration or even realizing the need to physically approach one mobile phone to the other, were all elements that contributed to their perception of security and trust. Having explicitly mentioned the security mechanisms integrated in our mobile payments system, users are likely to be validating those mechanisms and informing developers that initial perceptions may be mitigated in real-world contexts.

It is secure because in addition to hearing a beep, we receive a message. And then we can realize that the transactions were executed. (Lab_Cust9)

The protocol was important for the perception of security. I approached my mobile phone and received the amount to pay. I confirmed and approached the mobile phone again and received confirmation. (Lab_Cust5)

I think this is safe because it always asked for a PIN. (Ex_Cust3)

Apart from the troubles in understanding the security inherent to the payment process, almost all merchants mentioned that the fact that some of the transactions asking for a PIN gives the system a sense of security. This is curious, as merchants were never asked to enter a PIN, but they also have shown, in a real-world context, that they understand that the system must provide a sense of trust and security to users:

Because a PIN was needed, I thought it was very secure. The confirmation message is important, because otherwise we never know if the transaction was successful or not. (Ex_Mrch1)

We are always a bit distrustful at the beginning because it is a new technology and because we are dealing with money; at the beginning I was a bit confused, but with time, I realized that the system was secure. (Ex_Mrch3)

Contact with a real-word deployment of a mobile payments system was also very important for the perception that mobile payments share similar security issues with more conventional payment systems, such as debit or credit cards. Users have explicitly provided some comparisons with those systems:

In terms of safety I presume that it will be a secure system and it is like a credit card: if it got stolen, it needs a PIN, so the problems that exist in other payment methods also exist here. (Lab_Cust3)

Much more insecure than Internet payments, because it just uses a PIN. Is similar to the credit card payment. (Lab_Cust4)

Appendix D – MobiPag STCP Project

Appendix D.1 – MobiPag STCP usability testing sample characterization questionnaire

1. Age?

f) Less than 20 years
g) 20-35 years
h) 36-50 years
i) 51-65 years
j) More than 65 years

2. Gender?

c) Female
d) Male

3. Nationality

____

4. Country and Municipality residence

____

5. Educational qualifications?

a) 4^{th} year
b) 9^{th} year
c) 12^{th} year
d) Bachelor's, Graduate, Post-Graduate
e) Master's, PhD, Post-Doctorate

6. Occupation

____

7. On average, how often do you use public transport?

a) 1 to 5 times per week
b) 1 to 5 times per month
c) 1 to 10 times per year

d) Never

8. What type of travel do you make more often using public transport?

a) Urban
b) Intercity

9. On your urban / long-distance journeys, which means of transport you use most often. (If your journey normally includes transfers between different means of transport, you can select more than one option).

a) Bus
b) Metro
c) Train

10. Where do you buy travel tickets for public transport (Select all options that apply)?

a) Ticket vending machines
b) Andante stores
c) Payshop and CTT Agents
d) ATM network
e) Road Operator Terminals
f) Inside the Bus
g) STCP Attendance Centers
h) CP ticketing stores
i) Internet
j) Other. Which?

11. Do you have a smartphone?

a) Yes
b) No

If you answered no, your questionnaire ends here.

12. What is the operating system of your smart phone?

a) Android
b) IOS
c) Symbian
d) Windows Mobile
e) RIM
f) Other. Which?

13. Select (up to 5 types) the applications you use most often.

a) Books
b) Business/Finance
c) Education
d) Transport
e) Games
f) Health/Fitness
g) Lifestyle
h) Music
i) Navigation
j) Newspapers/Magazines
k) Photos/Video
l) Social networks
m) Sport
n) Utilities
o) Meteorology

Appendix D.2 – MobiPag STCP usability testing tasks script

You should read the tasks aloud and think aloud while you work them out.
At the end of each task you should assign a rating of 1 to 5 regarding the difficulty you had in resolving the task in question, where 1: Very difficult, 2: Difficult, 3: More / less difficult, 4: Easy, 5: Very Easy.

1. Register in the application

Since you are not yet registered in the mobile application and therefore have no data to log in, please register in the application by selecting the "Register" option.

The data you enter will not be recorded, nor will its veracity be verified.

When you are asked for the verification code (in step 2 of the registration), you should use the verification code: 1234, because it is a prototype, it does not have interconnection with your mobile phone.

2. Plan a journey

Suppose you want to go from the *Aeroporto* to *Aliados*, but you do not know how. Go to the "Trips" menu and plan a trip with the following data:

a. From: *Aeroporto*
b. To: *Aliados*
c. When: 09/20/2011; 16:20
d. Operators: Metro
e. Walking (min.): 10

3. View maps

Look in the "Info" menu for the subway map. Select the Blue Line and say which station is following the *Estádio do Dragão*.

4. Check prices

Imagine you want to know the price of occasional tickets. Tell us how you would search for the prices.

5. Buy travel tickets by zone

Suppose you want to buy travel tickets. Go to the "Buy" menu and:

a. Select the option: Occasional Travel Titles
b. On the next page, choose:
c. Type: Z2

d. Quantity: 5
e. Confirm
f. Use code 1111 when you are asked to confirm your purchase

6. Buy travel tickets by station

Buy travel tickets from the *Aeroporto* to the *Aliados*, using the following data:

a. Type of ticket: Occasional travel ticket
b. From: *Aeroporto*
c. To: *Aliados*
d. Quantity: 2

7. Check balance

Imagine that you have already purchased several travel tickets and want to know what your travel balance is. Tell us your current travel balance.

8. Check validation history

Suppose you have used your mobile phone to validate your travels. Tell which were the last three stations in which you validated your travel ticket.

9. Validation

Imagine that you validated a travel ticket today at 17:45.

Then focus on the Scan menu and see the 25 min.

Suppose it is 6:35 p.m., and that the maximum duration of a travel ticket Z4 is 1:15 p.m.

What does the 25 min number on the Scan screen mean?

a. It has been reviewed 2 times
b. 25 minutes to reach the maximum travel time
c. The next transport arrives in 25 minutes

10. Add bank account

Suppose you want to add a bank account. Go to the "Configuration" menu and add a bank account, with NIB, with the following data:

a. Country: Portugal
b. First Name: Hugo
c. Last Name: Rodrigues
d. Name of Bank: BES

e. Location of the Bank counter: Gandra
f. NIB: 123456

11. Disable Automatic Renewal of Monthly Subscription

Imagine you do not want to automatically renew your Monthly Subscription. In the Setup menu, disable this option.

12. Disable Sound and Vibration options

Turn off the options: Sound and Vibration.

Appendix D.3 – MobiPag STCP usability testing final evaluation questionnaire

1. What do you think of the Mobipag STCP mobile application? Useful or not? Why?

2. What did you like most about the application?

3. What did you did not like about the application?

4. What did you find confusing or difficult about using the application?

5. What do you suggest to improve the application?

6. What options would you like to have available that the application does not have?

7. What do you think about the safety of the application?

8. Once the transport ticket is purchased, it is stored in the mobile phone. Ticket validation will be done by bringing the mobile phone closer to the existing validators (see figure). Thus, the mobile phone communicates with the validator through Near Field Communication (NFC) technology. This technology can be compared to Bluetooth, but it is preferable to make payments, since it provides faster connectivity between equipment, less probability of interference, and works only at short distances (4cm), making use safer in crowded places.

Suppose you have a smart phone equipped with NFC, would you use this application to buy and validate transport tickets? Would you feel safe?

____

If you answered "No" move to Question 10.

9. If you answered yes, would you be willing to pay an additional fee for the service?

   a. No
   b. Only the value of the application (up to € 2)
   c. 5 Cents per ticket
   d. 10 Cents per ticket
   e. 20 Cents per ticket

Your questionnaire ends here.

10. If you answered no, would you change your mind if tickets purchased through the app were cheaper?

Appendix D.4 – MobiPag STCP pilot sample characterization questionnaire

1. How long do you have a smartphone?

a. Less than 6 months
b. Between 6 months and 2 years
c. More than 2 years

2. Select (up to 5 types) the applications you use most often.

a) Books
b) Business/Finance
c) Education
d) Transport
e) Games
f) Health/Fitness
g) Lifestyle
h) Music
i) Navigation
j) Newspapers/Magazines
k) Photos/Video
l) Social networks
m) Sport
n) Utilities
o) Meteorology

3. On average, how often do you use public transport?

e) 1 to 5 times per week
f) 1 to 5 times per month
g) 1 to 10 times per year
h) Never

4. What type of travel do you make more often using public transport?

c) Urban
d) Intercity

5. On your urban / long-distance journeys, which means of transport you use most often. (If your journey normally includes transfers between different means of transport, you can select more than one option).

d) Bus
e) Metro
f) Train

6. Where do you buy travel tickets for public transport (Select all options that apply)?

k) Ticket vending machines
l) Andante stores
m) Payshop and CTT Agents
n) ATM network
o) Road Operator Terminals
p) Inside the Bus
q) STCP Attendance Centers
r) CP ticketing stores
s) Internet
t) Other. Which?

7. What means of payment do you usually use to pay the tickets?

a. Notes and coins
b. ATM card

8. What type of tickets do you usually buy more often?

a. Occasional titles. Zones? ________
b. Andante 24. Areas? ________
c. Monthly Pass. Zones? ________
d. Other. Which? __________

9. What kind of additional services related to public transport do you use?

a. Consultation of maps (travel plans, lines, ...)
b. Timetable consultation
c. Consultation of tariffs
d. Complaints
e. Customer service line
f. Discounts on partner services from your transport operator
g. SME Bus
h. Mobile applications. Which? _______________
i. Others. Which? ________________

10. What type of channels do you use to access the services of your public transport operator (information, maps ...)?

a. Physical stores
b. Stops / Stations
c. Website
d. Facebook

e. Telephone
f. Email

11. Rate (from 1 to 5) the following statements regarding the purchase and validation of tickets using currently available methods, where:

1 - Strongly Disagree
2 - Disagree
3 - I do not agree or disagree
4 - I agree
5 - Totally Agree

a. I have already lost my Andante card several times.
b. I have difficulty in understanding what kind of ticket (Z2, Z3, Z4 ...) I have to buy to make a certain trip.
c. I find it easy to buy tickets at the vending machines.
d. I have been through situations where I did not have the money (notes and coins) to buy tickets at the vending machines.
e. I do not (or would not) like to move to a physical store to renew my monthly pass.
f. I find it easy to validate tickets on the validators.
g. I would like to know how much time I have left after I've validated the ticket.
h. I would like the system to inform me of the stop to which I can travel with the ticket I have validated.
i. I would like to be able to store more than one type of different title (e.g. Z2 and Z3) on my walking card.
j. I would like access to my travel history.
k. I would like to know how much you spend per month on public transport.
l. I am more likely to forget the walking card at home than the mobile phone.

12. Rate (from 1 to 5) the following statements regarding the purchase of tickets through the mobile phone, where:

1 - Strongly Disagree
2 - Disagree
3 - I do not agree or disagree
4 - I agree
5 - Totally Agree

a. Buying transportation tickets with your mobile is a good idea.
b. I want to use my mobile phone to buy transportation tickets when this service is available.
c. Payments with your mobile phone are a useful payment method.
d. Buying transport tickets with the mobile phone is compatible with the other uses that I make of the mobile phone.
e. Buying tickets with the mobile phone is compatible with my lifestyle and habits.
f. I would feel safe buying tickets with my mobile phone.
g. Mobile phones are reliable enough to buy tickets.

h. Mobile networks are reliable enough to purchase tickets.
i. When buying tickets, the risk of running out of battery power or running out of a network is low.
j. The risk of problems with the ticket purchase application is low.
k. The risk of me making mistakes when buying tickets with my mobile phone is low.

13. Rate (from 1 to 5) the following statements related to the validation of tickets through the mobile phone, where:

1 - Strongly Disagree
2 - Disagree
3 - I do not agree or disagree
4 - I agree
5 - Totally Agree

a. Validating transport tickets with your mobile phone is a good idea.
b. I want to use my mobile phone to validate transport tickets when this service is available.
c. Phone validations are a helpful payment method.
d. Validating transport tickets with the mobile phone is compatible with the other uses I make of the mobile phone.
e. Validating tickets with my mobile phone is compatible with my lifestyle and habits.
f. I would feel secure in validating transport tickets with my mobile phone.
g. Mobile phones are reliable enough for ticket validation.
h. Mobile networks are reliable enough for ticket validation.
i. When validating tickets, the risk of running out of battery power or running out of a network is low.
j. The risk of problems with applying tickets validation is low.
k. The risk of me making mistakes in validating tickets with my mobile phone is low.
l. The risk of not receiving the ticket or receiving late is low.

14. What advantages do you associate with the purchase and validation of transport tickets through the mobile phone?

____

15. What disadvantages do you associate to the purchase and validation of transport tickets through the mobile phone?

____

16. Gender? _______

17. Age? _______

18. Name? ______

Appendix D.5 – MobiPag STCP pilot interview script

1. How do you usually commute in your day-to-day life?

- (Bus, metro, foot ... frequency of use of each means of transport)

2. You use the bus and metro, right? What activities do you do to travel on the bus? How is your public transport travel experience?

- How do you buy tickets? How do you validate tickets?
- Do you understand the MAP zone system?
- Where do you usually buy the tickets? Why do you buy from these sites?
- Context of validation: arrives to the bus in a hurry, carries a lot of things.

3. What do you consider important to have a good experience in these activities?

4. What do you value in a mobile ticket purchase and validation system?

5. What did you think of the MobiPag STCP application in the execution of purchase / validation and querying activities / tasks?

- Opinion on each task.
- Useful? Not useful? Why?

6. What did you like most about the application?

7. What did you dislike / find confusing / difficult in the application?

8. How and when did you buy tickets with the application?

9. How and when did you validate tickets with the application? (Was it convenient?)

10. What features would you like to have available that the application does not have?

11. What do you suggest to improve the application?

12. Compared to traditional payment methods, what do you think about the safety of the application?

13. In the future how do you see this application working in terms of payment? Would you rather have a separate account to pay for public transport and periodically load that account, or would you rather have your bank account directly linked to the application and the value of the tickets would be discounted directly, or would you prefer the value of the tickets to be deducted from your mobile phone balance?

14. Would you use this application to purchase and / or validate transportation tickets?

15. If you answered yes, would you be willing to pay an additional fee for the service?

- Value of the application; value per ticket

16. If no, would you change your mind if the tickets purchased by the application were cheaper?

Appendix D.6 – Discussion of MobiPag STCP qualitative results

Analysis of the Facebook content and interviews texts enabled a deep understanding of the customer experience with mobile ticketing services, with the identification of a rich set of customer experience factors. By aggregating and renaming the similar concepts, 33 initial categories were first identified. These were then aggregated into ten dimensions of experience factors, which are explained below. Table 10 summarizes the findings by listing the experience factors and related categories. The first column also presents the % of participants that mentioned each factor. The final column indicates whether the factors have a positive or a negative effect on the adoption of mobile ticketing services.

A. Ease of Use

The users enjoyed the concept of using mobile phones to buy and validate travel tickets and considered the application very intuitive and easy to use. There were no doubts regarding the use of the application and everyday participants reported how successful they were in purchasing and validating the tickets.

"The application is pretty, well developed and is very easy to use" (M, 30s)

"I think I will no longer travel by bus today. Thus for the first day it went well. 5 validations with success." (M, 30s)

B. Usefulness

The value and usefulness of the proposed ticketing solution was consensual among all participants. They highlighted several advantages regarding the system such as the possibility to make payments anytime and anywhere, to avoid queues and to carry several types of tickets in the same device. They also considered useful having access to information about their journeys such as the remaining time they can travel, the alighting station, and the validations historic.

"It is very useful, I do not have to go to the queue to buy tickets and to carry coins with me." (F, 30s)

C. Convenience

One of the main advantages of mobile ticketing solutions stressed by the participants is to be able to purchase travel tickets ubiquitously. Users considered this payment method more convenient in comparison to traditional ticketing solutions, since it allows to purchase travel tickets anywhere and anytime, regardless of stores' opening hours. The ease and speed of the purchase process, the avoidance of long queues and not having to carry coins are also decisive factors for users.

"The purchase is very comfortable. I do not need to go to the queues and I am not worried if I have coins for the ticketing machines." (M, 50s)

Since people carry mobile phones with them most of the time, they are conveniently available in most situations, making them ideal for making payments.

"When I am waiting for the bus I am always with the mobile phone in hand, seeing emails or webpages. So, validating the ticket with the mobile phone is very convenient, since I do not have to take my wallet out of the pocket, and the travel card out of the wallet." (M, 30s)

D. Complementary Services

The mobile phone characteristics (screen, memory, sound) allows to provide additional and complementary functionality which is not possible through a contactless card. Participants appreciated the fact of having access to information related with their journeys and their account. Such personalized information, like tickets balance, remaining time to travel, and journey history, is not possible to provide through a contactless card with no screen.

"(…) all other features are excellent: see to where we can travel, travel time available, validations historic, and balance inquiry." (F, 40s)

"After validating the ticket it was possible to check the remaining time of the validated ticket. I found it a very nice feature." (M, 60s)

"I liked the idea of showing the information about the maximum distance I can travel with the ticket I chose." (F, 40s)

Participants suggested the inclusion of further services related with the transport service such as journey planner, interactive maps, and real time bus arrival information. Therefore, the offer of additional and complementary services seems to be a decisive factor in the adoption of a mobile payment system.

E. Aesthetics and Functionality

Regarding the design and aesthetics of the mobile application, some participants found it appealing and pretty, while others considered it was not very attractive and suggested some improvements, such as colours, password and PIN procedures, and the way of selecting the stop (most used stops, alphabetical order, etc.). Aesthetical pleasure, satisfaction, sense of beauty and functionality may explain why people prefer some mobile payment systems over other.

"The background colour of the validated ticket screen is very strong, not allowing a good reading of the information related to the ticket." (F, 30s)

"When typing the password or PIN, the application should ask for a double confirmation since there may be an error when we type it for the first time" (M, 30s)

"Today I had some difficulty in identifying the stop where I was, so it would be easier if I could search by the code or name of the stop." (M, 30s)

New functions were also suggested, such as the ability to choose the language of the application, save the history of the most used stops and receive alerts about the expiration of the monthly subscription. Some of these ideas were implemented during the test phase, while others set directions for future versions of the system.

"The application could save the last selected trips. Many people use only one bus line, home-work-home and so it would be easier to not have to reselect the same line and stop travelled." (M, 30s)

F. Complexity

Complexity is often mentioned as a barrier to the adoption of mobile payments. Among the most complex issues, the ticket validation process was the one that received most criticism. To validate a travel ticket, users had to choose the entry stop and line as well as the corresponding ticket. This procedure was considered laborious and heavy when compared to the current system which simply consists of sweeping the Andante card.

Participants advocated for the simplification of the process and suggested several ideas to it, such as choose the stop from a pre-defined list of last used stops, possibility to create a list of favourite stops, or use other technologies like NFC or QR Codes. Therefore, ticket validation process using mobile phones need to be simple and fast in order to be able to compete with physical cards.

"The main advantage of this system is the purchase of tickets. The other operations, such as validations, are more labour intensive than the actual system. That is, in my opinion, the part that needs to be worked. However it may be only a matter of habit." (F, 40s)

G. Reliability and Availability

A reliable mobile ticketing system must ensure that the mobile application and the backend perform a set of functions under certain circumstances and at a given time. If the system depends on internet connection, sensors or GPS to work, they must be available and reliable at every situations.

In this case, to purchase and validate travel tickets it is necessary that the mobile phone is connected to the internet. All participants had 4G data that could be used to perform those transactions, however they expressed concerns about who do not have that type of service, limiting the use of the proposed solution. Also, in some cases, participants had to turn on the 4G data to purchase and validate tickets, since the data service is usually turned off by default.

Moreover, in order to facilitate the validation process, it was necessary to locate the passenger using triangulation or GPS signal. This allows to find the boarding stop more quickly than a manual search. However, we found that GPS took some time to locate the passenger and geolocation through mobile networks proved in many cases to be quite inaccurate. Most of times users ended up on selecting the boarding stop manually which delayed the validation process due to this extra step. This fact also contributed to impoverish the validation experience.

"The GPS location has not been working very well, usually it chooses the wrong stop and today I validated when I was inside the bus (usually I go to the stop at the last minute, running). Even with this fixed, the GPS location could be optional, manual choice has been faster and more effective with my phone." (F, 20s)

Another concern expressed by participants has to do with the device reliability. They were worried that the battery of the mobile phone could run out and they had no way to prove they were travelling legally.

“Regarding the validations, a lot can happen: battery, damage, etc. It should exist some kind of security for the user so the system can be used without any 'fear'.” (F, 30s)

H. *Security*

Mobile ticketing systems usually involve sensitive information such as personal and financial data. Therefore, security concerns may become a barrier inhibiting mobile payments adoption.

During the tests, participants felt secure to pay with the mobile phone. They tended to compare it with structures that are familiar to them such as mobile banking systems. Those who already use mobile banking applications felt equally safe to purchase tickets with the mobile application.

“I use mobile banking applications on my mobile phone and I feel secure. Why should I not feel secure using this application?” (M, 30s)

“I feel equally safe to pay with the mobile phone as to pay in physical stores. If I receive a message saying that the purchase is validated and I see the travel tickets there, I feel safe.” (F, 30s)

I. Perceveid risks and fraud

Perceived risks of mobile payments mentioned by participants include risk of theft and errors in payment transactions.

Risk of theft was mentioned by participants that were worried about using the mobile phone to perform transactions in front of other people, especially at night. They perceive the mobile phone as more attractive to thieves than the contactless card.

“During overnight trips I have a certain fear of showing the mobile phone, the contactless card is not so tempting.” (F, 30s)

Errors in payment transactions was pointed as a potential risk by participants. The errors may arise from the payment system itself or by their own fault while using the system.

“It also happens to validate improperly and unintentionally, then there is no hypothesis to cancel the transaction and we lost the tickets.” (M, 60s)

The inspection process may raise some fraud and security concerns from the service providers’ perspective. In this case, the inspectors check visually the validity of the tickets. This technique may not be very safe in order to confirm the effective validity of the ticket, requiring, for instance, the use of reading devices in order to automate the process.

Moreover, regardless of the ticketing system used, there will be always risks associated with the behaviour of the people itself. Some participants questioned about what would prevent passengers from validating the ticket only when they saw the inspector approaching. Further prevention mechanisms could be implemented to avoid this kind of situations, such as blocking validation when the inspectors arrive or delay the validation process.

“When we enter the bus, the bus driver do not see us validating the ticket on the machine. So, it would be better if we had to show our phone to the driver with the valid ticket.” (M, 20s)

TABLE 10. MOBILE TICKETING EXPERIENCE FACTORS

Experience Factors	Category	Proposed Effect on Adoption
Easy of Use	Intuitive	+
	Easy to use	+
Usefulness	Useful	+
	Several advantages over traditional ticketing systems	+
Convenience	Remote and ubiquitous access to payment	+
	Queue avoidance	+
	Not necessary to carry cash	+
	Easy and fast to purchase tickets	+
	Several types of tickets available in the same device	+
	Availability of mobile phone	+
Complementary services	Personalized information (past journeys, tickets balance, …)	+
	Information about public transport (maps, schedules, …)	+
Aesthetics and Functionality	Appealing and attractive	+
	Soft colors	+
	PIN and password avoiding error procedures	+
	Availability of several languages	+
	Historic of most used stops	+
	Alerts	+
Complexity	Complex validation process	-
Availability	Need of 4G data	-
	Mobile network perfomance	-
	GPS performance	-
Security	Secure to pay with the mobile phone	+
	Feedback messages	+
Perceveid risks and fraud	Risk of theft	-
	Errors in payment transactions	-
	Device reliability (battery, damage)	-
	Fraud (travelling illegally)	-
Business Model	Pre-paid account	+
	Account linked with bank account	-
	Account linked with mobile phone account	-
	Pay for the mobile application	+
	Pay a fee per ticket	-

J. Business Model

When asked about how they would prefer to pay for the tickets, most of the participants (85%) answered they would prefer to have a pre-paid account for travelling purposes rather than having the bank account (4%) or mobile operator bill linked to the system (12%). This means that participants are reluctant to link their bank account to the mobile ticketing application and prefer separate accounts both for mobile operators and for transport operators. On the other hand, the pre-paid account may benefit transport operators since passengers are willing to pay for the service before they use it.

"Since the mobile phone is something that can be easily stolen, I would prefer to have a separate account. It is less dangerous than being linked to the bank account." (M, 30s)

"Linked to the bank account no, it is out of question. Linked to the mobile phone account is a hypothesis, but I would prefer a separate account." (F, 30s)

Regarding the payment of the mobile ticketing service, most participants (73%) stated they would be willing to pay to download the application, but not pay an additional fee per ticket purchased.

Appendix E – Anda Project

Appendix E.1 – Anda pre-pilot focus group sample characterization questionnaire

1. Age?

a) Less than 20 years
b) 20-35 years
c) 36-50 years
d) 51-65 years
e) More than 65 years

2. Gender?

a) Female
b) Male

3. Do you have a smartphone?

a) Yes
b) No

If you answered no, move to Question 9.

4. How long have you had a smartphone?

a) Less than 6 months
b) Between 6 months and 2 years
c) More than 2 years ago

5. What is the operating system of your smart phone?

a) Android
b) IOS
c) Windows Mobile
d) Other. Which?

6. Your smartphone has (you can check more than one option):

a) Bluetooth
b) NFC

7. Have you ever paid with your mobile phone?

a) Yes. Where? ___________________________
b) No

8. Select (up to 5 types) the applications you use most often.

a) Books
b) Business/Finance
c) Education
d) Transport
e) Games
f) Health/Fitness
g) Lifestyle
h) Music
i) Navigation
j) Newspapers/Magazines
k) Photos/Video
l) Social networks
m) Sport
n) Utilities

9. On average, how often do you use public transport?

a) 1 to 5 times per week
b) 1 to 5 times per month
c) 1 to 10 times per year
d) Never

10. What type of travel do you make more often using public transport?

a) Urban
b) Intercity

11. On your urban / long-distance journeys, which means of transport you use most often. (If your journey normally includes transfers between different means of transport, you can select more than one option).

a) Bus
b) Metro
c) Train

12. Where do you buy travel tickets for public transport (Select all options that apply)?

a) Ticket vending machines

b) Andante stores
c) Payshop and CTT Agents
d) ATM network
e) Road Operator Terminals
f) Inside the Bus
g) STCP Attendance Centers
h) CP ticketing stores
i) Internet
j) Other. Which?

13. What means of payment do you usually use to pay the tickets?

a) Notes and coins
b) ATM card

14. What type of tickets do you usually buy more often?

a) Occasional titles. Zones? ________
b) Andante 24. Areas? ________
c) Monthly Pass. Zones? ________
d) Other. Which? __________

15. What kind of additional services related to public transport do you use?

a) Consultation of maps (travel plans, lines, ...)
b) Timetable consultation
c) Consultation of tariffs
d) Complaints
e) Customer service line
f) Discounts on partner services from your transport operator
g) SME Bus
h) Mobile applications. Which? _______________
i) Others. Which? ________________

16. What type of channels do you use to access the services of your public transport operator (information, maps ...)?

a) Physical stores
b) Stops / Stations
c) Website
d) Facebook
e) Telephone
f) Email

Appendix E.2 – Anda pre-pilot focus group script

A. Project Presentation

B. Questionnaire to characterize the sample (distribute questionnaires in paper format)

C. Discussion

Open questions and some using prototypes. Interpretation of prototypes. Redo prototypes using post-its, papers and pens.

Technology / Concept

1. Payment based on Beacons. What do you think? (Obligation to have data and Bluetooth connected)
2. What do you think about rate optimization? Would it lead to an adoption of the mobile payment?

App Entry

3. PIN whenever they open the App? Or Sign in directly to the user account? (If you want to log out, enter username and password the next time you want to log in)
4. What would you like to see on the 1st screen when they open the App? (e.g. last trips, balance, validation screen)

Validation

5. You are at the stop, the Bluetooth on the mobile phone identifies beacons and a popup appears on the mobile phone with the lines / stops it is identifying.
    - What do you think of this method (pop-up)?
    - Should the stop with a stronger BLE signal be preselected? Or what do they usually use, based on history?
6. Would you rather have to call the application and say you want to validate for the app to look for the nearest lines / stops?
7. Validation at the entrance of the bus, before sitting down. What do you think?
    - If they validated after sitting down. What do you think of going through the driver without showing anything? What would others think?
8. They are on a bus in progress and pass by a subway stop. The mobile phone detects a new stop and sends a popup asking if it wants to validate. Or they are walking the city on foot and whenever they pass near a bus they receive a pop-up asking if they want to validate.
    - Do you mind if you're always receiving these notifications?
    - Do you run the risk of always answering "no" to the popup and when is it even validate to load "no" again?

Validation History

9. What information would you like to have in the validation history?

10. Look at the screens and interpret the information.
11. Information on zones corresponding to the trip (worst case scenario) vs. Best Case scenario

Inspection

12. "What do you think the inspection system could be?"

Payment

13. Load prepaid account vs. Associate to Credit Card Vs. Paypal vs. ...
14. Pay weekly? Pay monthly?

Appendix E.3 – Anda first usability testing script

Participants information:

Name: ____

Email: ____

Mobile phone number: ____

Tasks:

You should read the tasks aloud and think aloud while you work them out.
At the end of each task you should assign a rating of 1 to 5 regarding the difficulty you had in resolving the task in question, where 1: Very difficult, 2: Difficult, 3: More / less difficult, 4: Easy, 5: Very Easy.

1. Open the Anda application

Time (seconds)	
Rating (1 to 5)	
Comments (verbal user comments, menu selection errors, difficulties, ...)	

2. Register in the Anda application:

Time (seconds)	
Rating (1 to 5)	
Comments (verbal user comments, menu selection errors, difficulties, ...)	

3. Imagine you are at *Castelo do Queijo* and want to travel to *Vila do Conde*. You have already consulted the public transport maps of the Metropolitan Area of Porto and know that:

a) You will need to travel on the bus line 203 towards the *Marquês* and get off at *Casa da Música* stop.

b) At *Casa da Música* you will have to change your mode of transportation. Thus, you will start your trip on the metro, from the blue line, towards *Povoa de Varzim*. The final destination will be *Vila do Conde*.

Imagine that you are at *Castelo do Queijo* and want to start the trip described above. Start your trip on the bus line 203 towards the *Marquês*.

Time (seconds)	
Rating (1 to 5)	
Comments (verbal user comments, menu selection errors, difficulties, ...)	

4. During the trip, when you pass in *Praça do Império*, a white rectangle appears in the upper green bar with information on line 207. What do you understand by this information?

Time (seconds)	
Rating (1 to 5)	
Comments (verbal user comments, menu selection errors, difficulties, ...)	

5. Imagine that you arrived at *Casa da Música* stop and got off the bus. Now enter the metro station at *Casa da Música*, on the blue line.

Time (seconds)	
Rating (1 to 5)	
Comments (verbal user comments, menu selection errors, difficulties, ...)	

6. During the trip, several stations appear. What do you understand by this information? Do you find it useful?

Time (seconds)	
Rating (1 to 5)	
Comments (verbal user comments, menu selection errors, difficulties, ...)	

7. You arrived at *Vila do Conde*, got out of the metro and started to walk away from the station. The application ends the trip automatically. What do you think of this functionality?

Time (seconds)	
Rating (1 a 5)	
Comments (verbal user comments, menu selection errors, difficulties, ...)	

8. Check your travel history. Describe the information presented. (Where did you enter, where did you leave, which was the 1st and 2nd trip, on which day were they made)

Time (seconds)	
Rating (1 to 5)	
Comments (verbal user comments, menu selection errors, difficulties, ...)	

9. In the travel history menu, check the trips made during the month of January.

Time (seconds)	
Rating (1 to 5)	
Comments (verbal user comments, menu selection errors, difficulties, ...)	

10. See how much you have to pay for your trip. How do you interpret this information? (1xZ6)

Time (seconds)	
Rating (1 to 5)	
Comments (verbal user comments, menu selection errors, difficulties, ...)	

11. Check the inspection screen. What do you think of the icon?

Time (seconds)	
Rating (1 to 5)	
Comments (verbal user comments, menu selection errors, difficulties, ...)	

12. Check your profile and change the address to *Rua Júlio Dinis*.

Time (seconds)	
Rating (1 to 5)	
Comments (verbal user comments, menu selection errors, difficulties, ...)	

13. Log out of the application.

Time (seconds)	
Rating (1 to 5)	
Comments (verbal user comments, menu selection errors, difficulties, ...)	

Appendix E.4 – Anda heuristic evaluation (heuristics list)

The heuristics checklist is presented below. The complete subheuristics checklist may be reviewed in (Amorim 2018).

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
11. Skills
12. Pleasurable and Respectful Interaction with the User
13. Privacy

Appendix E.5 – Anda second usability testing sample characterization questionnaire

Participants information:

Name: ____

Email: ____

Mobile phone number: ____

1. Age?

a) 18-29 years
b) 20 to 44 years
c) 45 to 59 years
d) 60 or more years

2. Gender?

a) Female
b) Male

3. How long have you been using an Android operating system smartphone?

a) Up to 3 months
b) Between 3 and 12 months
c) More than 1 year

4. How well do you consider to know the Andante system (types of tariffs, operation of the zones, and duration of trips)?

a) I do not know
b) Little
c) Reasonable
d) Well
e) Very well

5. How long have you been using the Anda application?

a) Never used it
b) Up to 3 months
c) Between 3 and 12 months
d) More than 1 year

Appendix E.6 – Anda second usability testing tasks script

You should read the tasks aloud and think aloud while you work them out.
At the end of each task you should assign a rating of 1 to 4 for the intelligibility and usefulness of the application function used during the task in question, where 1: Not understandable / Not useful; 2: Not very understandable / Not very useful; 3: Easy to understand / Useful; 4: Very clear or obvious / Very useful or essential.

1. Open the Anda application

Time (seconds)	
Comprehensibility (1 to 4)	
Utility (1 to 4)	
Comments (verbal user comments, menu selection errors, difficulties, ...)	

2. Register in the Anda application

Time (seconds)	
Comprehensibility (1 to 4)	
Utility (1 to 4)	
Comments (verbal user comments, menu selection errors, difficulties, ...)	

3. Start a journey in the application

Time (seconds)	
Comprehensibility (1 to 4)	
Utility (1 to 4)	
Comments (verbal user comments, menu selection errors, difficulties, ...)	

4. Following the trip in the application.
   a) Several stations appear during the trip. What do you understand by this information? Do you find it useful?

Time (seconds)	
Comprehensibility (1 to 4)	
Utility (1 to 4)	

Comments (verbal user comments, menu selection errors, difficulties, ...)	

b) During the trip, white rectangles can appear on the upper green bar with information about bus, metro and city trains. What do you mean by this information? Do you find it useful?

Time (seconds)	
Comprehensibility (1 to 4)	
Utility (1 to 4)	
Comments (verbal user comments, menu selection errors, difficulties, ...)	

5. Check the inspection screen (during the trip). What do you think of the icon? What do you think of the information displayed on the screen?

Time (seconds)	
Comprehensibility (1 to 4)	
Utility (1 to 4)	
Comments (verbal user comments, menu selection errors, difficulties, ...)	

6. Closing of the trip.
   a) After arriving at your destination, getting off the bus / subway / city train and starting to move away from the vehicle / station, the application must end the trip automatically. What do you think of this functionality?

Time (seconds)	
Comprehensibility (1 to 4)	
Utility (1 to 4)	
Comments (verbal user comments, menu selection errors, difficulties, ...)	

b) You remembered that you must be somewhere else and need to continue the trip, however the application has closed it and has already calculated its price. What do you think happens if you re-validate? (e.g. "The app starts a new trip," The app resumes the previous trip, "" It depends on where I am going, "etc.)

Time (seconds)	
Comprehensibility (1 to 4)	
Utility (1 to 4)	
Comments (verbal user comments, menu selection errors, difficulties, ...)	

7. Check the amount you have to pay for the trip you just made. How do you interpret this information? (e.g. "1x Trip ticket Z2").

Time (seconds)	
Comprehensibility (1 to 4)	
Utility (1 to 4)	
Comments (verbal user comments, menu selection errors, difficulties, ...)	

8. View the travel history in the application.
   a) Describe the information presented and how you perceive it.

Time (seconds)	
Comprehensibility (1 to 4)	
Utility (1 to 4)	
Comments (verbal user comments, menu selection errors, difficulties, ...)	

   b) Check the trips made during the month of May 2018.

Time (seconds)	
Comprehensibility (1 to 4)	
Utility (1 to 4)	
Comments (verbal user comments, menu selection errors, difficulties, ...)	

9. Check the inspection screen (out of trip). What do you think of the information presented?

Time (seconds)	
Comprehensibility (1 to 4)	
Utility (1 to 4)	

Comments (verbal user comments, menu selection errors, difficulties, ...)	

10. Check your profile and change the address to "*Rua Júlio Dinis, 16*".

Time (seconds)	
Comprehensibility (1 to 4)	
Utility (1 to 4)	
Comments (verbal user comments, menu selection errors, difficulties, ...)	

11. Change your password.

Time (seconds)	
Comprehensibility (1 to 4)	
Utility (1 to 4)	
Comments (verbal user comments, menu selection errors, difficulties, ...)	

12. Payment method.
    a) Enter your data for payment.

Time (seconds)	
Comprehensibility (1 to 4)	
Utility (1 to 4)	
Comments (verbal user comments, menu selection errors, difficulties, ...)	

b) Check your data for payment.

Time (seconds)	
Comprehensibility (1 to 4)	
Utility (1 to 4)	
Comments (verbal user comments, menu selection errors, difficulties, ...)	

13. Log out of the application.

Time (seconds)	
Comprehensibility (1 to 4)	
Utility (1 to 4)	
Comments (verbal user comments, menu selection errors, difficulties, ...)	

14. Sign in to the application using previously recorded data.

Time (seconds)	
Comprehensibility (1 to 4)	
Utility (1 to 4)	
Comments (verbal user comments, menu selection errors, difficulties, ...)	

Appendix E.7 – Anda second usability testing final evaluation questionnaire

1. What do you think of the Anda mobile application? Useful or not? Why?

2. What did you like most about the application?

3. What did you did not like about the application?

4. What did you find confusing or difficult about using the application?

5. What do you think about the security of the application?

6. What do you suggest to improve the application?

7. What options would you like to have available that the application does not have?

Appendix E.8 – Anda pilot sample characterization questionnaire

1. How long have you had a smartphone?

a) Less than 6 months
b) Between 6 months and 2 years
c) More than 2 years ago

2. Select (up to 5 types) the applications you use most often.

a) Books
b) Business/Finance
c) Education
d) Transport
e) Games
f) Health/Fitness
g) Lifestyle
h) Music
i) Navigation
j) Newspapers/Magazines
k) Photos/Video
l) Social networks
m) Sport
n) Utilities

3. How do you consider your knowledge of mobile payments?

a) High
b) Medium
c) Low
d) Without knowledge

4. Have you ever paid with your mobile phone?

a) Yes. Where? ___________________
b) No

5. On average, how often do you use public transport?

a) 1 to 5 times per week
b) 1 to 5 times per month
c) 1 to 10 times per year
d) Never

6. What type of travel do you make more often using public transport?

a) Urban
b) Intercity
c) Other. Which? ____________

7. On your urban / long-distance journeys, which means of transport you use most often. (If your journey normally includes transfers between different means of transport, you can select more than one option).

a) Bus
b) Metro
c) Train
d) Other. Which? _____________

8. Why do you use public transport? (Select all that apply)

a) It is more economical
b) It is less polluting
c) I travel in the company of other people
d) It allows me to do other activities during the trip
e) It is faster
f) The coverage of the public transport network is very good
g) I do not like driving
h) I have trouble parking the car
i) I do not have a driving license
j) I do not have a car

9. Where do you buy travel tickets for public transport (Select all options that apply)?

a) Ticket vending machines
b) Andante stores
c) Payshop and CTT Agents
d) ATM network
e) Road Operator Terminals
f) Inside the Bus
g) STCP Attendance Centers
h) CP ticketing stores
i) Internet
j) Other. Which? ____________

10. What means of payment do you usually use to pay the tickets?

a) Notes and coins
b) ATM card

c) Other. Which? ___________

11. What type of tickets do you usually buy more often?

a) Occasional titles. Zones? ________
b) Andante 24. Areas? ________
c) Monthly Pass. Zones? ________
d) Other. Which? __________

12. What kind of additional services related to public transport do you use?

a) Consultation of maps (travel plans, lines, ...)
b) Timetable consultation
c) Consultation of tariffs
d) Complaints
e) Customer service line
f) Discounts on partner services from your transport operator
g) SME Bus
h) Mobile applications. Which? _______________
i) Others. Which? ________________
j) None

13. What type of channels do you use to access the services of your public transport operator (information, maps ...)?

a) Physical stores
b) Stops / Stations
c) Website
d) Facebook
e) Telephone
f) Email
g) Other. Which? _______
h) None

11. Rate (from 1 to 5) the following statements regarding the purchase and validation of tickets using currently available methods, where:

1 - Strongly Disagree
2 - Disagree
3 - I do not agree or disagree
4 - I agree
5 - Totally Agree

a. I have already lost my Andante card several times.
b. I have difficulty in understanding what kind of ticket (Z2, Z3, Z4 ...) I have to buy to make a certain trip.

c. I find it easy to buy tickets at the vending machines.
d. I have been through situations where I did not have the money (notes and coins) to buy tickets at the vending machines.
e. I do not (or would not) like to move to a physical store to renew my monthly pass.
f. I find it easy to validate tickets on the validators.
g. I would like to know how much time I have left after I've validated the ticket.
h. I would like the system to inform me of the stop to which I can travel with the ticket I have validated.
i. I would like to be able to store more than one type of different title (e.g. Z2 and Z3) on my walking card.
j. I would like access to my travel history.
k. I would like to know how much you spend per month on public transport.
l. I would like to have information about public transport (maps, timetables).
m. I am more likely to forget the walking card at home than the mobile phone.

12. Please rate (from 1 to 5) the following statements regarding the use of mobile phones to make payments on public transport, where:

1 - Strongly Disagree
2 - Disagree
3 - I do not agree or disagree
4 - I agree
5 - Totally Agree

a) Making payments with the mobile phone is a good idea.
b) Making payments with the mobile phone is smart.
c) Making payments with the mobile phone is enjoyable.
d) Users of mobile payments are innovative.
e) Mobile payments are fashionable.
f) People who are important to me will probably recommend that I use mobile payments.
g) Making payments with my mobile phone is compatible with my needs.
h) Making payments with my mobile phone is compatible with my lifestyle and habits.
i) Mobile payments are compatible with my way of using public transport.
j) I think using mobile payments would increase my productivity.
k) I think using mobile payments will save time.
l) I think mobile payments are useful for carrying out my tasks.
m) Mobile payment is a useful payment method.
n) When using mobile payment services my choices as a consumer are improved (e.g. flexibility, speed).
o) I think learning to make payments with the mobile phone is easy.
p) I think it will be easy for me to become an expert in the use of mobile payments.
q) I would like to use mobile payment services instead of alternative modes of payment (e.g. credit card, cash).
r) I plan to use my mobile phone to pay for public transport when this service is available.

s) Mobile phones are reliable enough to make payments.
t) Mobile operators are reliable enough to make payments.
u) The requirement to have a data plan to make mobile payments is a negative factor.
v) The requirement to connect GPS or Bluetooth to make mobile payments is a negative factor.
w) I think the risk of my mobile phone running out of battery power or running out of power is low.
x) I think the risk of making payment errors with my mobile phone is low.
y) I think the risk of stealing my mobile phone while I make a mobile payment is low.
z) I think the risk of problems with internet connection, GPS or Bluetooth is low.
aa) I consider that the risk of the mobile payment application having many errors is low.
bb) I think the risk of making mistakes in billing is low.
cc) I believe that the risk of customers traveling illegally with mobile payments is low.
dd) I would feel safe to make payments with the mobile phone.
ee) I would feel secure to provide personal information through mobile payment.
ff) The risk of an unauthorized third party accessing the payment process is low.
gg) Receiving feedback messages (e.g. successful completion) gives me security regarding mobile payments.
hh) Making payments with the mobile phone reduces the queues for the purchase of tickets / monthly subscriptions.
ii) Making payments with the mobile phone is independent of the moment.
jj) Making payments with the mobile phone is independent of the location.
kk) I can replace the need to carry money or Andante card through payment by mobile phone.
ll) I would like to find mobile payment services appealing and aesthetically attractive.
mm) I would like to find mobile payment services available in several languages.
nn) I would like to find mobile payment services with alerts regarding my use of public transport.
oo) I would like to find mobile payment services integrated with other services (maps, schedules).
pp) I would like to find mobile payment services of easy interaction.

16. Do you want to use your mobile phone to make payments when the service is available?

a) Yes
b) No
c) Occasionally

17. If you answered "no" or "occasionally" to the previous question, would you use the mobile phone to pay in any of the following situations? (You can select more than one option)

a) The physical card (Andante) has no balance
b) I do not have the money to buy the ticket
c) I am in a hurry or need a ticket very quickly
d) I need a ticket unexpectedly and I am not prepared to buy it
e) There are queues to buy the ticket
f) If the ticket vending machines are not working

18. What additional benefits do you associate with the payment of public transport services through the mobile phone?

____

19. What additional disadvantages do you associate with the payment of public transport services through the mobile phone?

____

20. With regard to payment for the use of public transport services via mobile phone, which option would you prefer?

a) Prepaid account only for public transport (load an account and spend the balance)
b) Direct debit to the bank account
c) Credit card
d) Paypal
e) Debit in the balance of the mobile phone.
f) Other. Which? __________________

21. Would you be available to pay to download a mobile payments application?

a) Yes. How much? ____________
b) No

22. Gender? ___________

23. Age? _______

24. Educational qualifications?

a) 4th year
b) 9th year
c) 12th year
d) Bachelor's, Graduate, Post-Graduate
e) Master's, PhD, Post-Doctorate

25. Occupation? ______________________

26. Name? ___________________

Appendix E.9 – Anda post-pilot focus group script

A. Open questions

Concept

1. Mobile payments on public transport. What do you think?

2. Payment based on Beacons. What do you think? (Obligation to have Bluetooth connected (and data), perception about battery consumption)

3. What do you think about the tariff optimization? Do you trust? Do you think it calculates the optimal value? Would it lead to an adoption of the mobile payment or is it not a determining factor? (Example of an optimization)

4. Do you feel in any way "followed" by the fact that your journey is being identified by the application / beacons? Or do not you think about it?

5. How do you see the relationship with the service provider, with the introduction of a mobile payment system? Would it change? How? (E.g. greater transparency (balance, history), greater interaction (alerts, warnings),)

6. Do you feel safe using the application to pay for travel?

7. What additional services would you like a mobile payments application for public transportation to make available?

8. What factors would lead to the adoption of mobile payments?

App Entry

9. PIN whenever you open the App? OR Sign in directly to the user account? (If you want to log out, enter username and password the next time you want to log in.) OR Automatic log-out from time to time? (Assess perceived safety)

Validation

10. How and when you validate? (Describe the validation experiment - how they did it and how it would be best)

11. Is the validation screen simple to interact with? Do you see the beacons associated with each transport? (Sometimes errors occurred in validation)

Traveling

12. What do you think about the functionality of being able to see the stops you are passing through during the trip?

End of trip

13. Manually ending vs. Auto Finish vs. Notification that it will close.

Validation History

14. What information would you like to have in the validation history? (Information on zones corresponding to the trip (worst case scenario) vs. Best case scenario? Information on saving?)

Inspection

15. How do you think the inspection system could be?

Payment

16. Upload prepaid account vs. Post-paid (ex: associate credit card, Paypal, debit account).

17. Pay weekly? Pay monthly?

18. Do you prefer a mobile application in which you travel indicating only the origin and/or destination and then the amount to be paid for the trips is calculated (e.g.: Anda) OR an application in which you buy and validate the tickets using the mobile phone (same logic of the Andante , but with the mobile phone).

Mobile Application

19. What you liked the most about the application.

20. The least liked / found confusing / difficult.

21. Suggestions for improvements.

22. Would you use this application to make payments on public transport?

23. What has changed (perception of mobile payments) after testing the system?

24. Battery? Do you spend too much or too little?

25. Mobile data consumption?

Appendix E.10 – Anda post-pilot focus group analysis

At the end of the field tests, 3 Focus Group sessions were performed with selected users. The selection of the participants took into account the individual performance during the tests, namely total number of validations and frequency of interaction with the project team. The sessions were moderated by 3 people from the project team and had 10, 7 and 8 participants each (see Table 11). The objectives of the Focus Group sessions were to understand the users' experience with the application and perception of the payment of the public transport service with the mobile phone. The script of questions asked during the sessions is in Appendix F.9.

TABLE 11. ANDA POST-PILOT FOCUS GROUP SESSIONS CHARACTERIZATION

Focus Group	**Nr of Participants**	**Nr of Moderators**	**Duration**
Focus Group 1	10	3	1:40h
Focus Group 2	7	3	1h
Focus Group 3	8	3	1:30h

The sessions were recorded in audio and their content was literally transcribed and later analysed. Table 12 presents a summary of the analysis performed. The "Topic" column refers to the topic addressed in each issue; "Opinion" refers to participants' responses and opinions; and "Suggestions" refers to the suggestions for improvement proposed by the participants for each topic addressed.

In short, all participants enjoyed the experience of using the mobile phone to travel on public transport. They consider a practical and innovative solution, a good alternative to vending machines when they do not work or when customers do not have notes and coins to buy tickets. The technology of beacons is interesting, but the application only works well if they are close to the beacons. They suggest, therefore, the placement of more beacons in the stations in order to increase the coverage.

They consider the optimization of the tariff to be the differentiating factor of the application, because it promotes savings in the payment of travelling services. It is undoubtedly a determining factor for the adoption of the mobile phone as a means of payment, and operators should invest in effective and effective communication of this added value to their customers. The fact that they can travel without having to buy tickets or monthly passes, nor need to think about whether they have the indicated pass for a given trip is another determining factor in the adoption of such a system. Paying just what they travel, avoiding queues, machines that do not work and going to the physical stores are additional advantages referred to.

They do not feel at all "followed" by the transport operators because they use the mobile phone to travel. They also consider it useful to be able to follow the route of their journey. Feel secure using the application to pay for travel. However, they suggest introducing an optional PIN to the application entry and somehow hiding the profile's personal information. The confidence conveyed by the application is also critical for security awareness. The fact that the application crashes or gives error raises doubts as to the effectiveness of the actions performed, such as validation being registered or not, whether the trip legally or not. They consider it useful to integrate a payment application in public transport with information related to mobility, such as maps, schedules and prices.

The offline validation feature enables validation to be avoided by avoiding situations of lack of mobile network coverage. However, participants maintain the perception of offline validation as being random (sometimes it works, others it is necessary to turn on the mobile data). In this sense they suggest the introduction of information that allows to know if it is possible to start the trip offline, thus avoiding the trial-error. On the other hand, internal mechanisms for searching the Internet signal more frequently may alleviate this sense of randomness. Regarding the end of the trip, they prefer the automatic finalization option, considering, however, that it should be more effective and faster. The warning about automatic finalization is also considered useful.

They consider that such a system tends to reduce fraud, since it is always available, does not depend on notes and coins and conveys the image of being a more controlled system. They argue that monitoring the validity of travel should be a quick procedure, taking advantage of inspectors' machines to read, for example, a code (bar code or QR Code) on the mobile phone.

For payment, they prefer to pay at the end of the month, since a prepaid account takes the advantage out of the application regarding the savings at the end of the month. They suggest several payment methods such as low value payment, invoice with entity / reference or debit to account. Finally, participants enjoyed experimenting the ANDA mobile application, and were pleasantly surprised. At the end of the tests, all were available to use it as soon as it was available in the market.

TABLE 12. ANDA POST-PILOT FOCUS GROUP SESSIONS ANALYSIS

Topic	Opinion	Suggestions
1. Perception of mobile payments in public transport	- Useful; - Practical; - Innovative; - No need to worry about coins or notes.	
2. Payment based on Beacons	- Interesting; - It works fine if it is next to the validators, otherwise it will not.	- Place beacons in more places.
3. Tariff optimization	- It is the added value of the application. People realized that saving with the application would help attract and retain customers; - Very useful, especially in situations like vacations, trips to the beach and to the hospital.	- Report the savings to the user. It is the most important message to convey to users.
4. Do you feel followed by the fact that the course is being identified by the application?	- Do not feel followed; - Does not bother; - It is not a concern; - It is even useful to see the stops they are going through.	
5. How do you see the relationship with the service provider?	- The use of the mobile phone made it easier. It did not require moving to the physical store, nor waiting in lines.	

Topic (cont.)	Opinion (cont.)	Suggestions (cont.)
6. Security	- Yes, it is secure; - Insecurity if they lose or steal the mobile phone (PIN to enter the application or not); - "Hide" or limit access to personal profile information; - Concern about application errors.	- PIN (e.g. 4 digits) at the input of the optional application; - PIN to access the profile (or other way of limiting access or hiding information).
7. Additional services to be made available by the application	- Schedules; - How much time is left to the bus arrival; - information on transport network; - Price information; - Services that require travel to the Andante store; - Integrate with Move-Me.	- Schedules; - How much time is left to the bus arrival; - information on transport network; - Price information; - Services that require travel to the Andante store; - Integrate with Move-Me.
8. Factors that would lead to the adoption of mobile payments	- Pay only what will be used; - Do not have to think if they have pass or tickets to the zone where they want to travel; - Do not have to anticipate the need for a monthly pass or not; - Avoid queues to pay; - Practical, simple and fast; - Good alternative for ticket vending machines destroyed or when there are no notes and coins.	
9. Application entry	- Prefer without Auto Logout. They do not want PIN. They like it that way.	
10. Validation experience	- There are stations with weak signal of beacons (*Agues Santa's*, *São Bento* CP); - It is more practical to validate in the metro next to the boarding platform. It even has information about how long it takes the vehicle to arrive; - Lack of network coverage of some mobile operators in certain stations (e.g. NOS *in Ponte D. Luís* and *São Bento*).	- Creation of an alert to revalidate the ticket, in the line changes; - Information about the time or message to say that it is able to validate offline.
11. Interaction with the validation screen	- Practical, simple, aesthetically pleasant; - Operator logos are larger and more visible.	- Bring closer the check box to select the vehicle and the "start trip" button. It would improve usability.

Topic (cont.)	Opinion (cont.)	Suggestions (cont.)
12. Functionality of following the stops during the journey	- It is good; - It is useful to follow the journey stops; - In the underground metro, it already scans all the beacons. Makes more sense this way.	- Auto-complete the route when it does not catch some beacons. The failure of some stations is something that bothers them since they want to see the complete route; - Show the whole line and as it passes through the beacons it would change the colour. This is interesting since it allows to know which the next stops are.
13. End of the journey Automatic vs. Notification that it will end	- Prefer automatic finalization. But it has to work; - The warnings that the trip will close are important and useful, especially in cases of long waits inside trains.	- Alerts to warn that the trip will close. Notifications with audible signal, at the user's choice.
14. Validation history	- It is easy to understand	
15. Inspection process	- This system is best in terms of fraud prevention. It passes the image that it is a more controlled system than a physical card.	- Show the ticket screen validated to the driver when entering the bus (not showing anything to the bus driver can be a problem); - Take advantage of inspectors' machines. Reading a code on the phone, or QR Code (something of fast reading); - How does the inspector see that the application is mine? I can lend the phone to someone else to travel. Solution: put photography; - Problem: see the inspector approaching and validate. Solution: The app realizes that the inspector is there and does not allow validating.
16. Payment: prepaid account vs. post-paid	- Prepaid takes advantage of the application of becoming more economical at the end of the month; - Debt at the end of the month is great; - If you do not pay, you cannot validate with the application.	- Two options: pre-paid for tourists (load account and travel); post-paid to others (pay at the end of the month); - If it debits the bank account, it should notify people that they are going to be charged, to make sure they have enough money in the bank account to pay; - Entity / Reference ATM in the invoice; - Low value payment.

Topic (cont.)	Opinion (cont.)	Suggestions (cont.)
19. What they liked the most in the application	- Very functional; - After the new update works always well.	
20. The least liked in the application	- It takes a long time to finish the trip.	
21. Improvements		- Allow a user to have two accounts on the phone. One personal and other from the company. Invoices with different NIFs.
22. Would you use this application to travel on public transport	Yes.	
23. Perception of mobile payments after testing the system	- At first I was reticent, but after experiencing I liked it; - Meets expectations; - I was pleasantly surprised. It is very easy to understand. Intuitive.	
24. Battery consumption	- Do not spend more; - Spends 2%, 3%; - It does not appear as one of the applications that consumes more battery.	
25. Data consumption	- Almost nothing. They do not notice too much difference; - Spends little. In May I spent 0.7Mb. In June I spent 1.5Mb.	

Appendix E.11 – Anda pilot comments and email analysis

During the tests users contacted the project team daily via email and Facebook to ask questions, share experiences, difficulties and suggestions for improvement. Some of the comments were also accompanied by screenshots of the screens of the application to which they referred to. These media allowed daily interaction between users and the development team, being also possible through Facebook interaction among users. This Appendix describes the qualitative analysis of the emails and comments on Facebook posted during the first set of tests that occurred from April to July 2017. All comments placed on the Facebook page and emails were transcribed to a platform, developed internally for that purpose, and categorized. In total, 672 comments / emails were categorized into 27 categories. Table 13 summarizes the categories created and the number of comments for each category. Below is a detailed analysis of the categories most referred by users.

TABLE 13. ANDA PILOT EMAILS AND FACEBOOK COMMENTS CATEGORIZATION

Category	Nr of comments
No detection of beacons	276
Application works well	122
Problems with application performance	66
No automatic trip ending or incorrect ending	56
Difficulty in starting a journey	42
No intermediate stations detected	11
General opinions	10
ES - validate in wrong station	10
Suggestion	11
Automatic logout	7
Buses without beacon	7
History without records	7
Updated version	7
Problems with Bluetooth	6
Using excessive battery	6
Doubts	4
Slow journey start and beacon detection	4
Interaction with inspectors	3
"End Trip" Message	3
App updates (not in Playstore)	3
Wrong Operator Validation	3
Button colour	2
Error in algorithm	2
Operators logos (design)	1
Location error	1
Change route (bus)	1
Feedback message from the app	1
Total	**672**

a) **Automatic logout (7 comments)**

In the first version of the application an automatic logout function was contemplated whenever people did not use the application for more than two days. The purpose of this function was to increase the security of the application, requiring a login after two days without use. However, several users reported that this Login requirement was inconvenient, often delaying the validation process. Thus, in the 22.05.2017 application update, this automatic logout option was removed.

"Whenever I start the application for a trip I have to log in with the email and password. Is it supposed to be like this? It would be easier if the data were automatically saved for a faster start of travel." (Female, 20s)

b) **Problems with application performance (66 comments)**

These problems reported by the users have to do with the performance of the application. About half concern server connection issues, reported at the end of April 2017. In fact there was a computer attack to the servers that prevented the establishment of this connection. Others refer to problems with the application such as blocking and closing it without justification.

c) **Application works well (122 comments)**

Users also provided positive comments about the app. About its correct functioning and good performance.

"Today I'm happy with the application. On the train as usual it worked very well and I'm going at the moment in the 500 and for the first time to work well too. Good week!!!" (Female, 40s))

"Hello, the app has worked well on the Metro, even though some stations are still without beacons. I have done the IPO-Trinity-IPO course, and the validations worked correctly." (Male, 20s)

d) **Buses without beacon (7 comments)**

Sometimes the buses that circulated on line 500 of STCP or 30 of ES had no beacon installed and therefore users could not validate. The operators were alerted immediately to this fact, in order to use vehicles with beacon installed in these lines.

e) **No detection of beacons (276 comments)**

Much of the user feedback was related to non-detection of beacons. This lack of detection then gave rise to other problems, namely:

i. Does not detect the beacon at the entrance station

Sometimes the Anda application could not find beacons at the origin station, preventing users from validating correctly. Many times they tried to validate along the journey, validating in the first beacon they encountered.

"I've been using the yellow line, but, I do not know why, my phone has a lot of trouble in detecting the transport. It always says there's no transport nearby ... I'm usually in a hurry, I cannot register my entrance on the metro and then, during the journey, I also cannot start the trip because it stills not detecting anything ..." (Female, 16s)

"10 minutes ago, I could not start a trip in S. Bento to Agues Santa's. I had data working because I received a lot of notifications from Twitter and Youtube. Even though I had mobile data I could only start the trip in the second station, in Campanhã." (Male, 40s)

"Good afternoon, a few minutes ago I was in João de Deus and I had difficulty in detecting the beacon and also in the application getting data from the server. I had mobile data working because I received notifications from other applications. I could only start the trip two stations later, in Câmâra de Gaia station. " (Male, 40s)

ii. Does not detect the beacon at the alight station

The application detects the beacon of the entrance station and some stations during the journey, but does not detect the alight station. Thus, the trips are recorded with the wrong destination, considering as destination stations before the alight one.

"Once again my morning trip at CP from Agues Santa's to S.Bento ended in Campanhã! I have been checking in the history and this happens already since May 24. Since then it has never ended in S. Bento which is the station where I alight. I have a good day."(Female, 50s)

iii. It only detects the beacon at the entrance station

In some cases the application only detected the beacon of the entrance station and could not detect any more during the trip. This problem recurred throughout the entire testing period and was being improved by the development team. However, it was found that the correct functioning of beacon detection depended on a set of factors not controlled by the project team, such as mobile phone brands and models and operating system versions. An analysis was made of the number of journeys starting and ending at the same station for the months of May, June and July of 2017 (see Table 14). In May this situation occurred in 18% of validations and in July 10%.

TABLE 14. VALIDATIONS WITH THE SAME ENTRANCE AND ALIGHT STATION

Transport Operator	**May**	**June**	**July**
MP	300	178	88
CP-Porto	139	101	67
STCP	31	18	22
Espírito Santo	22	5	
Total	492	302	177
% over total validations	18%	12%	10%

f) No automatic trip ending or incorrect ending (56 comments)

Trips should close automatically, with no need for user interaction with the application. However, several users reported that the trip did not close automatically, and had to be closed manually.

Much of this problem has to do with the previous one (Application only the beacons at the entrance station). If only the start station is detected the application does not close the trip automatically, because it waits for the beacons of the next stations.

"The application still does not identify the route taken and does not automatically end the trip. Yesterday I started the trip in S. Bento (CP) and it did not recognize the exit station (Campanhã). "(Female, 40s)

"Today, I had to finish the journey manually because the application only detected the entrance station. I was already at home and app was still with the trip opened." (Female, 50s)

If the application identifies more than one beacon in addition to the entrance station, the application should close the trip automatically. However, this process may take a few minutes until the application realizes that the user has already moved away from the station and is walking. This delay was perceived by some participants as an error, since they felt that the application took a long time to close and opted to close the trip manually.

"It worked fine, but it still does not finish automatically." (Female, 40s)

"Yes indicates all stations. But when I get out of the metro, I have to close the trip manually." (Female, 40s)

Another situation reported by users has to do with the fact that the application closes the trip at the wrong alight station. This is the case, for example, of trains that stop at a particular station for a long period of time, or cases where the alight station is not detected by the application.

"Today the train stopped at Contumil for a long time, and after about 10 minutes the application ended the trip." (Male, 50s)

"I have already updated the app and cleared the cache, but in the meantime the metro trips finished in stations previous to those in which I left, one should have finished in IPO station and the other in S. Bento station." (Female, 50s)

g) Difficulty in starting a journey (42 comments)

To start a trip the users had to have connected: Bluetooth, mobile data and location services. Sometimes even picking up the signal from the station's beacons, users could not start the trip because they had no internet signal to perform the validation.

"This morning, in the direction of Agues Santa's towards Porto, it detected the beacon but did not start the trip, it showed a message that there were communication problems." (Male, 40s)

"There must be a correlation between the mobile operator, the fact that it is using 3G or 4G. When I have difficulty starting the trip, it is always when I am in the platform next to the train. When I start the trip in the station' atrium it works well. I suggest that the application allows to start a trip offline and then sync with the server. Or use NFC to validate with the phone, by the same method as the Andante ticket. "(Male, 40s)

After validation difficulties in online mode and after suggestions from the participants, a new version of the application was released in 26.06.2017 that allowed to validate in offline mode, that is to say, without need of internet connection. This function was implemented with some particular characteristics, in which it was only possible to validate offline if in the last 12 hours the application had made an internet connection. This check was made at the 11th hour. As there were some complaints about the impossibility of validating offline, the internet access check began to be performed more frequently and not just once, at the 11th hour, solving most of the problems.

h) No intermediate stations detected (11 comments)

The beacons were installed inside the validators of the metro and train stations and inside the buses. In the case of underground metro stations, the validators are far from the boarding platforms, and therefore it is difficult to get a beacon signal during a metro trip. So what happened was that the users validated the start of a metro trip near the validators and during the trip had no information about some stations of the route that was being carried out, because the application did not identify signs of underground station beacons. This situation caused confusion in the mental model of the users because the information was not coherent with the route carried out, nor with other means of transport (train and bus) that, from the outset, presented the complete route.

"Hello, I used the application on the metro yellow line in direction to São João station and it worked fine. However, it does not identify the Salgueiro station on the way, and the history is as if it had jumped from Polo Universitário to Combatentes. "(Male, 20s)

"This was the mistake that occurred to me today in line D of the metro! I do not understand how but the application only recorded the first and the last stations."(Male, 16s)

After realizing that it was important for users that the application detect all the stations of the trip, beacons were installed in the underground metro platforms, thus increasing the beacons signal range.

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